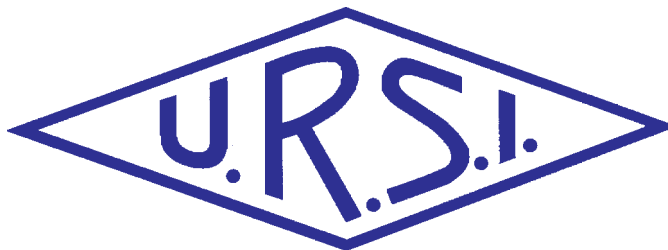


The Radio Science Bulletin

ISSN 1024-4530

INTERNATIONAL
UNION OF
RADIO SCIENCE

UNION
RADIO-SCIENTIFIQUE
INTERNATIONALE



No 326
September 2008

Publié avec l'aide financière de l'ICSU
URSI, c/o Ghent University (INTEC)
St.-Pietersnieuwstraat 41, B-9000 Gent (Belgium)

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Front cover: The new URSI Board of Officers and the two Assistants Secretary General: from left to right: P. Wilkinson, U.S. Inan, Y.M.M. Antar, G. Brussaard (President), F. Olyslager, P. Lagasse, F. Lefeuvre, W.R. Stone, M.T. Hallikainen. This picture was taken after the new Board Meeting at the end of the XXIXth General Assembly in Chicago, IL, USA.

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We have two papers in this issue. In addition, you will find the triennial reports of several of the URSI Scientific Commissions in these pages, along with news items from the XXIX URSI General Assembly in Chicago.



The Square Kilometer Array (SKA) Radio Telescope is a truly historical undertaking. Not only will it be the most sensitive, flexible, and by far the largest radio telescope ever built: It will also foster and depend upon decades of research and development into the substantial improvements in science and technology necessary to bring it to fruition. P. J. Hall, R. T. Schilizzi, P. E. F. Dewdney, and T. J. W. Lazio provide us with an invited *Review of Radio Science* from Commission J that gives an update on the SKA. They begin with a summary of the key scientific programs the SKA will support. They then provide an overview of the specifications and performance goals of the SKA. Several types of sensors (radio-telescope elements) will be needed to achieve the goals of the SKA, and these are discussed. This is followed by a detailed description and discussion of the technologies involved in several of the specific sensor designs. Information on moving and processing the data collected by the SKA follows, along with an evaluation of the challenges associated with operating this huge endeavor. A number of radio telescopes have been designed and are either being built or tested to support the development of the SKA, and these are or soon will be producing important scientific results in their own right.

The efforts of Ray Norris and Phil Wilkinson in bring us this review are gratefully acknowledged.

Solid-state lasers capable of providing output in the mid-infrared (e.g., 5-10 μm) wavelength region are a challenge. In the past few years, significant progress has been made in the development of injectorless quantum cascade lasers for these wavelengths. Markus Amann and Simeon Katz have provided us with an invited *Review of Radio Science* from Commission D describing the progress that has been made in this area. They begin with a very understandable description of the theory of both injector-based and injectorless quantum cascade lasers. They explain the basic design and electrical parameters involved. They then look at the device-technology issues, including epitaxial growth, device processing, device mounting, and issues associated with measuring the output of the devices. A description of the characteristics of the devices obtained to date concludes the paper. As an example, 196 mW at a wavelength of about 6.9 μm has been obtained in a room-temperature device.

The efforts of Franz Kaertner and Phil Wilkinson in bringing us this review are greatly appreciated.

You will also find an interesting doctoral dissertation abstract in this issue. Please encourage those who have recently completed dissertations in the field of radio science to send an abstract to Peter Watson so that we can share it with our readers.

A Correction

Due to an error on my part, we had a mix-up in papers in the June issue's Special Section Honoring Jennifer Haselgrove. The paper by A. D. M. Walker, "Ray Tracing of Magnetohydrodynamic Waves in Geospace," should actually have appeared in a subsequent issue, with a different paper by the same author that was supposed to have appeared in that June Special Section. The paper by Prof. Walker that was supposed to appear in the June Special Section will now appear in the December Special Section. I apologize for the error. However, be sure to take note of that June Special Section paper. It contained a whole new method for ray tracing of magnetohydrodynamic waves that avoids the violations of the ray-tracing assumptions associated with other methods.

Welcome, and Thank You!

In the front of this issue you will find a list of the new Associate Editors for the *Radio Science Bulletin* for each of the URSI Commissions. We welcome them to the *Bulletin*. We also thank the Associate Editors for the Commissions who have served for the past triennium. They have done an excellent job, and their efforts are really appreciated.

Remember, if you have a paper that is likely to be of interest to radio scientists in general, please consider submitting it to the *Bulletin*. We are fully peer-reviewed, and indexed and abstracted in INSPEC. We have no page charges, and are often able to publish a paper within three months or less after it is received, assuming the author is prompt in responding to reviewer requests. The *Bulletin* goes to all Radioscientists, as well as the academies of science of all of the URSI Members.

The Square Kilometer Array (SKA) Radio Telescope: Progress and Technical Directions



P.J. Hall
R.T. Schilizzi
P.E.F. Dewdney
T.J.W. Lazio

Abstract

The international SKA project will deliver the most sensitive and flexible radio telescope yet built. This paper outlines the significant recent progress in the project, discusses briefly key technology components, and describes some of the suite of Pathfinder instruments and design studies now being pursued.

1. Introduction

The SKA was “born global,” and arose out of suggestions in the early 1990s for a very large “hydrogen telescope” operating at 1.4 GHz and below (see, for example, [1-3]). Since then, the SKA mandate has grown to include a range of astronomy applications that, taken together, demand an instrument with frequency coverage extending from 70 MHz to at least 25 GHz, and an array of antennas spread over at least 3000 km.

In 1993, URSI established a Large Telescope Working Group to begin an international study of the next-generation radio observatory. In the period since then, the SKA project has grown to include 19 countries, 55 institutes, and over 200 scientists and engineers. This global effort is steered by the SKA Science and Engineering Committee, a 22-member body with representatives from Europe, USA, and the rest of the world. After being coordinated on a day-to-day basis for five years by the International SKA Project Office, hosted at the ASTRON institute in the Netherlands, the project is now run by the SKA Program Development Office (SPDO), located at the Jodrell Bank Centre for Astrophysics in Manchester (UK).

The SKA global engineering development effort includes an expanding team at the SPDO in Manchester, together with large regional ventures associated with Pathfinders and design studies. In the period 2008 to 2011, the SKA Preparatory Phase Study (PrepSKA), an international effort operating under the aegis of the European

FP7 initiative, will see delivery of an SKA design and completion of a number of policy initiatives designed to advance funding and construction. In effect, the PrepSKA program will take the SKA to the point of construction readiness, at least for the first phase of the instrument. The goal is then to have a full-capacity telescope operating at frequencies less than 10 GHz by 2020.

Since 2004, five key science areas have been identified as prime drivers for SKA specifications and three antenna technologies have been selected as the basis of a reference design. After an intensive characterization process, two possible sites for the core of the telescope have been identified. One site is in the Karoo wilderness of South Africa, while the other is in the Murchison region of Western Australia. Worldwide, over €150M has been allocated to SKA-related research and development in recent years, with at least a similar amount being devoted to the roll-out of Pathfinder instruments. A highlight of the past two years has been the engagement of national funding agencies with the project. Some 15 agencies now meet regularly to discuss SKA realization strategies.

2. Key Science Programs

The SKA Key Science Programs (KSPs) have been selected by an international Science Working Group as observations enabling fundamental progress in modern astronomy, physics, or astrobiology [4]. The five Key Science Programs are listed below.

2.1 Probing the Dark Ages and the Epoch of Re-ionization

The ionizing ultraviolet radiation from the first stars and galaxies produced a fundamental change in the surrounding intergalactic medium, from a nearly completely neutral state to the nearly completely ionized universe in which we live today. The most direct probe of this Epoch of

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Joseph Lazio is with the US Naval Research Laboratory, Washington, DC, USA. This is an invited Review of Radio Science from Commission J.

Re-ionization (EoR), and of the first large-scale structure formation, will be obtained by imaging neutral hydrogen and tracking the transition of the intergalactic medium from a neutral to an ionized state. Moreover, as the first galaxies and active galactic nuclei (AGN) form, the SKA will provide an unobscured view of their gas content and dynamics via observations of highly redshifted, low-order molecular transitions (e.g., CO).

2.2 Galaxy Evolution, Cosmology, and Dark Energy

Hydrogen is the fundamental baryonic component of the universe. The SKA will have sufficient sensitivity to the 21-cm hyperfine transition of H I to detect galaxies to redshifts $z > 1$. One of the key questions for 21st century astronomy is how galaxies were first assembled. The SKA will probe how galaxies convert their gas to stars over a significant fraction of cosmic time, and how the environment affects galactic properties. Simultaneously, baryon acoustic oscillations (BAOs), remnants of early density fluctuations in the universe, serve as a tracer of the early expansion of the universe. The SKA will collect a large enough sample of galaxies to measure baryon acoustic oscillations as a function of redshift to constrain the equation of state of dark energy.

2.3 The Origin and Evolution of Cosmic Magnetism

Magnetic fields likely play an important role throughout astrophysics, including in particle acceleration, cosmic-ray propagation, and star formation. Unlike gravity, which has been present since the earliest times in the universe, magnetic fields may have been generated essentially *ab initio* in galaxies and clusters of galaxies. By measuring the Faraday rotation toward large numbers of background sources, the SKA will track the evolution of magnetic fields in galaxies and clusters of galaxies over a large fraction of cosmic time. The SKA observations also will seek to address whether magnetic fields are primordial and dating from the earliest times in the universe, or were generated much later by dynamo activity.

2.4 Strong Field Tests of Gravity Using Pulsars and Black Holes

With magnetic field strengths as large as 10^{14} G, rotation rates approaching 1000 Hz, central densities exceeding 10^{14} g cm⁻³, and gravitational fields about 10^{11} times stronger than that of the Earth, neutron stars represent extreme laboratories. Their utility as fundamental laboratories has already been demonstrated through results from observations of a number of objects, resulting in two Nobel Prizes. The SKA will find many new millisecond pulsars and engage in high-precision timing of them in order to construct a Pulsar Timing Array for the detection

of nanohertz gravitational waves; probing the space-time environment around black holes via both ultra-relativistic binaries (e.g., pulsar/black-hole binaries) and pulsars orbiting the central super massive black hole in the center of the Milky Way; and probe the equation of state of nuclear matter.

2.5 The Cradle of Life

The existence of life elsewhere in the universe has been a topic of speculation for millennia. In the latter half of the 20th century, these speculations began to be informed by observational data, including organic molecules in interstellar space, and proto-planetary disks and planets themselves orbiting nearby stars. With its high sensitivity and resolution, the SKA will be able to observe the centimeter-wavelength thermal radiation from dust in the inner regions of nearby proto-planetary disks and will be able to monitor changes as planets form, thereby probing a key regime in the planetary-formation process. On larger scales in molecular clouds, the SKA will search for complex prebiotic molecules. Finally, detection of transmissions from another civilization would provide immediate and direct evidence of life elsewhere in the universe. The SKA will provide sufficient sensitivity to enable, for the first time, searches for unintentional emissions or “leakage.”

In addition to the Key Science Programs listed, and recognizing the long history of discovery at radio wavelengths (pulsars, cosmic microwave background, quasars, masers, the first extra-solar planets, etc.), the international science community also recommended that the design and development of the SKA have “Exploration of the Unknown” as a philosophy. Wherever possible, the design of the telescope is being developed in a manner to allow maximum flexibility and evolution of its capabilities to probe new parameter space (e.g., time-variable phenomena that current telescopes are not well equipped to detect). This philosophy is essential, as many of the outstanding questions of the 2020-2050 era – when the SKA will be in its most productive years – are likely not even known today.

In an effort to guide the development of the telescope, a Reference Science Mission is now being assembled. The Reference Science Mission is designed to identify the main scientific requirements needed to conduct the Key Science Programs and to codify in more detail how they these requirements lead to the SKA engineering specifications. A common theme for all components of the Reference Science Mission is “Exploration of the Unknown,” including the search for cosmic radio transients.

3. SKA Technical Overview

The Square Kilometer Array will be an aperture-synthesis radio telescope that employs the concepts of radio imaging developed over the past four to five decades. These



Figure 1. The VLA in one of its more compact antenna array configurations. The 27 antennas are moveable on rail tracks, and different configurations are used to obtain different spatial samplings of incoming cosmic radiation (image from NRAO/AUI/NSF).

concepts amount to spatial, spectral, and temporal sampling of the incoming radio-radiation field to match the expected structure of the field in these three domains. In addition, careful attention will be paid to rejecting extraneous, manmade signals (radio-frequency interference).

Synthesis radio telescopes require an array of antennas and receivers (more generally, radio “sensors”) covering a large area on the ground, and configured to provide the required spatial sampling. The Very Large Array (VLA), currently undergoing a major upgrade, is an example of an aperture-synthesis telescope that employs many of these concepts (Figure 1). The complex voltages from the sensors are cross-correlated in pairs, then integrated to reduce noise. These data are used to reconstruct the original brightness distribution, typically giving images of the sky, radio-frequency spectra at each point in the sky, and (sometimes) spectral and spatial variations with time. The extremely weak astronomical radio signals require high sensitivity and low system noise. This is achieved principally by virtue of the very large total collecting area of the sensors, and by receiver systems that contribute the minimum possible noise.

Preliminary top-level specifications for the SKA have been developed [5] following science-engineering trade-offs that have taken into account current knowledge of key technologies (Section 4), and their likely evolution path and cost at the time of construction. A number of possible implementations are proposed (Section 5), which are estimated to cost 300M Euro for the first stage (Phase 1) of the array and 1200M Euro for the second stage (Phase 2). Phases 1 and 2 will cover frequencies from ~70 MHz to 10 GHz. The Phase 1 and 2 costs include 100M Euro and 500M Euro, respectively, for infrastructure, software, labor, management costs, and delivery; the remaining two-thirds in both cases is for hardware components. (All costs are expressed as 2007 currency). The third phase of the SKA Program, the extension to at least 25 GHz, is less well defined at this stage, and the technical outlines and costs of its implementation are left to future studies.

The science goals outlined in Section 2 require the SKA to be a radio telescope with the attributes set out below.

- The *sensitivity* to detect and image hydrogen in the early universe. This is to be accomplished by deploying a *very large collecting area*, up to several km² at the lowest frequencies. The sensitivity of the telescope at frequencies around 1.4 GHz, described in terms of the ratio of effective area to system temperature (A_e/T_{sys}), will be ~10 000 m² K⁻¹ (peak), about 50 times that of the Expanded VLA. (In communications-engineering sensitivity units, the G/T specification of the SKA is about 65 dB K⁻¹).
- A *wide frequency range* to enable the range of science in the Key Science Programs:
 - 70 to 300 MHz (low band)
 - 0.3 to 10 GHz (mid-band)
 - 10 to > 25 GHz (high band)

These bands are defined principally by the way that science maps into frequency space, but also by technology, and possibly site, considerations. Note that the operating range spans more than two decades in frequency.

- A *fast surveying capability* over the whole sky. This is to be accomplished by means of the high sensitivity, together with a *large angular field of view* (FoV), possibly several tens of square degrees at frequencies near 1 GHz, and up to 250 square degrees at the lowest frequencies. Above 1 GHz, an FoV of one square degree, scaling with wavelength squared (the scaling obtained with many conventional antennas), matches the science goals sufficiently well.
- A *central concentration of the collecting area* for optimal detection of hydrogen, pulsars, and magnetic fields. Fifty percent of the collecting area will be located within a radius of 2.5 km of the center of the array, a further 25% within 180 km of the center, and the remaining 25% out to the maximum extent of the array. The details of the array configuration are still being investigated, but Figure 2 depicts one possible layout and core-array arrangement.

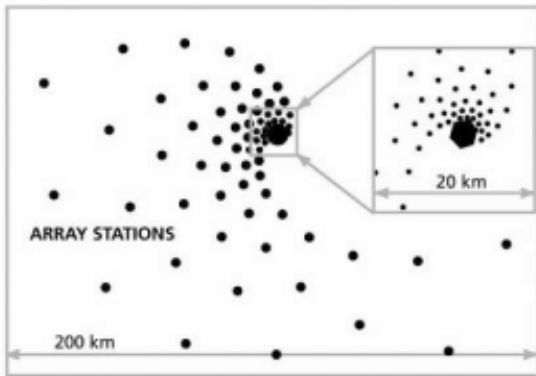


Figure 2a. An example of a possible SKA configuration. In this model, patches of collecting area (stations) extend from a dense core in a log-spiral arrangement. The pattern continues to baselines of ~ 3000 km. The huge number of SKA sensors gives excellent spatial sampling characteristics without the need to periodically relocate antennas.



Figure 2b. An artist's impression of the SKA core region, with planar-aperture arrays and dishes visible. All the sensor technologies will share wideband communication as well as signal-processing and data-processing infrastructures

- The capability for detailed imaging of compact objects and astrometry. This requires an array with a *large physical extent*, up to at least 3000 km.

4. SKA Sensor Concepts

An earlier review [6], in 2005, outlined six SKA concepts based on various sensor technologies. These were described originally in a series of 2002-2003 white papers (available via <http://www.skatelescope.org>). They were divided equally between “large- N , small- D ” and “small- N , large- D ” concepts, with N being the number of correlated entities (antennas or stations) and D being the antenna diameter. All concepts had signals from sensors in the central region of the array being directly cross-correlated; some arrangements grouped outer antennas into stations, thereby aggregating the corresponding signals prior to correlation. The 2005 review noted a high degree of post-sensor commonality among all concepts, unsurprising when the telescope is viewed as an information technology machine, transporting and processing defined data rates and

volumes over given distance regimes. In 2005, it was already clear that performance and cost considerations would most likely dictate a mix of sensors (Figure 3).

Over the past three years, guided interaction between astronomers and engineers has clarified a number of points, which has allowed engineers to advance the conceptual design of the telescope. These include the following considerations.

- High survey speed is a preeminent specification, ranking alongside the high point-source sensitivity, which has always been a key SKA requirement; for many (but not all) SKA science applications point-source sensitivity can be exchanged for survey speed. The sensitivity metric is taken as $A_{\text{eff}}/T_{\text{sys}}$ (Section 3), while a common survey speed figure-of-merit is $(A_{\text{eff}}/T_{\text{sys}})^2 \text{FoV}$.
- Most SKA science is well addressed by an instrument with an upper frequency limit of about 10 GHz. However, important observations – some likely to be linked to emerging ALMA (Atacama Large Millimeter Array) and EVLA (Expanded VLA) science – require a new-generation telescope operating to > 25 GHz; the 10 GHz breakpoint separates SKA Phases 2 and 3 (Section 3).

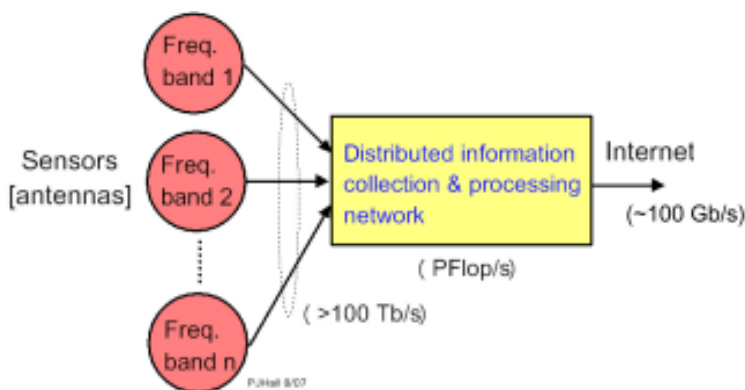


Figure 3. A view of the SKA as an information and communications technology (ICT) machine. Signals from a variety of different types of electromagnetic-field sensors (antennas and receivers) are transported and processed via common machinery. Sensors are chosen largely on the basis of their performance-to-cost ratio within particular frequency bands.

- The requirement of an SKA continuum imaging dynamic range of $>10^6$ is only likely to be achievable with the excellent interferometer baseline density (u, v -plane coverage) of large- N solutions, and then only with substantial development of current imaging techniques.
- Computing performance and cost are integral to the overall SKA system design, with the pace of change in this and related areas dictating the need for an evolutionary, or at least staged, instrument specification and implementation.
- With computing and signal-processing considerations in mind, and accounting for an N^2 (or number of baselines) dependence of correlation and first-level post-processing demands, technology offering high survey speed via wide FoV should do so without increasing the antenna count. This can be achieved by the production of multiple FoVs, each with an extent commensurate with the FoV of a primary element (e.g., a dish). Baseline-dependent processing then scales, to the first order, only linearly with total FoV.

Noting these points, and weighing additional issues such as operational flexibility and technology maturation timescales, the SKA project has adopted a Reference Design (RD), based on a mix of three sensor types in a large- N , small- D arrangement [7]. Two of these – aperture-plane phased arrays (AA) and small ($\sim 12\text{m}$) dishes with single-

pixel feeds (SD+SPF) – were included in the six concepts examined in [6]. The “new” sensor type in the Reference Design is a mid-frequency sensor based on small dishes equipped with focal-plane phased-array feeds (SD+PAF). This arrangement – which is, of course, an intermediate arrangement between “pure” AA and SD+SPF solutions – uses both optical and electronic beamforming to generate wide FoVs and high survey speeds in the region near 1 GHz. It is potentially a cost-effective SKA solution. Figure 4 shows the application of the sensor suite across the operating frequency range of the SKA.

An international Engineering Working Group, and many associated specialist task forces, have been active in mapping out the SKA system design as well as key elements of major subsystems [8, 9]. Interestingly, all the original concepts [6] for SKA sensors have proved to be important vehicles for exploration of scientific possibilities and system-design ideas. For example, the Large Adaptive Reflector contributed the “hybrid” dish plus phased-array feed; the Cylindrical Reflector underlined the value of wide FoV in enabling practical all-sky surveys; and the Luneburg Lens provided the basis of wide-field, large- N system architecture. The remaining concept, KARST, inspired the now-funded Chinese Five-hundred metre Aperture Spherical Telescope (FAST), is itself likely to be an important scientific precursor to the SKA.

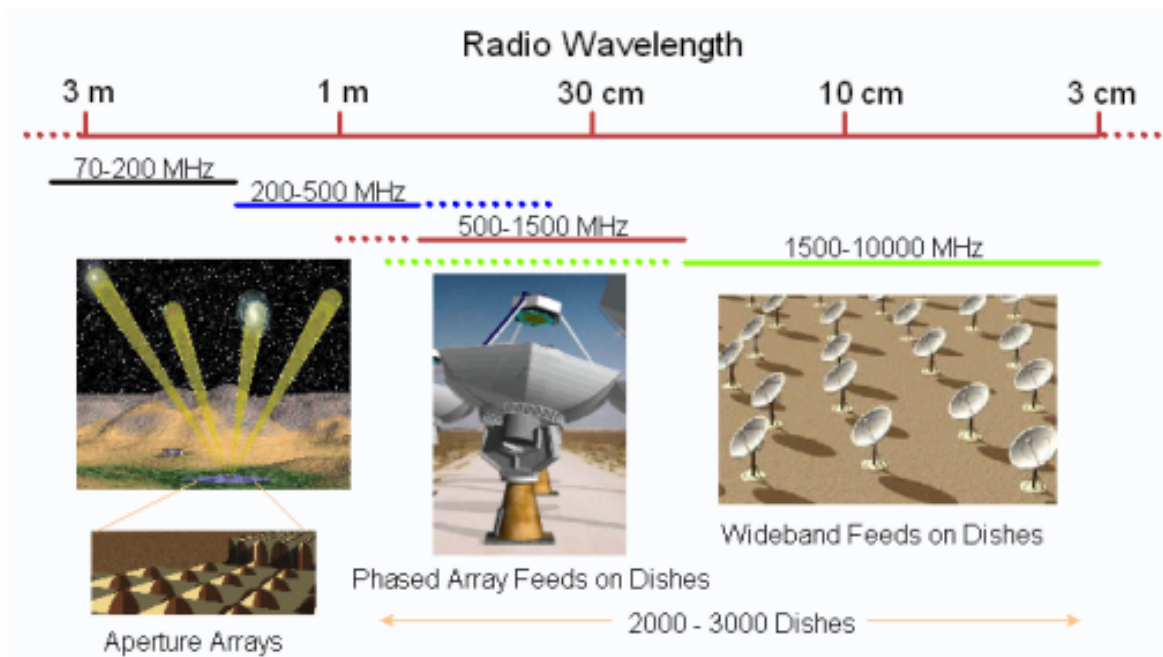


Figure 4. A schematic diagram of the Reference Design sensor technologies over the range of SKA wavelengths. The bars under the wavelength axis denote ranges over which four sensor technologies will be used. At the longest wavelengths (leftmost bar), sparse aperture arrays are the most practical solution. At intermediate wavelengths, potentially both dense aperture arrays (left-most middle bar) and reflectors with phased-array feeds (right-most middle bar) are possible. At the shortest wavelengths (right-most bar), only reflectors with single-pixel feeds are practical. The dotted lines indicate where technology choices may have to be made, or could coexist. The upper-left diagram shows an aperture array as a flat sensor system on the ground, “illuminating” the sky with multiple beams. The exploded view shows the elements of the aperture array, in this case, Vivaldi antennas. The middle diagram at the top shows a standard parabolic reflector with a phased-array feed at its focus. The upper-right diagram shows an array of parabolic reflectors with ultra-wideband feeds at their foci. In practice, the reflectors will likely have both feeds available, each covering a different frequency range.

5. SKA Specifications and Technology Implementations

Within the Reference Design, the numbers of each sensor type and the exact operating frequency band of each type are yet to be determined on the basis of refined science goals and demonstrated performance/ cost achievements. Recognizing this, the initial SKA specifications have been framed with several possible development outcomes in mind. All, or only some, of the Reference Design constituent technologies may prove successful, and the initial specifications reflect various technology mixes enabling high-impact science. While major science drivers are reflected in each mix, different technology-development outcomes will certainly give rise to different SKA optimizations.

Some Reference Design technologies are more mature than others, and are already being applied in astronomical observations. For example, LOFAR and several other telescopes are proving the merits of sparse aperture arrays (inter-element spacing $> \lambda/2$), and the Allen Telescope Array is demonstrating the effectiveness of small dishes equipped with wideband, single-pixel feeds (Section 8). There is therefore a “low-risk” SKA technology path. However, at the same time, the adopted specification and system design processes allow for the augmentation of this path with highly-attractive dense phased-array technology, having both aperture and focal-plane application. As described in Section 8, significant demonstrations are underway to bring Reference Design technologies to maturation within the four-year timescale of the SKA system design.

Detailed SKA specification considerations were discussed in [5], and a range of possible array implementations was given on the basis of various

technology research and development outcomes. Three scenarios are currently being investigated in some detail.

- Sparse aperture arrays (AAs) in the range of 70 MHz to 500 MHz, plus 3000×15 m diameter dishes equipped with wideband single-pixel feeds (SPFs) covering 0.5 GHz to 10 GHz.
- Sparse aperture arrays in the frequency range of 70 MHz to 500 MHz, plus 2000×15 m diameter dishes equipped with both phased-array feeds (PAFs), covering 0.5 GHz to 1.5 GHz, and single-pixel feeds, operating from 1.5 GHz to 10 GHz.
- Sparse aperture arrays in the range of 70 MHz to 500 MHz, plus a dense aperture array in the range of 0.5 GHz to 0.8 GHz, plus 2400×15 m diameter dishes equipped with single-pixel feeds covering 1 GHz to 10 GHz.

Figure 5 shows the two key SKA specifications, point-source sensitivity and survey speed, plotted as a function of epoch, with the spread in values representing the range of technology choices. Note that the large SKA Pathfinders (ASKAP and MeerKAT) are powerful telescopes in their own right, and that SKA Phase 1 provides order-of-magnitude improvements over the largest existing synthesis array. The final values of the SKA specifications depend on the adopted technologies and, by implication, the outcomes of the various research and development programs over the next few years.

In itself, the specification process has been an interesting one, requiring a global consensus in the face of incomplete engineering information. While recognizing the impracticality of a purely serial demonstration and design process, the SKA project has nevertheless sought to retire risk as early as possible by using many demonstrators with a succeed or fail-early approach, especially for base technology options, such as sparse arrays and small dishes.

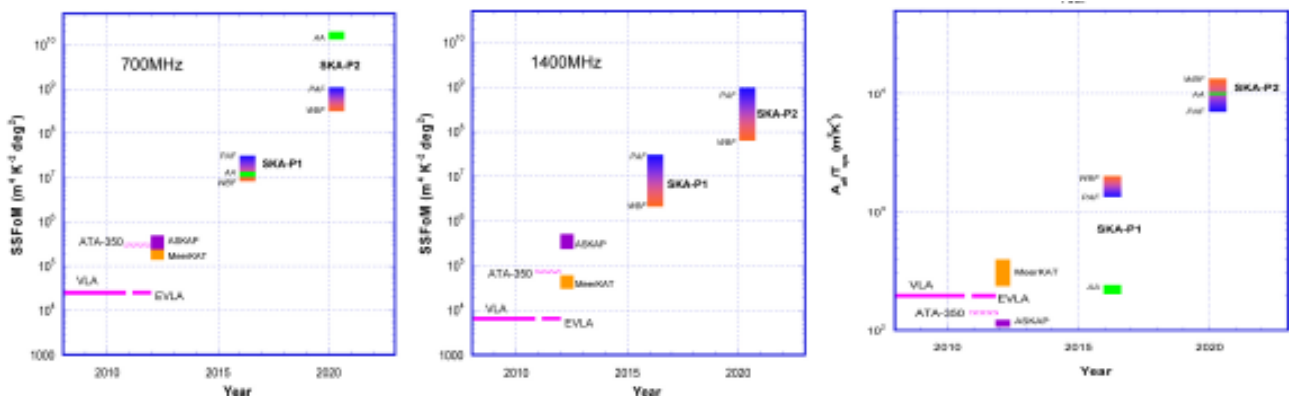


Figure 5. The progression of survey speed figure-of-merit and sensitivity between 2008 and 2020, when the mid-band SKA is expected to be complete. The top two plots are survey speed at two important frequencies for HI (hydrogen) and other surveys. The bottom plot is SKA sensitivity when the telescope is used to integrate deeply at a single pointing. For reference, these values have also been provided for the VLA, EVLA, ATA, and the SKA Pathfinders. The ranges shown by vertical bars delineate the impact on sensitivity of SKA technology assumptions.

The project is also using an evolving performance and cost-estimation tool, providing a framework for iterative science and engineering discussions. The tool, like the underlying system-design approach, is hierarchical in nature, allowing a boot-strapped design process as more complete information becomes available from SKA Pathfinders, design studies, and other sources. While much remains to be done, the inclusion of key system elements in the estimation environment has led to many insights, and has been important in bounding the design space to that summarized above.

6. SKA Sensor Technologies in More Detail

As far as possible, the Reference Design sensors have been chosen to capitalize on cost and flexibility gains provided by advances in technology, especially in the information and communications technology (ICT) area. Many potential SKA gains flow from the increasingly-feasible “software telescope” approach, in which analog components are replaced by programmable digital-signal-processing (DSP) engines, or even by general-purpose computers. While the radio/ICT marriage is currently most attractive at frequencies below ~ 1 GHz, the SKA system design will allow integration of “smart” high-frequency sensors as they become available. In this context, “smart” refers to antennas with associated (or embedded) DSP solutions. Even first-generation high-frequency SKA sensors will feature innovative solutions, many of which are based on gains in commercial off-the-shelf items, or at least in allied manufacturing processes (e.g., the use of low-noise highly-integrated receivers).

Some relevant general considerations and examples relating to each Reference Design technology are set out below, beginning with the more developed technologies employing “pure” beamforming solutions, either electronic or optical.



Figure 6a. An example of sparse aperture array technology from the LOFAR telescope (ASTRON): A polarization pair of “droopy dipoles” that operate from 30–80 MHz. The inset shows the low-noise amplifier hub.

6.1 Aperture Array (AA)

At frequencies below ~ 300 MHz, where the system noise is dominated by galactic noise (with a $\lambda^{2.6}$ spectrum), sparse aperture arrays are an attractive technology. With broadband receiving elements spaced by more than $\lambda/2$, the mutual coupling is relatively small. The effective collecting area grows as λ^2 , partially compensating for the rapid increase in galactic noise. In practice, the elements may be variants of “fat” dipoles or bowtie antennas (Figure 6), and, in present designs, arrays feature at least one stage of analog beamforming prior to digital processing. Even with beamforming, the field of view of a sparse-array station is very large: up to 250 deg^2 at hundreds of MHz. Furthermore, replicating the beamforming allows the collecting area to be reused, giving multiple independent fields of view, and increasing greatly the operational flexibility of the instrument (e.g., by supporting several users observing different parts of the sky).

While potentially excellent survey telescopes, the wide field of view and inescapable grating-lobe response of sparse arrays mean that strong cosmic sources and terrestrial radio-frequency interference (RFI) often intrude on the desired field. Much of the work of Pathfinders, such as LOFAR (Section 8) and the Murchison Widefield Array [10], is aimed at establishing the ability to calibrate sparse aperture arrays, bearing in mind the required imaging dynamic range and practical limits on computing.

Dense aperture arrays, in which the elemental broadband radiators are packed closer than $\lambda/2$ over much of the operating band, are a potentially attractive replacement for dish antennas below ~ 1 GHz. Like sparse arrays, the all-electronic realization allows completely independent fields of view, contributing greatly to operational flexibility, and enabling the time-intensive surveys effectively precluded on single-user telescopes. Unlike sparse arrays, the high



Figure 6b. An example of sparse aperture array technology from the LOFAR telescope (ASTRON): A “tile” of LOFAR high-band antennas, with the individual elements shown in the inset.



Figure 7a. Prototype dense aperture array elements for the EMBRACE demonstrator (section 8). The elements are Vivaldi end-fire types.



Figure 7b. An assembly of experimental printed versions of the Vivaldi elements.

mutual coupling of the dense arrangement leads to essentially constant effective area over the operating band, similar to a dish antenna.

In the SKA context, most of the dense aperture array work has so far been based on Vivaldi end-fire radiators (Figure 7) offering $>2.5:1$ bandwidth. The work of Pathfinders and design studies centers on establishing (i) whether new-generation dense arrays are competitive in a performance/cost sense with dish antennas, (ii) whether the expected superior control of sidelobes translates in practice into easier calibration than is the case in sparse aperture arrays, and (iii) whether other characteristics of highly-coupled arrays, including scan blindness, materially affect their application to radio astronomy.

6.2 Small Dish + Single-Pixel Feed (SD+SPF)

At frequencies above ~ 1 GHz, tiling a large collecting area with elemental sensors becomes prohibitively expensive, given the approximate λ^{-2} dependence of the number of elements and associated electronics. Furthermore, it becomes progressively more difficult at higher frequencies to maintain low-noise performance with economical receiving systems and a myriad of lossy RF interconnects operating at ambient temperature. Conventional “optical” beamforming therefore becomes more attractive, with a single feed element being placed at the focus of a parabolic dish. While one could contemplate using multiple feeds in a focal-region cluster to increase the field of view, the SKA science community has determined that more scientific

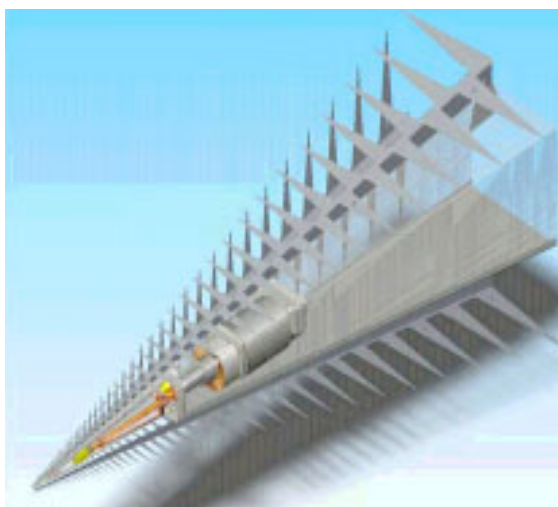


Figure 8a. An example of a new single-pixel, wideband feed for reflector antennas: A feed from the Allan Telescope Array.

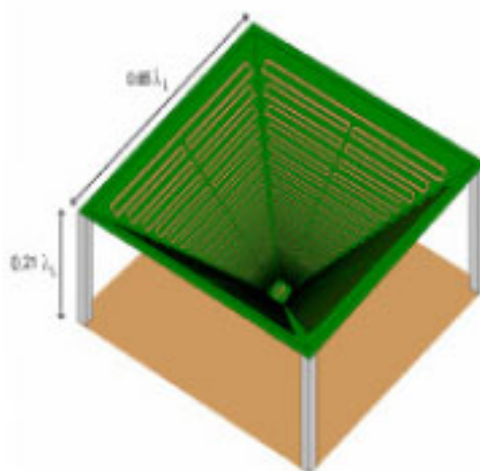


Figure 8b. An example of a new single-pixel, wideband feed for reflector antennas: A Chalmers feed [11].

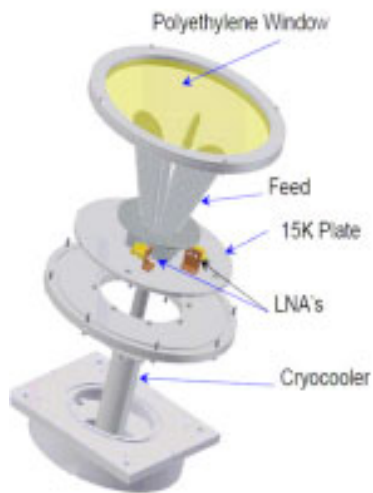


Figure 8c. An example of a new single-pixel, wideband feed for reflector antennas: A quad-ridge Lindgren horn [12].



Figure 8d. An example of a new single-pixel, wideband feed for reflector antennas: A quasi self-complementary antenna [13]. All of these dual-polarization feeds shown in Figure 8 are being evaluated for use with the SKA (illustrations courtesy of G. Cortes Medellin).

benefit accrues above 1 GHz from the use of a single, very wideband feed. (Close-packed feeds would inevitably exhibit restricted bandwidth).

A number of efficient single-pixel feed designs have been proposed. While demonstrations so far have been based on a logarithmic pyramid arrangement, other

designs are being developed (Figure 8). The thrust of SKA work in the SD+SPF area is (i) to demonstrate dish-manufacturing technologies resulting in a cost reduction factor of at least two relative to current 6 m to 15 m antennas; (ii) to demonstrate high-sensitivity-optics arrangements, including efficient decade-bandwidth feeds; and (iii) to establish the merits or otherwise of cooled receiving systems based on new-generation cryo-coolers.

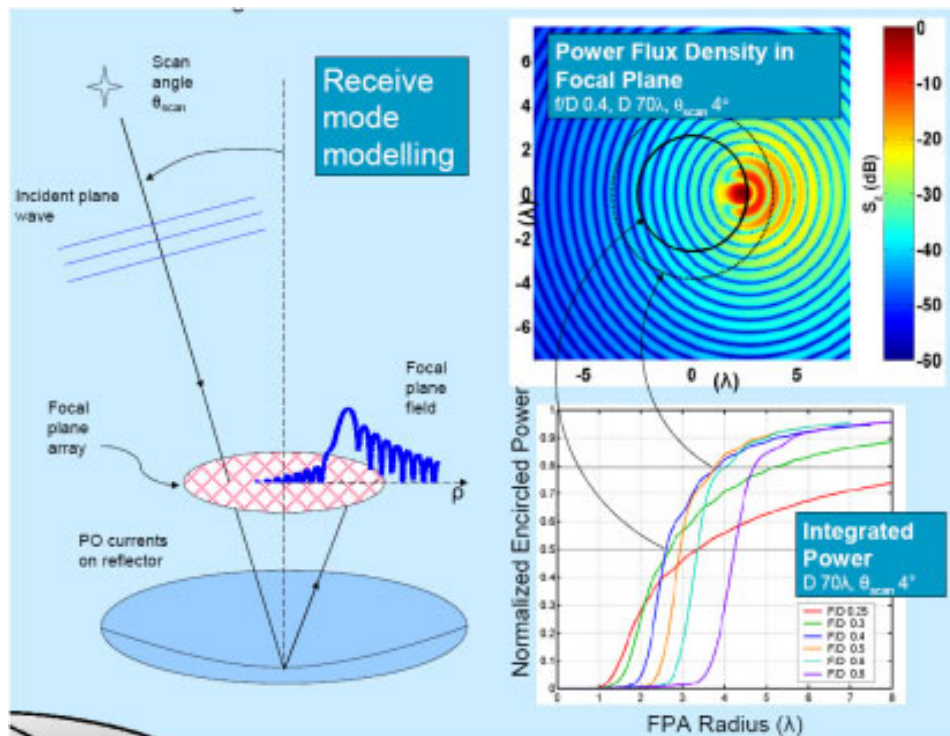


Figure 9. An illustration of the focal-plane field for a parabolic dish with $f/D = 0.4$ and the off-axis ("scan") parameters shown. The aberrations can be corrected with a phased-array feed and beamforming, but, as shown, badly distorted fields require sizeable arrays and concomitantly complex beamforming (courtesy D. Hayman et al. [14]).

6.3 Small Dish + Phased Array Feed (SD+PAF)

The SD+PAF concept uses a conventional metal beamformer (the dish), in combination with dense-phased-array field-of-view expansion technology. At radio frequencies, energy is concentrated by the dish into a focal zone of appreciable extent. In the on-axis case the field distribution is symmetrical, but off-axis distributions become progressively more distorted (Figure 9). By sampling the field pattern with a dense phased array of appropriate size and then using an electronic beamformer, it is possible to form clean off-axis beams exhibiting high efficiency, good polarization purity, and other desirable characteristics.

Each beam has an angular extent similar to the natural field of view of the dish, and, with tractably complex digital beamformers (< 100 inputs), one may generate perhaps 30 independent beams. A 15 m diameter dish has a natural field of view of $\sim 1\text{deg}^2$ at 1 GHz, so a typical SD+PAF sensor gives a total field of view of $\sim 30\text{deg}^2$. If the field-of-view expansion does not come at the expense of system temperature, the survey speed also increases by a factor of ~ 30 relative to a single-pixel-feed arrangement. Importantly, the field of view and survey speed increases come without increasing the SKA dish count, so the required increase in correlator and subsequent processing power grows only by a factor of about 30, rather than 30^2 (Section 4).

With a beamformer of given complexity, it is easy to adjust the field-of-view expansion factor across the operating band, and constant total fields of view across frequency ratios of at least 2.5:1 are possible. While still being refined, phased-array-feed technology offers, via a range of programmable beamforming solutions, much greater flexibility and survey efficiency than more conventional multiple-feed cluster arrangements [15]. SD+PAF prototyping is underway in both Australia and The

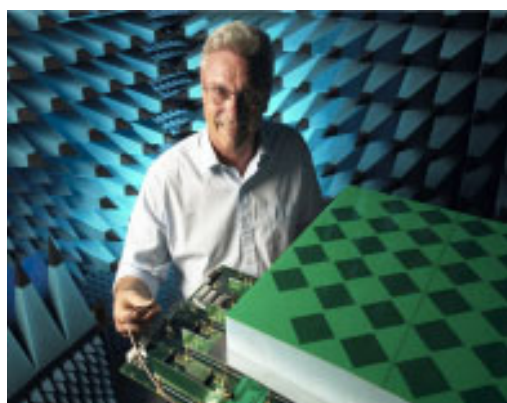


Figure 10a. A prototype phased-array feed system that is are being used to evaluate the technology for expanding the field of view of reflector antennas: The Chequer Board Array (CSIRO/ATNF Australia).

Netherlands; Figure 10 shows some examples of test systems.

One of the practical challenges for SKA antenna designers involves accommodating both phased-array feeds and single-pixel feeds on the one dish to give an upper frequency range extending to 10 GHz (Section 5). A number of options are currently being investigated, ranging from simple offset arrangements to folded optical paths.

7. Beyond the Sensors: Other SKA Design Challenges

While antennas are the visible face of the SKA, there are many other challenges associated with signal transport, processing, scientific post-processing, and data archiving and retrieval. Here, we discuss a few key points in each area.

7.1 Signal Transport

Challenges exist over a range of distance regimes, from intra-chip and inter-chip switching and routing through to trans-oceanic data connections. Low-cost, short-haul ($< \sim 50\text{m}$) signal transport, either digital or analog, is an enabling technology for wide-field-of-view sensors, such as aperture arrays. Typical data rates from individual dish antennas may be of the order of 100 Gbs^{-1} and, at the next level, aggregate data rates of several Tbs^{-1} will be required from each SKA station. Following centralized data processing near the SKA core region, transcontinental and transoceanic data rates of at least 100 Gbs^{-1} will be needed. While a large part of the telescope's internal data network will be owned by the SKA project, telescope data will at some point flow via other links, including those of national research networks and telecommunications carriers. Achieving the desired data rates at a tractable cost involves both technical and policy issues, and will undoubtedly figure prominently in final SKA site-selection discussions.



Figure 10b. A prototype phased-array feed system that is are being used to evaluate the technology for expanding the field of view of reflector antennas: The Phased Array Demonstrator (National Research Council, Dominion Radio Astronomy Observatory, Canada).

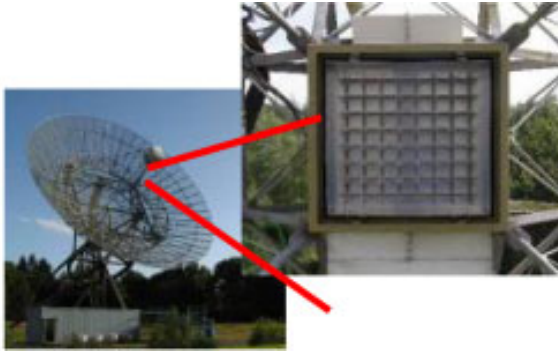


Figure 10c. A prototype phased-array feed system that is being used to evaluate the technology for expanding the field of view of reflector antennas: The APERTIF at the Westerbork Synthesis Radio Telescope (ASTRON, The Netherlands).

7.2 Signal Processing

The great majority of SKA signal processing will be digital, with the only likely exception being first-stage beamforming in first-generation aperture arrays. In a synthesis telescope of the scale of the SKA, the most cost-effective approach to cross-correlation involves an “FX” architecture, in which signal bands are split into channels prior to being cross-multiplied and integrated. This architecture, with the frequency-channelization done at the antennas or stations, also lends itself well to efficiently supporting other operations, including beamforming (at various hierarchical levels in the system) and RFI excision. The amount of station-based DSP will depend on sensor arrangements. In some cases, station-level beamforming can be used to reduce data rates from the station to the central-processing site, particularly if a reduction in processed field of view is acceptable in a given experiment.

The SKA correlator – or, perhaps more likely, correlator suite – could be constituted from a number of approaches being demonstrated in various Pathfinder instruments. These range from purpose-built machines based on field-programmable gate arrays (FPGAs) or application-specific integrated circuits (ASICs), through to high-performance computing solutions. Early indications are that with a total processing load of peta-operations per second, and constraints on available power (Section 7.4), purpose-built correlators are most attractive. There is no doubt, though, that flexibility and “time-to-market” demands will push SKA designers to consider wide-spread application of programmable DSP engines and high-performance computing (HPC) subsystems, where possible.

Apart from the synthesis imaging application, the SKA will need to support other operational modes, most notably time-domain and radio-transient observations. This imposes additional requirements on the telescope architecture, particularly in terms of preserving data-stream coherence and continuity across the huge number of signal paths, and in the provision of machinery to produce and process summed-array modes across the entire SKA, or within subarrays. Part of the PrepSKA task is to ensure non-imaging modes are well-integrated into the SKA design, perhaps via the use of data spigots to which an evolving suite of backend instrumentation can be attached.

7.3 Post-Processing

With correlation rates of 10^{15} operations per second, and each correlator output data point (or u, v plane sample) requiring thousands of accurate operations upon it if existing imaging algorithms are used, post-correlation solutions capable of more than 10^{18} floating-point operations per second (FLOPS) are needed. While leading-edge peak computing capacities of this order are in fact forecast on 2015-2020 timescales, keeping the SKA computation load affordable will require developments on several fronts, including new and more efficient algorithms, new super-computing architectures (possibly departing from full floating-point implementations), and the use of special-purpose hardware and high-performance computing in close concert.

Software for the SKA is also a major challenge. The push towards a “software telescope” reduces hardware costs, but with a natural desire to fully exploit the new paradigm – and a concomitant increase in complexity – the magnitude of the software-development task increases, perhaps disproportionately. One early estimate, derived by scaling costs in a recent large telescope project, put the SKA software task at about ~ 2000 person-years [16]. Likely mechanisms for controlling costs are based on capping complexity at each stage of SKA development. This requires system designers to consider not only progressive gains in DSP and computing hardware performance, but also to account for the evolution of software capacity. Making the best use of this capacity forces a shift towards the use of commercial software (where possible), and an emphasis on reuse of software components.

7.4 Infrastructure

Both candidate SKA sites have been chosen to be remote from human settlement, principally in order to minimize external RFI. Providing the infrastructure to construct and operate the telescope will therefore be a logistical challenge, and a challenge magnified by the need to support a progressive “build-out” of the array whilst scientific observations are taking place. Fortunately, both candidate sites will have Pathfinder instruments nearby, and the infrastructure plans for these telescopes provide for at least SKA Phase 1 requirements [17].

Power provision represents a major part of the SKA infrastructure project. Core requirements may be of order 30 MW (excluding any high-performance computing), and remote stations may need ~0.5MW each. If a high-performance computing facility is added, requirements in the range 50 to 100 MW are likely, resulting in energy costs of 50M Euro to 100M Euro annually, even with the relatively favorable unit costs foreseen by the candidate host nations. Apart from the need to keep overall consumption as low as possible, designers face a further challenge in powering remote stations: in Australia, at least many of these will require renewable energy solutions, together with appropriate storage technology. Provision of power, while normally considered a prosaic engineering activity, may well determine the capability of the installed SKA systems, and thus the ultimate scientific performance of the instrument.

7.5 Operations

The SKA Operations Working Group has produced two studies [18, 19] outlining operational considerations. First analyses have relied on resource scaling from existing radio arrays, and have also set down key lessons to be learned from facilities in both astronomy and other branches of science. In general terms, operational costs of the order of 10% of capital investment per year are foreseen, amounting to about 100M Euro per annum in 2007 dollars. Of this figure, 2% to 3% of capital is foreseen as being set aside for renewal and upgrades, while a similar fraction is expected to cover user support. With the SKA project confronting high energy costs (Section 7.4), constraining operations costs to 100M Euro per annum without compromising scientific utility will be challenging. Regardless of the exact figure, it is clear that total operational costs over a 30 to 50 year lifetime will far exceed initial capital investment. Life-cycle and support modeling is therefore a central activity of the PrepSKA design initiative.

First operational models see the SKA as part of a global e-science network, with Tier-1 science centers – each supporting base science and one or more specializations – spread around the world. The SKA will effectively supplant some national facilities, and the need to fund engineering innovation, education, and public outreach as part of the international program is specifically recognized.

8. SKA Pathfinders and Design Studies

Since the early days of the project, technology demonstration has been the basis of SKA engineering decision making. In the sensor area, some technologies are inherently more mature than others, and the challenge is to balance implementation risk against scientific promise. Not all technology demonstrations are of equivalent scale, if only because of regional research and development funding

variations. However, the general approach adopted requires demonstration of pivotal technologies, on a 2010-11 timescale, by the SKA Design Studies and Pathfinders (or significant parts thereof). This will allow key results to flow into the PrepSKA system design, which, in its early years, tackles generic issues common to all Reference Design sensor technologies. For more information on programmatic aspects of the SKA see Schilizzi et al. [20].

The summaries below outline the larger Pathfinder and design study projects now underway. Specifications given are only indicative. We have listed only projects born in the SKA milieu, but we note that other new radio telescopes, such as the Atacama Large Millimetre Array (ALMA), and major upgrades of existing instruments, are all contributing substantially to the SKA knowledge base. Two significant upgrades are the previously-mentioned EVLA project in the USA, and the eMERLIN (enhanced MERLIN) program in the UK. In addition, we record the key role of the APERTIF (Aperture Tile in Focus) upgrade project at the Netherlands Westerbork Synthesis Radio Telescope in advancing the development of phased-array feed technology (see Figure 10). Canadian SKA design and prototyping activities are also associated with phased-array-feed development, together with the construction of light-weight carbon-fiber dish antennas.

8.1 LOFAR (Low-Frequency Array)

- *Brief description:* Synthesis imaging telescope using sparse aperture phased arrays, 36 800 m² total effective collecting area at 150 MHz; see Figure 6.
- *Site:* Central site near Exloo (NL), with stations placed around The Netherlands and Europe.
- *Main proponent:* LOFAR Consortium, led by ASTRON (NL).
- *Investment:* 83M Euro cash + 83M Euro in-kind from Consortium partners.
- *Operating band:* 30-80 MHz, 110-250 MHz.
- *SKA Reference Design technology demonstration:* Sparse aperture array (AA).
- *Scale:* Operational astronomical instrument; sensitivity 70 m²K⁻¹; angular resolution 4 arcsec (Dutch component); 7 deg² remote station field of view (150 MHz specifications).
- *Key technologies and techniques:* Sparse aperture arrays; tile-level RF beamforming; direct RF-digital conversion; digital band separation and station beamforming; RFI mitigation algorithms; long-distance data transport and real-time processing; correlation based on high-



Figure 11. Part of the ATA-42 array that is now operational at Hat Creek Radio Observatory in Northern California. The hydro-formed 6.1 m diameter dishes use a Gregorian-optics configuration (with ground shield), incorporating the wideband pyramidal feed shown in Figure 8.

performance computing; new calibration algorithms including aperture array beam-level calibration; transient detection algorithms; multiple, independent field of view observing; structured software engineering; design for manufacture and significant industry involvement; generalized wide-area sensor network, including, e.g., geophysical and agricultural sensors.

- *Date commenced:* 2001 (R&D); 2004 (final design); 2006 (rollout).
- *Projected completion date:* 2010.
- *Status:* First central stations operational and producing astronomical data; 20 stations (13 in central core region) to be complete by end of 2008. Web site: <http://www.lofar.org>

8.2 Allen Telescope Array

- *Brief description:* 350 × 6.1 m dish synthesis array; see Figure 11.
- *Site:* Hat Creek Radio Observatory, northern California, USA
- *Main proponents:* University of California (Berkeley), SETI Institute, Allen Foundation.
- *Investment:* USD100M = 67M Euro.
- *Operating band:* 0.5-11 GHz.
- *SKA Reference Design technology demonstration:* Small dish + single-pixel feed (SD+SPF).
- *Scale:* Operational astronomical instrument; sensitivity 160 m²K⁻¹; angular resolution 72 arcsec; 2.5 deg² field of view (1.4 GHz specifications)

- *Key technologies and techniques:* Hydro-formed dishes with Gregorian optics; wideband single-pixel feed (20:1 bandwidth); cooled low-noise amplifiers with new topologies; low-cost cryogenic cooling based on commercial Stirling-cycle coolers; wideband analog (RF on fiber) signal transport; DSP design based on modular programmable-engine approach; RFI mitigation algorithms; wideband amplification of sky signal, allowing multiple experiments within wide field of view.
- *Date commenced:* 2001 (R&D); 2004 (construction).
- *Projected completion date:* 2011.
- *Status (August 2008):* 42-dish array operational and producing astronomical data. Web site: <http://ral.berkeley.edu/ata/>.

8.3 MeerKAT (extended Karoo Array Telescope)

- *Brief description:* >50 dish × ~12 m dish synthesis array.
- *Site:* Karoo wilderness, Republic of South Africa.
- *Main proponent:* National Research Foundation, RSA.
- *Investment:* ZAR 860M = 72M Euro.
- *Operating band:* Approximately 0.5-2 GHz (initially).
- *SKA Reference Design technology demonstration:* Small dish + single-pixel feed (SD+SPF).
- *Scale:* Operational astronomical instrument; sensitivity >160 m²K⁻¹; angular resolution ~10 arcsec; field of view 1.1 deg² (1.4 GHz specifications).
- *Key technologies and techniques:* Dishes optimized for low-cost, high-volume production; wideband single-pixel feeds; scalable signal-processing solutions; data-transport solutions; formalized system-engineering approach to design (including software) and operations; remote-area construction and operation; radio-quiet-zone establishment and operation; SKA infrastructure studies.
- *Date commenced:* 2006.
- *Projected completion date:* 2012.
- *Status:* Experimental 15 m dish constructed from composite material constructed and tested; seven-dish array scheduled for end of 2009; see Figure 12a. Web site: <http://www.ska.ac.za/meerkat/index.shtml>.

8.4 ASKAP (Australian SKA Pathfinder)

- *Brief description:* 30-45 × 12 m dish synthesis array.
- *Site:* Murchison Radioastronomy Observatory, outback Western Australia. One remote station at 3000 km for transcontinental data-transport demonstration.
- *Main proponent:* CSIRO Australia Telescope National Facility.
- *Investment:* AUD110M = 66M Euro.
- *Operating band:* 0.7-1.8 GHz.
- *SKA Reference Design technology demonstration:* Small dish + phased array feed (SD+PAF).
- *Scale:* Operational astronomical instrument; sensitivity $>85 \text{ m}^2\text{K}^{-1}$; angular resolution 8 arcsec; field of view 30 deg^2 (1.4 GHz specifications).
- *Key technologies and techniques:* Dishes optimized for low-cost, high-volume production; phased-array feeds (PAFs) with digital beamformers; low-cost receiver solutions, including system-on-chip; calibration and imaging using phased-array feeds; data-transport solutions; remote-area construction and operation; radio-quiet-zone establishment and operation; SKA infrastructure studies.



Figure 12a. An experimental dish antenna. The meerKAT 15 m diameter dish constructed with low-cost fiberglass material and flame-sprayed aluminum reflective layer. The 2 mm rms surface accuracy allows effective operation to about 10 GHz. This is a platform designed to test various design concepts, but is unlikely to be the actual design used in SKA Pathfinders

- *Date commenced:* 2006.
- *Projected completion date:* 2012.
- *Status:* Two-element interferometer phased-array feed test-bed completed and operational; new phased-array feed design (“Chequer Board”) developed and being tested (Figure 10 and Figure 12b); Parkes 12 m antenna test-bed facility completed. Web site: <http://www.atnf.csiro.au/projects/askap/>.

8.5 SKADS (SKA Design Studies)

- *Brief description:* European-led R&D program to produce end-to-end SKA designs and prototypes based principally on dense aperture phased arrays, together with generic SKA technology studies and simulations to verify SKA performance.
- *Site:* EMBRACE (Electronic Multibeam Radio Astronomy Concept) demonstrator elements at Westerbork (NL) and Nancay (FR); 2-PAD (two polarization, all digital) demonstrator in UK; BEST (Basic Element for SKA Training) development platform using Northern Cross radio telescope near Bologna (IT).
- *Main proponents:* European FP6 initiative; 26-institute consortium, including international collaborators.



Figure 12b. An experimental dish antenna. The ASKAP 12 m test antenna at Parkes. The Chequer Board feed shown in Figure 10a is mounted at the prime focus of the dish. The antenna uses a stretch-formed panel construction and operates to beyond 20 GHz; it is supplied by Patriot Antenna Systems, Inc. This is a platform designed to test various design concepts, but is unlikely to be the actual design used in SKA Pathfinders.

- *Investment:* 38M Euro, including 10.4M Euro funding from EC FP6 program.
- *Operating band:* 0.5-1.5 GHz (EMBRACE); 0.3-1.0 GHz (2-PAD); 0.4-0.414 GHz (BEST).
- *SKA Reference Design technology demonstration:* Dense aperture array (AA).
- *Scale:* Astronomically-capable, single-polarization dense aperture array demonstrator, 200 m² collecting area (EMBRACE). Technical demonstration of dual-polarization, dense array tile with all element signals digitized, ~10m² (2-PAD). Astronomically-capable development platform using part of Northern Cross telescope (BEST).
- *Key technologies and techniques:* Dense aperture phased arrays (Figure 7); highly-integrated RF and beamforming solutions; low-cost analog and digital signal transport; array phase-transfer technologies and techniques; multiple independent field of views; astronomical characterization of dense phased array telescope; simulation catalogues of the radio sky as seen by SKA; simulations of ionospheric and instrumental effects on SKA observations; SKA science and operations with aperture-array telescopes; low-cost aperture-array realization via design for manufacture and industry engagement; SKA infrastructure studies.
- *Date commenced:* July 2005.
- *Projected completion date:* June 2009.
- *Status:* Successful midterm review with first-round prototypes delivered. Construction and test of demonstrators underway. Web site: <http://www.skads-eu.org/>.

8.6 TDP (Technology Development Project)

- *Brief description:* US-led design and prototyping program to develop technology options for SKA; strong working links with PrepSKA.
- *Site:* Various US institutes.
- *Main proponents:* US SKA Consortium, with international collaborators.
- *Operating band:* Emphasis on mid- and high-frequency (>1 GHz) SKA technology and technology choices.
- *Investment:* USD 12M = 7M Euro.
- *SKA Reference Design technology demonstration:* Small

dish + single-pixel feed (SD+SPF).

- *Scale:* Astronomically capable dish demonstrators; selected signal transport and processing prototypes; delivery of prototype optimized SKA antenna.
- *Key technologies and techniques:* Antennas, feeds (Figure 8), and receivers focusing on low-cost single-dish optimization; system analysis and design, including choice of antenna diameter; determination of antenna cost versus frequency function; calibration and data processing.
- *Date commenced:* 2007.
- *Projected completion date:* 2011.
- *Status:* Work packages commenced, with first of annual top-level project reviews in September 2008.

9. Conclusion

The gestation time of mega-science projects is invariably long, with 20-30 years being typical. In the case of the SKA, much of the conceptual design and scientific positioning of the instrument is complete, and the project is entering the exciting phase in which the details of the telescope are being mapped out. With continued momentum, the SKA could be undertaking its transformational astronomy mission by 2020. Part of the excitement of the SKA journey comes from the highly innovative precursor radio telescopes spawned around the world, each of which is opening up new areas of radio science and astronomy.

10. Acknowledgements

Many people contribute directly and indirectly to the SKA project: we acknowledge with thanks their contributions – past and present – to the contents of this paper. In particular, we acknowledge the efforts of Chris Carilli, Steve Rawlings, and Bryan Gaensler (former International Project Scientists), and all members of science and engineering working groups and task forces. PJH is formerly SKA Project Engineer. RTS, PEFD, and TJWL are the Project Director, Project Engineer, and Project Scientist, respectively. TJWL acknowledges the support of NRL6.1 Base funding for radio astronomy research at NRL. We are grateful to the various SKA Pathfinder and Design Study groups for the majority of pictures used in this paper.

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Injectorless Quantum Cascade Lasers for the Mid-Infrared



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Abstract

The recent progress in the design and experimental realization of injectorless quantum cascade lasers (QCLs) for the 5-10 μm wavelength regime is reported. As with the common QCLs, these lasers are considered promising solid-state coherent light sources for the mid- to far-infrared spectral region. Differing from the common QCL, the injectorless counterparts accomplish the carrier transport from one stage to the next stage without the so-called injector region, consisting of a superlattice structure comparable in spatial extension to an active region. Accordingly, at equal total thicknesses, discarding the injector regions avoids optical losses in the injector regions and enables the incorporation of more stages, yielding higher optical gain. Being less extensively explored so far than the common QCLs, the injectorless devices have gained striking improvements over the past few years. Meanwhile, in terms of relevant device parameters, injectorless QCLs have approached or even surpassed the former types.

This article introduces the theoretical models underlying the laser concept, and discusses in detail the design goals and strategies. The device performance obtained is described, and a comparison to common QCLs in the same wavelength range clearly shows the progress achieved. A short outlook on further device developments completes this review.

1. Introduction

A quantum cascade laser (QCL) is a semiconductor-based device relying on inter-subband transitions for laser operation [1]. Differing from common bipolar semiconductor lasers that exploit transitions between the conduction and valence bands, where electrons recombine with holes, quantum cascade lasers use only one kind of carriers. Typically, these are electrons that perform transitions between different states or subbands within the conduction band. The laser design therefore requires at least two materials with different conduction-band energies to enable quantum confined states in the conduction band, as shown schematically in Figure 1. Differing from the band-band transitions in bipolar semiconductor lasers, where the photon energy corresponds to the bandgap energy ($\hbar\omega \cong E_g$), the width of the quantum well and the band offset, ΔE_c , define the inter-subband transition energy in the quantum cascade laser. Accordingly, the wavelength can be widely engineered by the quantum-well design and is independent of the bandgap energy, as long as $\hbar\omega < E_g$. A major limitation in going toward shorter wavelengths is given by the magnitude of the conduction-band offset limiting the maximum energetic spacing of the subbands. Nowadays, quantum cascade lasers span a range of two orders of magnitude in frequency, from about 1.5 THz to 100 THz, corresponding to the wavelength range of 3 μm to 200 μm [2-4].

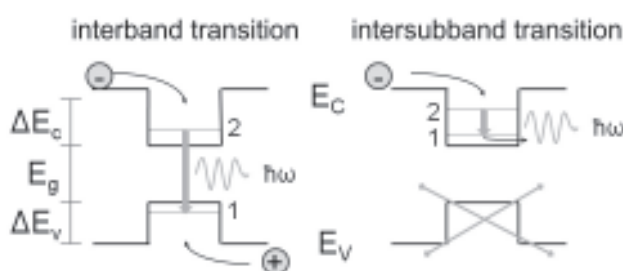


Figure 1. Two quantum wells, showing the interband transition (left) and inter-subband transition (right). The wavy arrow indicates light emission. E_g is the bandgap energy, and ΔE_c and ΔE_v denote the conduction and valence-band offsets, respectively.

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Being well known for over two decades, the concept of an inter-subband laser [5] became successful only in 1994, after introduction of so-called injector regions that accomplished the electron transport and injection into the laser states [1, 6]. However, it has recently been shown with the so-called injectorless quantum cascade lasers—a concept first introduced by Wanke et al. in 2001 [7]—that comparable or even smaller laser thresholds can be achieved by an injectorless design resembling the earlier approaches for inter-subband semiconductor lasers [8, 9].

In this paper, we shall review the designs and present status of the injectorless quantum cascade lasers in the mid-infrared. For this purpose, we first introduce the design principles and goals in Chapter 2, with particular emphasis on the quantum-mechanical, electrical, and optical properties of the devices. Noting that the majority of the injectorless quantum cascade lasers are based on the InP material system with strain-compensated ternary AlInAs-InGaAs alloys, Chapter 3 gives a short introduction into molecular-beam epitaxy and the general device processing of InP-based QCLs.

Finally, the operational characteristics of injectorless quantum cascade lasers are presented in detail in Chapter 4, and a comparison to the common quantum cascade lasers is made. Nowadays, it has also become possible to grow common quantum cascade lasers using MOVPE. These are capable of continuous-wave operation at room temperature, emitting more than 1.2 W of optical power [10, 11]. The best threshold performance under pulsed operation reported so far for QCLs at 300 K is 0.73 kA/cm² for coated devices [12], and 0.82 kA/cm² for uncoated devices [11].

2. Theoretical Models and Design Strategies

The minimal design concept of a three-level QCL requires an upper laser level, a lower laser level, and a ground state per stage, similar to all other types of three-level lasers. For laser operation, the population inversion between the two laser levels is obtained by a strong electrical pumping of the upper laser level and a fast depletion of the lower laser level to the ground state, e.g., by a relaxation processes using longitudinal optical (LO) phonons. This principle is shown in Figure 2, displaying an active region of a quantum cascade laser with the conduction band tilted under an applied electric field, and the three mentioned confined quantum states. The energy difference between states 2 and 1 determines the emission wavelength, while the energy difference between states 1 and 0 is chosen slightly higher than the longitudinal-optical-phonon energy (typically 30 to 40 meV in GaAs- and InP-based alloys), to ensure the fast depletion of the lower laser level. Usually, stacks of several tens of active regions of the type shown in Figure 2 are needed to yield sufficient optical gain, required for the compensation of internal and mirror losses during laser operation. Therefore, a second important mechanism in a quantum cascade laser is the electron transfer between two consecutive active regions. In the common QCL design, the electrons are injected from the lower state(s) of one active region into a dense manifold of states, the so-called injector region, and are then re-injected into the upper state(s) of the next active region. In this way, the injector regions assure a stable current flow between two stages, avoiding, for instance, negative differential resistance. The pairwise combination of an active region and an injector region is called a stage, as shown in Figure 3.

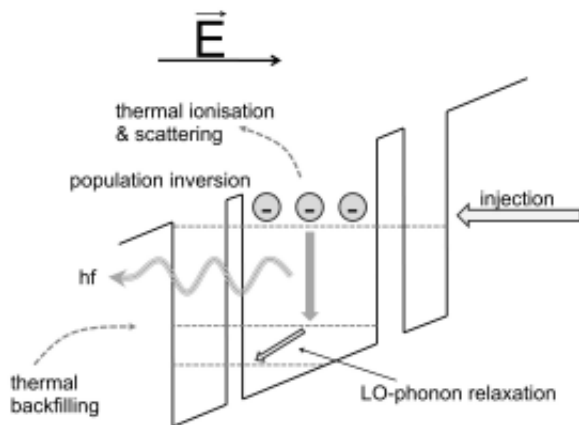


Figure 2. The active-region structure of a three-level QCL biased at threshold: the upper laser level (2), lower laser level (1), and ground state (0). The optical transitions occur between levels 2 and 1, and phonon relaxation occurs between levels 1 and 0.

On the other hand, the injectorless concept accomplishes direct injection of electrons from the ground state (0) of the previous stage into the upper laser state (2) of the following stage. This is done by designing sufficient overlap of the wavefunctions of the two states, enabling fast alloy and interface defect scattering, or by exploiting resonant tunneling.

2.1 Active Region Design

The quantum cascade laser can be regarded as an electronic waterfall, with electrons running through many stages, emitting a photon by stimulated emission in each stage. For estimating the performance of a quantum cascade laser, the so-called gain coefficient, g_c , is used. It is defined as [9]

$$g_c = \frac{4\pi e}{\epsilon_0 n \lambda} \frac{z_{if}^2}{L_p} \frac{1}{(2\gamma_{if})} \tau_i \left(1 - \frac{\tau_f}{\tau_{if}} \right), \quad (1)$$

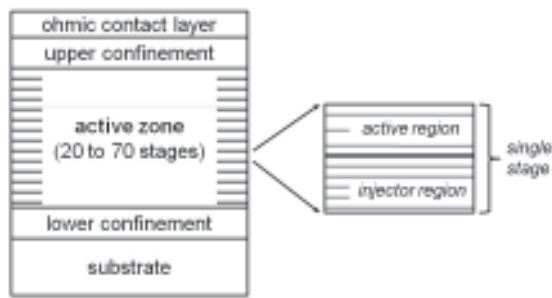


Figure 3. A schematic cross section of a common quantum cascade laser design. The active zone typically contains 20 to 70 stages, and each stage itself consists of an active region and an injector region.

with n being the effective refractive index, γ_{if} being the half width at half maximum of the luminescence line, and e being the elementary charge. The other parameters can be engineered by the design of the active region. They are defined as L_p , the length of the stage; λ , the vacuum wavelength; z_{if} , the dipole matrix element of the optical transition; τ_i , the upper-laser level lifetime; τ_f , the lower-laser-level lifetime; and τ_{if} , the lifetime of the longitudinal-optical-phonon transition. With an upper-laser-level lifetime in the range of a few picoseconds and the lower-laser-level lifetime in the sub-picosecond range, population inversion can be achieved.

Figure 4a schematically shows the conduction band of a common (i.e., injector-based) quantum cascade laser. Electrons are injected from the right-hand side, and the upper-laser-level lifetime assures the population inversion. The wavy arrow indicates the optical transition between levels $2'$ and $1'$. The two lowest energy states in the active region are used for depopulating the lower laser level ($1'$) by resonant electron-phonon scattering. The electrons in the ground state are next transferred into the injector, consisting of a superlattice structure, providing a manifold of (energetically) densely spaced states, i.e., a mini-band. Finally, the electrons enter the next stage by injection from the mini-band into the upper laser level ($2'$).

Unlike the common quantum cascade laser described above, the injectorless layout discards the injector region, reducing the total length of a stage by roughly a factor of two. In this way, for a given thickness, the reduction of the optically passive material (i.e., the injector) leads to a large number of stages, which, in turn, yields a higher gain coefficient and improved slope efficiency. Figure 4b shows the first injectorless quantum cascade laser structure based on a continuum-to-continuum transition [7]. In this design, the dipole matrix element and the upper-level lifetime were $z_{if} = 3.5$ nm and $\tau_i = 0.5$ ps, respectively. A more-advanced design of an injectorless quantum cascade laser is shown in Figure 4c [13], with a dipole matrix element of $z_{if} = 2.2$ nm and an upper-level lifetime of $\tau_i = 1.4$ ps. Both injectorless designs require an applied field suitable for direct electron transfer between the ground state(s) of

the previous stage into the upper laser level of the subsequent stage. This is accomplished by sufficient overlap of the two participating wavefunctions, allowing fast alloy and interface-defect scattering mechanisms and/or resonant tunneling. The lifetime of the transfer is in the range of a few picoseconds [14].

The active-region design can be characterized by a quality factor, Q , corresponding to [15]

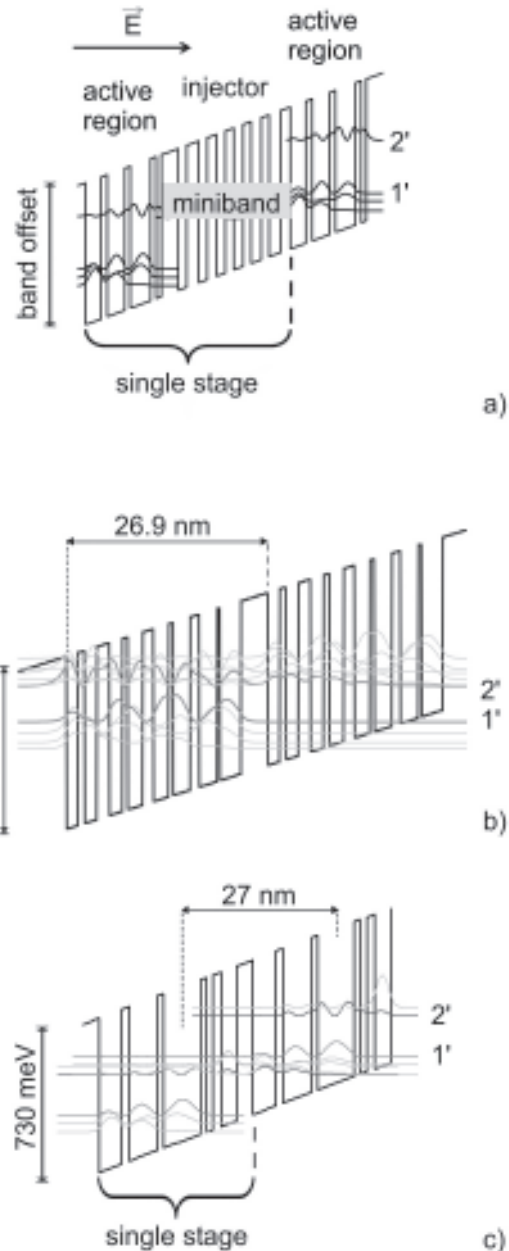


Figure 4. A schematic view of the conduction band and wave functions of an injector-based laser (a), the first injectorless design (b) by Wanke et al. [7], and a more recent design (c) by Friedrich et al. [13]. The layer sequences (in nm) of designs (b) and (c) read, from left to right: 3.7/1.6/0.9/1.7/1.7/1.8/0.78/2.0/1.5/2.1/0.61/2.4/1.2/2.5/0.4/2.9 and 2.8/4.0/1.3/5.0/1.0/6.5/1.0/1.2/1.4/2.8, respectively. The layers in bold are the barrier material while the others the well material, and the underlined layers are Si doped.

$$Q = \frac{z_{if}^2 \tau_i}{L_p \lambda}. \quad (2)$$

In addition to the Q factor, the alloy- and interface-defect scattering rates [16] are also of great importance in evaluating the performance of an injectorless quantum cascade laser design. The design presented in Figure 4b achieves a quality factor of only 20, while the advanced one shown in Figure 4c yields 37. Besides the quality factor, the confinement of the upper energy states and the wave-function alignment also have to be taken into consideration. The design presented in Figure 4c has better confined states than the design in Figure 4b, indicating an improved thermal behavior (see Sections 2.3 and 4). The design in Figure 4b also uses a continuum-to-continuum transition, which is more susceptible to thermal backfilling than the double-phonon design shown in Figure 4c.

Besides the widths of the quantum well and barrier, the material parameters of the well and barrier also significantly influence the design performance. The most important band parameters are the conduction-band offset, ΔE_c , and the effective electron mass, m_e , which both strongly depend on the alloys used. Figure 4b shows a design using the InP-based lattice-matched alloys Al_{0.48}In_{0.52}As and Ga_{0.47}In_{0.53}As, yielding a conduction-band offset of 520 meV. Figure 4c uses strain-compensated Al_{0.635}In_{0.365}As and Ga_{0.4}In_{0.6}As alloys with a band offset equal to 730 meV. Considering that a lower effective mass increases the lifetime ($\tau_i \propto m_e^{-1/2}$) of the upper laser level and the matrix dipole element ($z_{if}^2 \propto m_e^{-1}$), InP-based material systems are preferable in comparison to GaAs-based systems. This is because the quantum wells can be made of lower-bandgap alloys than on GaAs, and a lower bandgap usually corresponds to lower effective electron mass.

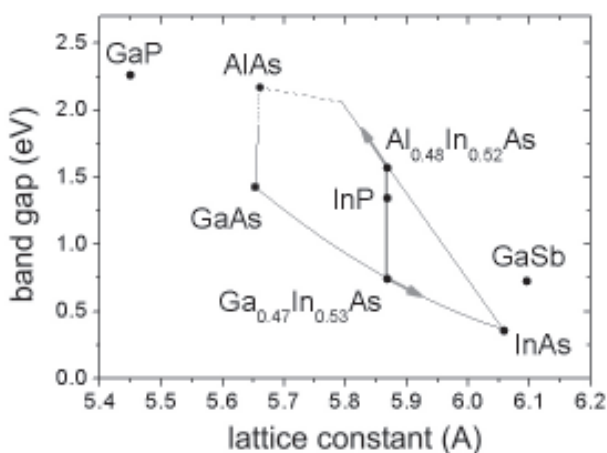


Figure 5. A map of III-V semiconductors, showing the almost unstrained AlGaAs alloys grown on GaAs and the AlGaInAs system lattice-matched on InP. The arrows indicate the regions for tensile (AlInAs) and compressively (GaInAs) strained compounds (on InP substrate).

Figure 5 shows the material map of relevant III-V compound semiconductors used for QCLs. The arrows indicate the possible strained material compositions based on InP yielding tensile strain for the AlInAs alloys (barriers) and compressive strain for the GaInAs alloys (quantum wells). Using the strained compounds, the bandgap energy differences as well as the band offsets can be enlarged. Applying oppositely strained quantum-well-barrier structures with proper thickness ratios, a compensation of the net strain is possible, alleviating the total thickness limitation (critical thickness) of strained-layer structures.

Although GaSb-based materials yield even lower bandgap energies and effective masses than the InP-based compounds, their large waveguide losses limit their suitability for quantum cascade lasers.

2.2 Waveguide Design

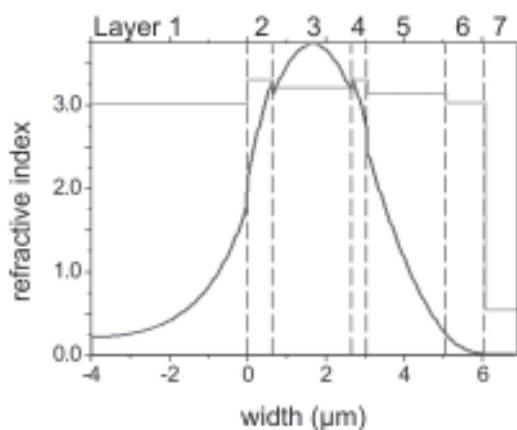
Another important issue for all laser types is the design of the waveguide. This determines the waveguide losses and the confinement factor, the latter defining the fraction of the wave intensity being guided inside the gain material. The most important device parameters affecting the confinement factor are the thicknesses and refractive indexes of the layers, including the effect of the doping on the refractive index, as well as the number of stages in the active zone. The doping also specifies the waveguide losses, α_w , since the major loss arises from free-carrier absorption. Both the refractive-index change, Δn , and the absorption losses, α , are linked by the Drude Model. For a bulk semiconductor, this yields

$$\Delta n = -\frac{e^2}{8\pi^2 \epsilon_0} \frac{n_e \lambda^2}{c^2 n m_e}, \quad (3a)$$

$$\alpha = \frac{e^2}{4\pi^2 \epsilon_0} \frac{n_e \lambda^2}{c^3 n m_e \tau}, \quad (3b)$$

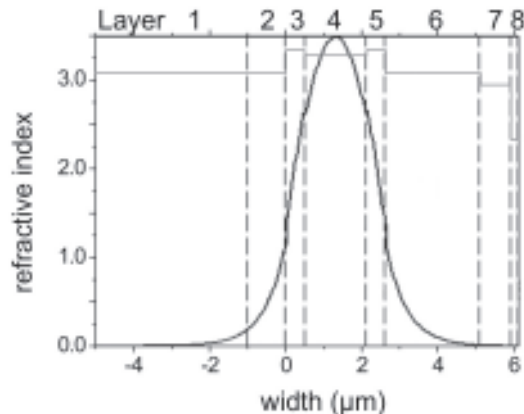
where n_e is the electron concentration, m_e is the effective mass, and τ is the scattering time. The waveguide losses, α_w , are composed of the losses in all layers weighted by the corresponding confinement factors.

Figure 6 shows the waveguide design of the first injectorless quantum cascade laser, starting from the left with a low-doped InP substrate, 650 nm of InGaAs ($n = 5 \times 10^{16} \text{ cm}^{-3}$), a 75-stage active zone with 2.02 μm , 400 nm of InGaAs ($n = 5 \times 10^{16} \text{ cm}^{-3}$), 2.0 μm and 1.0 μm of AlInAs ($n = 1 \times 10^{17} \text{ cm}^{-3}$ and $n = 3 \times 10^{17} \text{ cm}^{-3}$, respectively), and, finally, 800 nm of InGaAs ($n = 4 \times 10^{18} \text{ cm}^{-3}$). The wavelength of the laser transition is calculated to be 11.5 μm , and the confinement factor, Γ , is 0.51 [7]. The disadvantage of using AlInAs as waveguide



Layer	Composition	Thickness	Doping	Refractive Index
1	InP	-	-	3.02
2	GaInAs	650 nm	$5 \times 10^{18} \text{ cm}^{-3}$	3.31
3	AlInAs/GaInAs	2020 nm	$2.5 \times 10^{11} \text{ cm}^{-3}$	3.21
4	GaInAs	400 nm	$5 \times 10^{18} \text{ cm}^{-3}$	3.31
5	AlInAs	2030 nm	$1 \times 10^{17} \text{ cm}^{-3}$	3.14
6	AlInAs	1020 nm	$3 \times 10^{17} \text{ cm}^{-3}$	3.03
7	GaInAs	800 nm	$4 \times 10^{19} \text{ cm}^{-3}$	0.55

Figure 6. The waveguide of the first injectorless quantum cascade laser by Wanke et al. [7]. The waveguide losses were measured to 70 cm^{-1} for the emission wavelength of $11.5 \mu\text{m}$. The table summarizes all important values for each layer.



Layer	Composition	Thickness	Doping	Refractive Index
1	InP	-	-	3.08
2	InP	1000 nm	$6 \times 10^{18} \text{ cm}^{-3}$	3.08
3	GaInAs	500 nm	$6 \times 10^{18} \text{ cm}^{-3}$	3.34
4	AlInAs/GaInAs	1630 nm	$5 \times 10^{18} \text{ cm}^{-3}$	3.28
5	GaInAs	500 nm	$6 \times 10^{18} \text{ cm}^{-3}$	3.34
6	InP	2500 nm	$6 \times 10^{18} \text{ cm}^{-3}$	3.08
7	GaInAs	800 nm	$5 \times 10^{18} \text{ cm}^{-3}$	2.95
8	GaInAs	200 nm	$1 \times 10^{19} \text{ cm}^{-3}$	2.33

Figure 7. The waveguide design using InP claddings below and above the active zone, with waveguide losses below 4 cm^{-1} for $6.8 \mu\text{m}$. The table summarizes all important values for each layer.

cladding is its relatively high refractive index ($n = 3.16$ at $11.5 \mu\text{m}$), which requires higher doping levels for proper guiding of the waves. A doping of $5 \times 10^{17} \text{ cm}^{-3}$ is needed for an equal refractive index to low-doped InP with $n = 3.04$ at $11.5 \mu\text{m}$, according to Equation (3a). Consequently (c.f. Equation (3b)), the AlInAs waveguide cladding resulted in high waveguide losses around 60 to 100 cm^{-1} .

Therefore, low-loss InP waveguides, which have been used in common QCLs for a long time, were introduced in the injectorless QCLs in 2005 [17]. The resulting significant reduction by a factor of 10 to 20 of waveguide losses (depending on the wavelength and the design) moved the injectorless quantum cascade laser into competitive range towards the standard QCLs. Figure 7 shows the currently most widely used waveguide design, built upon a low-doped InP substrate: 500 nm of GaInAs ($n = 6 \times 10^{16} \text{ cm}^{-3}$) directly below and above the active zone, which typically contains 30 to 60 stages with doping sheet densities ranging from $2.5 \times 10^{10} \text{ cm}^{-2}$ to $1 \times 10^{11} \text{ cm}^{-2}$ per stage. Finally, the $n = 6 \times 10^{16} \text{ cm}^{-3}$ doped InP cladding with its low refractive index is deposited, followed by the top contact layer, consisting of 800 and 200 nm -thick n-doped GaInAs layers with $n = 5 \times 10^{18} \text{ cm}^{-3}$ and $n = 1 \times 10^{19} \text{ cm}^{-3}$, respectively [13]. This advanced waveguide design yields a confinement factor, Γ , up to 0.6 for sixty stages at a wavelength of $6.4 \mu\text{m}$.

The most-frequently-used laser cavity for injectorless quantum cascade lasers is still the Fabry-Pérot resonator,

using cleaved semiconductor facets as mirrors with a reflectivity around 25% .

2.3 The Electrical Parameters

As for any other semiconductor laser, the most important characteristic of an injectorless QCL is the threshold current density, and its temperature dependence. A suitable approximate fit for the temperature-dependent current density of a QCL, as given by Capasso et al. [7], is

$$j_{th(T)} = j_0 + j_1 e^{\frac{T}{T_0}}, \quad (4)$$

where T_0 is the characteristic temperature. Normally, T_0 ranges between 100 K and 200 K for common quantum cascade lasers, but only reached 48 K with the first injectorless designs. T_0 is basically determined by the temperature dependence of the waveguide losses, the linewidth broadening, and the phonon population, but also by design-dependent processes such as thermal backfilling or leakage currents.

The threshold current density can be calculated from the waveguide losses, α_w , the mirror losses, α_m , the confinement factor, Γ , and the gain coefficient, g_c , depending on the active region design (see Section 2.1), according to [1]

$$j_{th} = \frac{\alpha_w + \alpha_m}{\Gamma g_c} . \quad (5)$$

The confinement factor depends mainly on the number of stages within the active zone and the waveguide design, as discussed in Section 2.2. The mirror losses are determined by the resonator length and the facet reflectivity, which ranges from simple semiconductor facets to distributed Bragg reflectors. The doping of each layer influences not only the refractive index and waveguide losses, but also the ohmic losses. The ohmic losses are in turn influenced by the internal heating limit, the maximum operating temperature, the output power, and the temperature stability. The effects of doping, the number of stages, and different designs on the laser's performance will be discussed below in detail in the device-characteristics section.

3. Device Technology

The device technology comprises the epitaxial fabrication of the multilayer heterostructures and the subsequent chip processing, defining the stripe laser structure that accomplishes the lateral current and optical confinement.

3.1 Epitaxial Growth

The device fabrication starts with the design-specific layer sequence epitaxially deposited, usually by a molecular-beam epitaxy (MBE). Figure 8 shows the picture of our molecular-beam epitaxy system, capable of controlling atomic layer growth. The material system used for most lasers is AlInGaAs on InP, while (n-) doping is done via an Si source.

A matter of particular interest is the strain management, by which the lattice constants of the grown alloys are adjusted with respect to the substrate (InP). The thickness

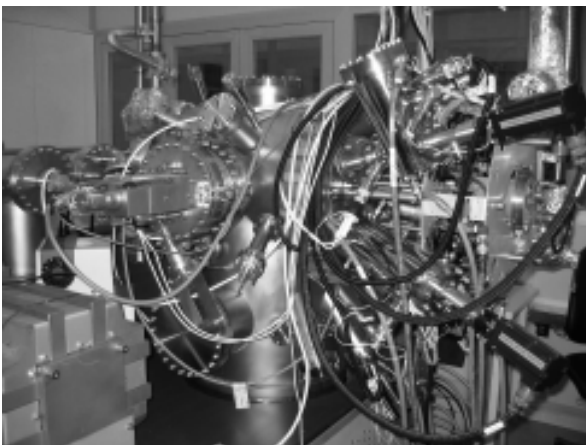


Figure 8. Molecular beam epitaxy, with the different sources on the right, the chamber in the middle, and the lock on the left side.

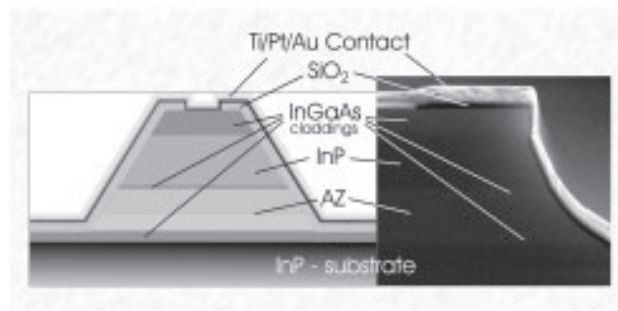


Figure 9. A schematic cross section of the laser waveguide (left), and an SEM viewgraph (right).

of strained layers is limited to the critical thickness, because of lattice relaxation that leads to damaged layer structures. Most importantly, the strain changes the band offsets (ΔE_c and ΔE_v) and the effective mass, m_e , and therefore offers a considerable potential for adjusting and improving the laser's performance.

3.2 Device Processing

Subsequently to the molecular-beam epitaxy growth, the heterostructure wafers are processed into mesa-type stripe lasers. The critical steps involved are the wet or dry chemical etching of the laser ridges, and the correct alignment of the top contacts. Figure 9 shows a schematic cross section and a corresponding scanning electron micrograph (SEM) of an injectorless quantum cascade laser. The processing starts with the wet chemical etching of the 10 to 30 μm wide laser ridges. Under-etching and the overall etch profile have to be taken into concern with respect to further processing steps. After the ridge fabrication, a passivation of silicon dioxide is sputtered onto the sample. Because of the relatively large operating voltages (~ 10 V), a sufficiently thick passivation must be used to avoid electrical breakthrough. Therefore, a tradeoff occurs between avoiding electrical breakthrough in the silicon dioxide, and the lateral heat conductivity, on the other hand.

The next step is the application of the top contact window, followed by a structured Ti-Pt-Au contact layer. In order to realize a lower thermal resistance, additional gold can be electroplated onto the sample. The last step is the thinning of the substrate to about 100 μm , and the evaporation of the backside contact, made of Ge-Au-Ni-Au. Finally, laser bars are cleaved, yielding 0.5-4 mm long lasers.

3.3 Laser Setup

In order to measure the laser characteristics, the chips are mounted onto a copper heatsink. Figure 10 shows an example with a copper heatsink and bond wires for connecting the top contacts of several lasers.

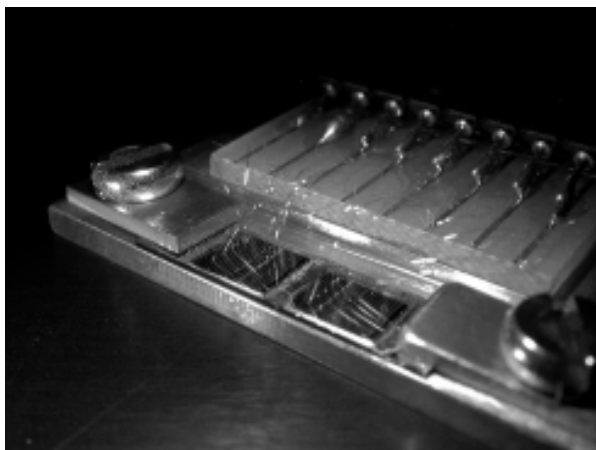


Figure 10. A sample setup on a copper heatsink comprising two different samples, each containing 18 laser stripes.

The measurement itself requires adequate detectors, such as liquid-nitrogen (LN)-cooled mercury-cadmium-telluride photo resistances (MCT) or thermopile detectors. Because of the relatively large wavelengths, special lenses can be used, but high-reflective gold-plated mirror systems are most often the first choice. For cooling down and temperature stabilization, He-flow or liquid-nitrogen cryostats with heating capabilities are used. Measurements of the laser spectra are either accomplished with Fourier-transformation spectroscopy, or with grating spectroscopy.

4. Device Characteristics

The first injectorless quantum cascade laser (see Figure 4b) did not reach the performance of the common injector-based lasers, as shown in Figure 11. The maximum temperature of operation was limited to 195 K, and the threshold current density, at 7 K, was as large as 3.5 kA/cm² [7]. The characteristic temperature, T_0 , was only 48 K.

As outlined in Section 2, the performance-limiting factors in these devices have been the high waveguide

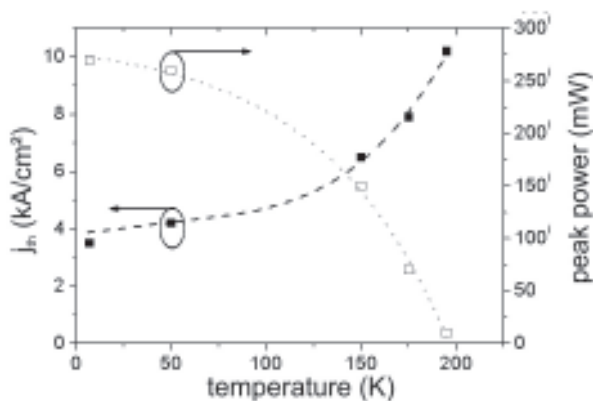


Figure 11. A compilation of pulsed optical power (?) and threshold current density (•) from a single facet of a 1.5 mm long and 24 μm wide laser [7], as a function of the heatsink temperature (solid). The emission wavelength was 11.5 μm

losses ($\alpha_w \sim 60\text{cm}^{-1}$) and the low upper-laser-level lifetime. The latter yielded a quality factor of only 20 for the active-region design.

With the reduction of waveguide losses and improved quality of the active-region design, the threshold current density decreased significantly. With the improved waveguide design [17], using InP for upper and lower confinement, low doping, and a modified active-region design ($Q = 27$), the performance was significantly improved. At 350 K, the maximum temperature of operation exceeded room temperature for the first time. The threshold current density at low temperatures (77 K) decreased to 0.9 kA/cm², and was 3.1 kA/cm² at 300 K [17].

Ongoing advancement in the design of the active region (see Figure 4c) shifted the quality factor up to 37. With reduced doping, the waveguide losses decreased, but so did the maximum temperature of operation. Figure 12 shows the doping sheet density dependence of the maximum operating temperature and of the threshold current density for 3.5 mm long and 26 μm wide samples with 40 stages.

In 2006, the threshold current density reached an outstanding 0.73 kA/cm² at 300 K, exceeding the threshold performance of common quantum cascade lasers. The characteristic temperature and the maximum temperature of operation were determined to be 90 K and 340 K, respectively. The devices used an optimized design, with 60 stages and low waveguide losses [18]. P(I) and U(I) measurements of this device are shown in Figure 13. The threshold density was measured to be 0.74 kA/cm², while the slope efficiency revealed 400 mW/A, with a maximum output power of 71 mW.

In the last years, further advanced designs, using more than two materials, have been introduced [19, 20]. To improve the barriers, thin AlAs layers within the AlInAs barrier layers were implemented in the active region for common and injectorless quantum cascade lasers. Although the first AlAs-based injectorless quantum cascade lasers

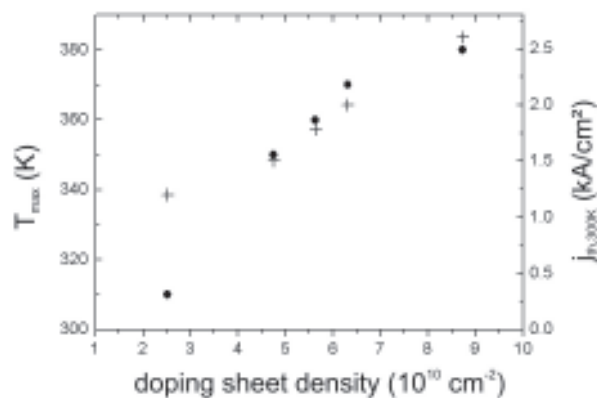


Figure 12. The maximum temperature of operation (•) and threshold current density at 300 K (+) as a function of the doping sheet density for the design used by Friedrich et al. [13].

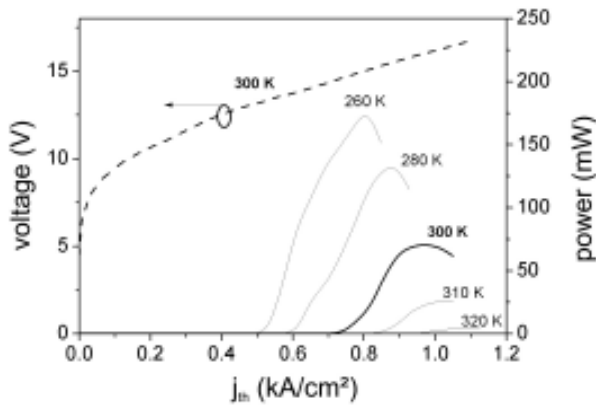


Figure 13. The pulsed peak optical power as a function of the current density at various heatsink temperatures for a 4 mm long and 26 μm wide sample containing 60 stages of the design presented in Figure 4c. The (n-) doping sheet density was $2.5 \times 10^{10} \text{ cm}^{-2}$. The voltage (dashed) as a function of the current density for 300 K has also been plotted.

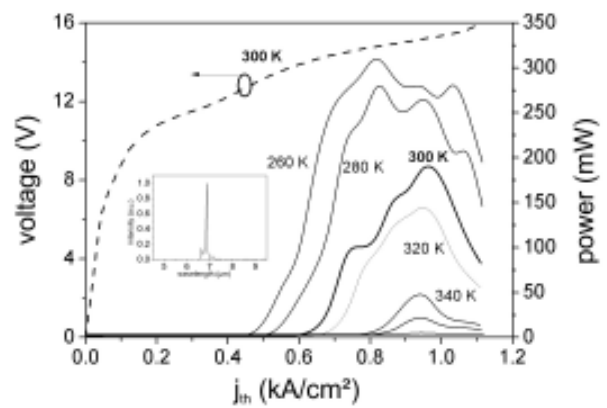


Figure 15. The pulsed peak optical power at various heatsink temperatures (solid) and the voltage at 300 K (dashed) as a function of current density for a 4 mm long and 26 μm wide sample, containing 60 stages of the design presented in Figure 14, with a doping sheet density of $2.5 \times 10^{10} \text{ cm}^{-2}$. The inset shows the emission spectrum at 77 K.

did not achieve the performance of previous designs, with a threshold current density of 4.8 kA/cm² at 300 K, shorter wavelengths, around 4.5 μm at room temperature, were possible [19]. Today, injectorless quantum cascade lasers span the range from 4.3 μm to 11.2 μm . However, longer and shorter wavelengths should be possible as well, but have not yet been realized.

The next step was the implementation of low-effective-mass materials, such as InAs, within the relevant quantum wells. Additionally, the InAs layers were used for strain compensation of AlAs barriers, allowing an improvement in the active-region design. Figure 14 shows the conduction band of an injectorless quantum cascade laser that uses four different materials [15]. The simulation yielded 1.4 nm for the dipole matrix element, 4.2 ps for the upper laser lifetime, and a quality factor as large as 47.

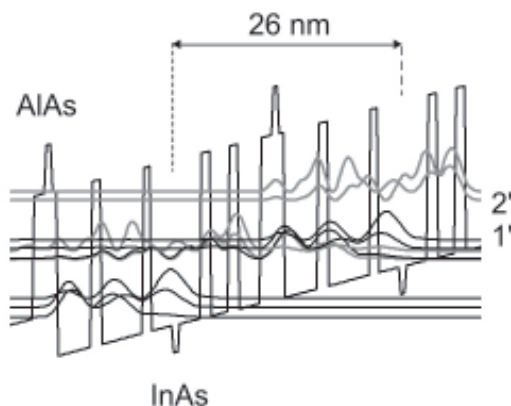


Figure 14. The conduction band and wave functions of an injectorless quantum cascade laser [15] using the Al(In)As-(Ga)InAs material system. The layer sequence was: 1.45/0.5/0.56/4.03/1.1/5.0/0.9/2.6/0.5/2.6/1.0/2.1/1.0/2.7 with four material compositions: **AlAs in bold and italic**, ***Al*_{0.635}***In***_{0.365}***As*** in bold, *Ga*_{0.4}*In*_{0.6}*As* in regular type, and *InAs* in italic. The underlined layers were Si doped.**

The experimental results shown in Figure 15 clearly prove the enhanced performance. The threshold current density at 300 K was reduced to only 0.6 kA/cm² with uncoated facets, and the characteristic temperature improved to 150 K. The maximum output power and the slope efficiency at 300 K were measured to be 196 mW and 1080 mW/A, respectively. The devices were designed for an emission wavelength of 6.9 μm , according to previous designs. The wavelengths were measured to be 6.86 μm and 7.15 μm at 77 K and 300 K, respectively. The lowest threshold current density reported so far for common QCLs at 300 K in the same wavelength range was 40% higher [11].

It should be noted that the slope efficiencies, the maximum output powers, and the characteristic temperatures of the common injector-based devices are still higher (up to 2 W/A, 1.3 W, and 210 K, [10, 12, 21, 22]), making them better suited for continuous-wave operation at room temperature.

5. Conclusion

First realized in 2001, injectorless quantum cascade lasers have shown a steady improvement, with strongly advanced threshold performance (see Figure 16), which meanwhile significantly exceeds that of the common QCLs up to room temperature. With the latest improvements in design regarding the characteristic temperature and the low threshold current density, continuous-wave operation at 300 K appears feasible, which is a precondition for many applications. In comparison to the common quantum cascade laser, the injectorless devices should enable about twice the slope efficiency and a higher output power [7]. Due to their more compact stage design, they could play a key role in the development of terahertz sources based on difference-

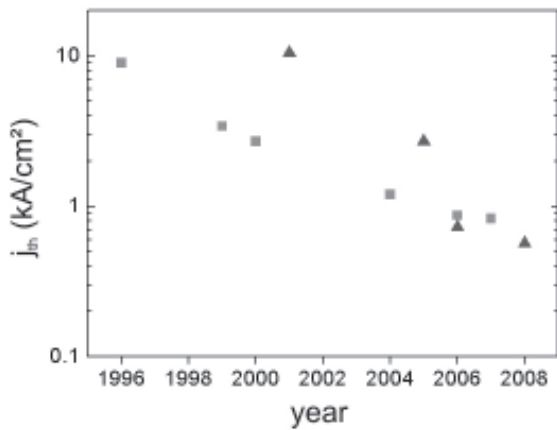


Figure 16. The lowest reported threshold current density as a function of the date for common quantum cascade lasers (square) and injectorless lasers (triangle) at 300 K heatsink temperature (except first triangle with 200 K). All lasers emitted between 4.5 μm and 11.5 μm .

frequency generation [23]. For this goal, two powerful mid-infrared pump sources for generating the terahertz wave are collocated inside the active zone with its high nonlinearity [24].

Besides the improvement in threshold performance, injectorless quantum cascade lasers have not yet approached the common quantum cascade laser regarding continuous-wave operation and maximum output power, due to less research and a more complex design.

6. Acknowledgement

The author gratefully acknowledges helpful discussions with G. Scarpa and A. Friedrich, and financial support by the German excellence cluster “nanosystems initiative Munich (NIM).”

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Christian Sohl, *Dispersion Relations in Scattering and Antenna Problems*, Department of Electrical and Information Technology, Lund University, PO Box 118, Sweden, August 2008; E-mail: Christian.Sohl@eit.lth.se> Relevant Commission: B

Abstract

This dissertation deals with physical bounds on scattering and absorption of acoustic and electromagnetic waves. A general dispersion relation or sum rule for the extinction cross section of such waves is derived from the holomorphic properties of the scattering amplitude in the forward direction. The derivation is based on the forward-scattering theorem via certain Herglotz functions and their asymptotic expansions in the low-frequency and high-frequency regimes. The result states that for a given interacting target, there is only a limited amount of scattering and absorption available in the entire frequency range. The forward dispersion relation is shown to be valuable for a broad range of frequency-domain problems involving acoustic and electromagnetic interaction with matter on a macroscopic scale. In the modeling of a metamaterial, i.e., an engineered composite material that gains its properties by its structure rather than its composition, it is demonstrated that for a narrow frequency band, such a material may possess extraordinary characteristics, but that tradeoffs are necessary to increase its usefulness over a larger bandwidth.

The dispersion relation for electromagnetic waves is also applied to a large class of causal and reciprocal antennas to establish a priori estimates on the input impedance, partial realized gain, and bandwidth of electrically small and wideband antennas. The results are compared to the classical antenna bounds based on eigenfunction expansions, and it is demonstrated that the estimates presented in this dissertation offer sharper inequalities, and, more importantly, a new understanding of antenna dynamics in terms of low-frequency considerations.

The dissertation consists of 11 scientific papers, of which several have been published in peer-reviewed international journals. Both experimental results and numerical illustrations are included. The “General Introduction” addresses closely related subjects in theoretical physics and classical dispersion theory, e.g., the origin of the Kramers-Kronig relations, the mathematical foundations of Herglotz functions, the extinction paradox for scattering of waves and particles, and non-forward dispersion relations with application to the prediction of bistatic radar cross sections.

COMMISSION A

This report was prepared by Dr. P. Banerjee, Commission Chair 2006-2008. Unexpectedly Dr. Stuart Politt, Commission Chair, resigned in January 2007. Since then Vice Chairman Dr. P. Banerjee took over as the acting Chair of the Commission A.

In the triennium 2006-2008, Commission A has been active through the following events.

1. Terms of Reference

Terms of reference of Commission A has been modified in the last GA 2005. These may further be evolved in due course of time keeping space with the rapid advancement in radio science and communication and the related technologies.

2. Activities

In the report of Long Range Planning Committee (LRPC) the following aspects have been emphasized for Commission A.

It is apparent that significant opportunities exist in the establishment of time standards, for example with the emergence of atomic clocks that may have stabilities of 1 in 10^{15} . Another topic of interest is Nano metrology, for which a special Tutorial session has been scheduled for the upcoming General Assembly. Opportunities also exist in the area of characterization of electromagnetic properties of materials, especially with the preponderance of metamaterials with unprecedented properties. In the area of realization and dissemination on time and frequency standards, new technologies of navigation and time, based on combined usage of atomic clocks and GPS timing must constitute new opportunities. Precise time transfer techniques via GPS and two-way-satellite time/frequency transfer and antenna measurement techniques (jointly with Commission B) are also seen as emerging opportunities.

The preparation of the session of the 2008 General Assembly in Chicago was the major activity on which most attention was given since early 2007. Dr. Banerjee with the help of very enthusiastic session conveners of the technical programme, the overall technical programme of Commission A of the Chicago general assembly took a nice shape.

The some emerging topics have been focused in the technical session of the General Assembly. Few speakers

who are eminent in respective field could be consented to give invited talks. A tutorial talk on very special emerging topic of "Nano-metrology" would be given by Dr. Janssen (change of speakers). Some joint Commissions could be arranged and a good response from the delegates with contributed papers was received.

Few sessions on the emerging areas have been organized. Some of them are

- Primary Frequency Standards in which area very interesting developments have been reported,
- Characterization of EM Materials which are currently the area of major emphasis,
- Measurements to Support Advanced Communications Systems and
- Antenna Characterization which has become more and more important for smart antenna design.

Other sessions are also related to the current issues. Responses from the researchers in the respective field are quite encouraging.

The issue related to the continuation of "Leap Second" has been an important international debate. International Telecommunication Union (ITU) is supposed to decide on this based on Recommendations ITU_R_TF.460-6.

3. Radio Science Bulletin

One paper of Commission A is supposed to be published in June 08 issue of RSB "P. Banerjee" GPS: a powerful tool for time transfer". Some contacts have been developed and some of them may persuaded to submit papers for the publication in RSB

4. Report of China

1 Structure of EM Metrology Commission in URSI China CIE

Chairman: Prof. WANG Nanguang, China Academy of Space Technology (CAST).

Vice-Chairman: Prof. WANG Yiqiu, Peking University (PU).

Secretary: Mr. LI Zizhong, Beijing Institute of Radio Metrology and Measurement (BIMM).

There are 10 members who come from institutes, universities and academies of the country

2. Overview

In this triennium, the papers published at the conferences showed that some progresses have been made in Electromagnetic Metrology in China.

In time and frequency metrology field, the National Institute of Metrology (NIM) completed the first cesium cold atom fountain frequency standard at the end of 2003. Recently the set-up is reconstructed for further improving the magnetic shielding to eliminate the Majorana transition. NIM now has constructed the second fountain standard with minor size with physical package of $0.6\text{m}\times 0.8\text{m}\times 1.8\text{m}$ and better performance, it can be transportable with rollers. Recent evaluation of the frequency uncertainty of the set-up is less than 3×10^{-15} .

For hydrogen maser frequency standard, Shanghai Astronomical Observatory (SO) has completed the prototype of small size passive hydrogen maser standard and started to manufacture this type of standard in 1998. Now they are struggling for further reducing the size of the standard and improving the performance by using some new technique of cavity, magnetron cavity. And BIMM are now working on the development of hydrogen maser frequency standards in both active and passive modes. Their maser is particular in using the sapphire cavity to reduce the volume of physical package.

For the Rubidium optical pumped gas cell frequency standards, Wuhan Institute of Physics and Mathematics (WIPM) recently has made a miniaturized cavity-cell assembly and tested the frequency shift characteristics. The results seem very promising. In collaboration with PU, WIPM, and BIMM, CAST is working on the compact rubidium gas cell standards, mainly for onboard use.

The cold atoms are very promising for new generation of frequency standard. Groups at PU and Shanghai Institute of Optic and Fine Mechanics (SIOM) have made some proposals in this field. Included are the laser decelerated continuous atomic beam fountain, a new space atomic frequency standards for working on the micro-gravity environment and a novel compact and transportable cold atom fountain clock. The experimental work on small rubidium fountain clock has been carried out at SIOM.

In the recent few years the optical frequency standards have shown a revolutionary progress due to the breakthrough of the optical synthesis technique by use of the frequency comb produced from a fs pulse laser. Now there are several groups in China have initiated the work in this direction, included NIM, Institute of Physics, PU, WIPM, Shanghai East-China Normal University, etc. At PU, a device for observing the optical Ramsey pattern of Ca atomic beam has been constructed, and the Ramsey signal has been obtained recently. Shanghai East-China Normal University

has already realized an optical frequency chain covering from microwave to optical frequencies. The international comparison of four fs laser frequency synthesizers, namely East-China Normal University (ECNU-C1), BIPM-C2, NIST-BB1 and BB2 showed surprisingly high level of uncertainty approaching 10^{-19} .

In quantum metrology field, a proposed program for SI base units such as kilogram, ampere to fundamental and atomic constants is under consideration. The Quantum Hall Resistance Standard at NIM has got excellent result in BIMP key comparisons, shown that the standard has the top performance in the world. And new reference standards, the Josephson Voltage Standard and Quantum Hall Resistance Standard were established at Beijing Orient Institute of Measurement and Test (BOIMT) recently.

In DC and LF Metrology field, BOIMT realized the digital simulation impedance standard. And the national patent right was got for the new concept of the Digital Simulate Impedance. A DC zero magnetic field standard was set up in 2007 at BIOMT. And an alternating weak magnetic field standard was established at Yichang Institute of Testing Technology, ranging from $1\times 10^{-11}\text{T}$ to $3\times 10^{-6}\text{T}$ with uncertainty 2×10^{-3} T to 7×10^{-3} T at frequencies 10Hz to 10kHz.

In RF and microwave metrology field, the measurement technique for emissivity of microwave blackbody, a high accuracy frequency and phase measuring technique, a new noise source calibration method, calibration technique for Compact Range CR), an optimizing design on electromagnetic characteristic of microwave band blackbody calibration target, the experiment of the frequency-stirred technique for the reverberation chamber, time-domain transmission coefficients of skeletal bi-conical antennas in test sites,....., the papers reported recent years by BIMM scientists showed that the measurement standards and calibration techniques in RF, microwave and mm band have made much progress and improvements at BIMM.

3. Conference Organized by China

1. The Internal Conference of Metrology and Measurement 2005 (ICMM 2005) was held in Xining City, Qinghai Province, China, Sep. 2005.
2. The Internal Conference of Metrology and Measurement 2006 (ICMM 2006) held in Nanchang City, Jiangxi Province, China., Sep. 2006.
3. The International Conference of Metrology and Measurement 2007 (ICMM 2007) was held in Xiangshan Park Hotel, Beijing, China, in Sep., 2007.

URSI China CIE (Beijing) is applying that Beijing is a candidate of the Venue of the next URSI General Assembly in 2011.

This report was prepared by Lot Shafai, Commission B Chair 2006-2008.

This triennial covering the period of October 2005 to August 2008 was exceptionally busy for Commission B. The Commission organized two conferences in 2007 and in 2008 the technical section of Commission B for the General Assembly in Chicago. The two conferences in 2007 were the Commission's international conference the "Electromagnetic Theory Symposium, EMTS", and the North American URSI conference, a joint meeting of the "Canadian and US" URSI national committees. Both conferences were held in Ottawa, Canada. Commission B also initiated five (5) student's best paper awards, to be selected from among papers submitted to the General Assembly in Chicago. The value of each Award was \$1000 US dollars. The first five winning students were selected from among the papers submitted to the General Assembly in Chicago.

1) Electromagnetic Theory Symposium, EMTS

EMTS is the Commission's international conference and is held every three years, in a country selected by the national Commission B Chairs, from among proposals submitted by the member countries. EMTS 2007 suppose to be held in Alexandria Egypt, which has a long history. Originally, it was suppose to be held in 2004. However, because of the security concerns, it was moved to Pisa, Italy, and Egypt was to hold the 2007 conference. Unfortunately, for the same reason, concerns were expressed by number of countries. Consequently, Egypt voluntarily declined to hold it in Alexandria on May 2006. This decision by Egyptian local Organizers threatened the cancellation of EMTS 2007.

As a last desperate attempt, invitations were sent out to all Commission B national committees to solicit their interest for holding the conference in their country. No interest was shown up until August 2006. At the time Commission B of Canada was preparing to organize the North American URSI conference in Ottawa. In late August Dr. Ross Stone suggested to us to consider joining the two conferences and holding them together in Ottawa, as the infrastructure was already in place. His suggestion was put to international vote, on a "Yes or No" basis. The decision of international committees was to go ahead and hold EMTS 2007 in Ottawa. In late October however, Japan showed interest in holding EMTS jointly with ISAP 2007 in Niigata. Since I was from Canada and the earlier decision was to hold EMTS in Canada, I felt obligated to overturn that decision and give Japan a chance to put their request to a vote. As a result, I stepped aside and requested Dr. Karl Langenberg, the Vice Chair of the Commission to take a

new vote from the international Commission B Chairs, between Japan and Canada. Their decision was received by Dr. Langenberg and again was for Canada, which became final in November 2006. Thus, upon receiving the voting results, the preparation started in full speed to hold EMTS 2007 in Ottawa on July 26 - 29, 2007.

The preparation for organizing EMTS 2007 in Ottawa commenced in early December 2006, a mere eight (8) months before the conference. Not having much time, the organizing committees of North American URSI conference were integrated with those of EMTS, to have a full conference infrastructure in place in early December 2006. Then, a solicitation was made from all international colleagues to organize sessions in main interest areas of EMTS. The response was outstanding, and by early 2007 a Call For Papers was sent out and 21 organized sessions were put in place. This guaranteed at least about 200 papers for the conference. Unfortunately, we had only three months to receive the submitted papers. As a result, the total number of accepted papers for the conference, after the paper reviews, reached only to 241. Consequently, nearly the entire conference was due to the organized sessions. We are truly indebted to our international colleagues for their extraordinary efforts, in such a short time, to solicit papers and organizing their oral sessions.

The final statistics of EMTS 2007 was as follows

- Total accepted papers	241
- Total registrants	258
- Total full registrants	202
- Total students registrants	56
- Total Young Scientists	24

The conference supported financially 24 Young Scientists. The initial support came from the Commission budget of 9,000 Euros. The remaining amount was paid from the conference income. All in all, the conference was successful, and we received significant number of comments from Young Scientists and other participants on the quality of papers, scientific discussions, and the caliber of senior scientists attending the conference.

2) North American URSI Conference

Commission B also organized a joint North American conference of Canadian and US national committees, on July 22 – 26, 2007, in Ottawa Canada. This was a major undertaking for the Commission, and in effect saved the EMTS 2007. The final statistics of this conference was.

- 684 Abstracts
- 630 Total registrants
- 430 Full registrants
- 200 Students registrants

The two conferences overlapped by one day on July 26, and provided an excellent opportunity for the students and Young Scientists from around the world to meet together, as well as with the senior scientists of all URSI Commissions. It was a truly outstanding experience for the students.

3) General Assembly in Chicago

The format used for this conference was similar to the other two. Senior colleagues from around the world were invited to select the session of their choice and organize them with invited papers. As a result, all oral sessions of Commission B were fully complete before January 2008. This meant, all submitted papers had to be placed in the poster session. All in all, we have 310 accepted papers, to be presented in the General Assembly in Chicago. We are grateful for our colleagues for accepting the task of organizing the oral sessions and reviewing the submitted papers. Commission B also proposed successfully a General Lecture by Dr. S. Hagness, and a tutorial lecture by Dr. Eleftheriades. The details of Commission B program in GA 08 is provided at the end of this document.

4) Commission B Student Paper Prizes

To encourage the young generations of students to attend the URSI conferences and participate in its scientific activities, Commission B, in spring of 2008, established five (5) "Students Best Paper Prizes", each valued at 1000 US dollars. The funds came from the \$5,000 extra budget URSI allocated to each Commission. Commission B believes that this is a positive way of encouraging students to excel in their research and the affairs of the URSI Commission B. We hope this tradition to continue in the future General Assemblies, by up coming Commission Chairs. The winning students will receive a certificate of Best Paper Prize at the first business meeting of Commission B, during the General Assembly in Chicago. The winning students in order of their paper number are:

- Christian Sohl for paper #1162
- Yvonne Weitsch for paper #1651
- Thomas H. Hand f or paper #1856
- Jurgen De Zaeytjij for paper #2415
- Taeyoung Yang for paper #2769

The full title, authors, and affiliations of these winning papers, again in order of the paper number, are:

- Paper #1162, "SOME PARADOXES ASSOCIATED WITH A RECENT SUMMATION RULE IN SCATTERING THEORY" by C. Sohl, M. Gustafsson, A. Bernland, Lund University, Lund, Sweden.
- Paper #1651, "A NON-RADIATING COMPOSITE RIGHT-/LEFT-HANDED TRANSMISSION LINE DERIVED FROM SUBSTRATE INTEGRATED RECTANGULAR HOLLOW WAVEGUIDE" by Y. Weitsch, T. F. Eibert, Universität Stuttgart, Stuttgart, Germany.

- Paper #1856, "CONTROLLABLE MAGNETIC METAMATERIAL USING DIGITALLY ADDRESSABLE SPLIT-RING RESONATORS" by T. H. Hand, S. A. Cummer, Duke University, United States.
- Paper #2415, "THREE-DIMENSIONAL LINEAR SAMPLING APPLIED TO MICROWAVE BREAST IMAGING" by J. G. De Zaeytjij, C. L. Conmeaux, A. Franchois, Ghent University, Ghent, Belgium.
- Paper #2769, "THE DESIGN OF ULTRA-WIDEBAND ANTENNAS WITH PERFORMANCE CLOSE TO THE FUNDAMENTAL LIMIT" by T. Yang, W. A. Davis, W. L. Stutzman, Virginia Tech, United States

5) Selection of New Vice Chair

The call for nomination of the new Vice-Chair of the Commission was sent out early in December 2007. It was repeated again twice, one in mid January and another in mid February. As a result, by the deadline of March 1, 2008, three excellent colleagues were nominated. The nominations were forwarded to URSI, immediately after the closing date of nomination. The call for the vote has been sent out twice more, after the first announcement by URSI. The interest in voting has been strong, which will be finalized after the final vote, during the first business meeting of the Commission, at the General Assembly in Chicago.

6) Selection of Symposium Site for EMTS 2013

The first call for proposals to organize EMTS 2013 was sent out in early December 2007. It was repeated again twice in January and March 2008. By the deadline, two excellent proposals were received. Immediately after the deadline, the proposals were circulated among the national Commission B chairs for voting. The request for vote has been repeated twice more, since then. The voting interest has been light. The final vote will be taken during the first business meeting of the Commission, at the General Assembly in Chicago.

7) Young Scientist Selection Criteria

In total 27 papers were submitted by 26 applicants from, Canada, Egypt, Finland, Germany, India, Israel, Korea, Singapore, Sweden, Switzerland, Taiwan, Ukraine and USA. All 27 papers were subjected to multiple reviews by Commission B Chairs, and members of Commission B from Canada, Finland, Germany, Ireland, Hungary, Switzerland and Taiwan. The Vice-Chair of Commission B, Dr. Karl Langenberg, was the chair of the Selection Committee. The foremost criterion for the selection was the excellence of the submitted papers, but formal aspects had also to be considered (age, completeness of the submitted

material and so on). Finally, 24 applicants were chosen as recipients for a Young Scientist Award. All Young Scientists received a certificate and complementary Conference registration. However, only 19 received Financial support for travel, accommodation and expenses. The following Table shows the list of winning Young Scientists.

8) EMTS 2007 Young Scientists

Euler Timo, Technische Universität Darmstadt, Germany: Funding

Gupta Shulabh, École Polytechnique de Montréal, Canada: Funding

Hadad Yakir, Ben Gurion University, Israel: Funding

Ismatullah, Universität Stuttgart, Germany: Funding

Jylha Liisi, Helsinki University of Technology, Finland: Funding

Perruisseau-Carrier Julien, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland: Funding

Sohl Christian, Lund University, Sweden: Funding

Winebrand Emil, Tel Aviv University, Israel: Funding

Alù Andrea, University of Pennsylvania, USA: Funding

Lin Yo-Shen, National Central University, Taiwan R.O.C.: Funding

Lomakin Vitaliy, University of California, USA: Funding

Mahanfar Alireza, Simon Fraser University, Canada: Funding

Ng Mou Kehn Malcolm, University of Manitoba, Canada: Funding

Oh Soon-Soo, ETRI, Korea: Funding

Yang Songnan, University of Tennessee, USA: Funding

Yang Fan, University of Mississippi, USA: Funding

Shramkova Oksana, National Academy of Sciences of Ukraine, Ukraine: Funding

Eshrah Islam, Cairo University, Egypt: Funding

Kumar Dheeraj, Agra College, India: Funding

Alitalo Pekka, Helsinki University of Technology, Finland: Certificate

Foroozesh Alireza, University of Manitoba, Canada: Certificate

Hossain Iftekhar, University of Manitoba, Canada: Certificate

Latif Saeed, University of Manitoba, Canada: Certificate

Tzoulis Andreas, FGAN-FHR, Germany: Certificate

9) Emerging Issues in URSI Commission B

Based on Consultation with National Committees the following are felt to be the most important emerging issues.

A – Administrative

There are five issues of concern.

A1 – Equal voting weights.

At present, important decisions are made by consultation with the membership, a true democratic way. Two examples are the selection of Vice-Chairs and selection of EMTS

conference sites proposed by member countries. The difficulty is that a good number of member countries never attend meetings or conferences and do not make any contribution to the Commission activities. However, they participate in voting, which cause serious difficulties in arriving at meaningful decisions, as they are not familiar with the dynamics of the commission and its scientific activities. Commission B requested the Board to initiate discussions and dialogues on this topic. This will provide an opportunity for exchange of ideas with other Commissions and URSI senior administration. The result could be an improvement over the current practice.

A2 – National committee Chairs living in other countries.

A number of national commission Chairs live in other countries. For instance, in Commission B the Chair from New Zealand has moved to Canada a number of years ago and is a professor at Simon Fraser University in Vancouver. Yet, he still represents New Zealand. Obviously this gives Canada effectively two votes in any voting, and no vote for New Zealand. Another example is, the Commission Chair from Russia. He was in Turkey for a number of years, and for the last couple of years he resides in Sweden, again giving these countries two votes and no vote for Russia. These are only two examples, but there are others. As a result, major countries like Russia and China are not represented in URSI. Some discussion is needed to find a solution to this problem.

A3 – Potential new countries.

During my term, I came to know that some countries, like Singapore, Vietnam, Iran and a few others, currently are not a member, but their scientific community hope to be one. But, the lack of URSI visibility causes problems, as initiatives by interested colleagues are not taken seriously in their countries. Some type of formal process is needed to expand the URSI activities to such emerging countries.

A4 – Young Scientist Support.

The future strength of Commissions depends on their young scientists. For this reason, Commission B spends its entire budget for support of Young Scientists, to attend its international conference “Electromagnetic Theory Symposium, EMTS”. Last year, Commission B supplemented the Commission B budget from the conference revenue and managed to support 24 Young Scientists. The National organizations should be encouraged to further supplement the commission budget and help young scientists to attend URSI international conferences. Can URSI help in this area?

A5 – Commission and URSI visibility

One problem for attracting young generation to URSI sponsored research is the low visibility of URSI, as compared to IEEE. To improve the situation the Commission websites should be improved and the conference publications to be placed on the Commission websites. Last year, Commission B initiated this step and the scientific program and entire “Electromagnetic Theory Symposium, EMTS” conference

publications were placed in its website. The Commission website is currently being expanded to include other areas of importance to Commission B.

B – Scientific

The electromagnetic science has been experiencing some sort of Renaissance in recent years, and thus, a few issues have emerged.

B1 – New scientific research areas.

New research areas, like metamaterials and NanoElectromagnetics, have emerged as a result of innovative thinking. These areas have common research interests in Physics and physical chemistry. Significant benefit can arise from collaboration or formal research contacts with these disciplines, and the methodology for establishing such contacts should be explored. Unfortunately, such out-reach activities are difficult to establish, as the research cultures are different, and the regulations of the funding agencies do not encourage them. URSI can play a useful role in this area.

B2 – New applied research areas

Other new but applied research areas are in Sensor Technology like RFID, sensors for Structural Health Monitoring, Medical Applications and remote Sensing. The emergence of NanoTechnology has dramatically changed the sensor technology, and thus, the electromagnetics. Strengthening the collaboration with other Commissions, as well as the related science areas like physics and chemistry, has become a necessity.

B3 – Microwave and millimeter wave imaging

The emergence of new requirements like low cost or high performance imaging systems in medicine, and safety and security issues have encouraged increasing research activities in inverse electromagnetism. This area has increasing need for growing collaboration with colleagues in mathematical science areas. Currently, establishing formal collaboration experiences problems similar to Applied Research areas, indicated in B2.

10) Commission B Scientific Program at General Assembly, GA 2008

1- Oral Sessions

B01 - Electromagnetic theory, 11 papers (ICP)

Tuesday AM

Convenors: Gerhard Kristensson, Lund Technical University, Sweden, gerhard.kristensson@es.lth.se
Ben Zion Steinberg, Tel-Aviv University, Israel, steinber@eng.tau.ac.il

Summary

This session focuses on the fundamental aspects of electromagnetic theory in a broad sense. It includes new solution methods and approaches for problems in

electromagnetics, as well as other theoretical aspects of electromagnetic theory. Advances in mathematical methods, solutions to canonical problems and electromagnetism in micro-and nano-technologies are of interest. Optimization and design for EM applications, as well as, mathematical modeling of nonlinear phenomena, EM problems of complex and nonlinear materials and new approaches for solving wave propagation problems in these materials are especially welcome.

B02 - Scattering and diffraction, 10 Papers (ICP)

Wednesday PM

Convenors: Ludger Klinkenbusch, Technical University of Kiel, Germany, lbk@tf.uni-kiel.de
Guiliano Manara, University of Piza, Italy, d6951@ing.unipi.it

Summary

The session will review topics covering a wide range of scattering and diffraction problems, including edge diffraction, high frequency methods, hybridization with high frequency methods, use of artificial structures for optimal control of wave propagation, scattering from disordered media and potential applications. Study of scattering from non-linear/anisotropic media as well as mathematical problems will also be emphasized.

B03 - Inverse scattering, 7 Papers (ICP)

Monday PM

Convenors: Edwin Marengo, North Eastern University, USA, emarengo@ECE.NEU.EDU
Qing H. Liu, Duke University, USA, qhliu@ee.duke.edu

Summary

This session covers contributions that detail new advances in the wave inverse theory, its methods and applications. This includes the development of efficient and rapid algorithms for solving linear and nonlinear inverse scattering problems in areas such as geophysical probing, remote sensing, non-destructive testing, medical imaging, target identification, etc. Radio frequency, microwave tomography and applications, iterative nonlinear inverse scattering techniques and electromagnetic techniques for nondestructive testing and evaluation are also of interest.

B04 - Antennas and arrays, 10 Papers (ICP)

Friday PM

Convenors: Hisamatsu Nakano, Hosei University, Japan, nakano@k.hosei.ac.jp
Richard W. Ziolkowski, University of Arizona, USA, ziolkows@ece.arizona.edu

Summary

This session will concentrate on methods for the design, analysis and synthesis of antennas and arrays with a particular emphasis on electromagnetics aspects. It will include wideband and multiband elements and arrays, novel and exotic materials as well as material modifications for antenna performance enhancements, miniaturization methods and

associated issues relating to bandwidth and efficiency, applications of formal antenna shape and volume design optimization methods and related algorithms, large finite arrays and associated fast methods, reconfigurable antennas and arrays, and coupling among antenna elements and large arrays/subarrays, interaction and coupling effects with the environment, numerical and hybrid methods, conformal antennas and antennas in layered media, antennas for space-based applications, efficient design methods for arrays and associated feed networks, fabrication and integration aspects of antennas and arrays, including material development processes.

B05 - Numerical, asymptotic and hybrid methods, 7 Papers (ICP)

Friday AM

Convenors: Vincenzo Galdi, University of Sannio, Italy, vgaldi@unisannio.it

Makoto Ando, Tokyo Institute of Technology, Japan, mando@antenna.ee.titech.ac.jp

Summary

This session will address the developments in the construction of integral and differential equation methods, as well as, hybrid and asymptotic techniques for efficient solution of radiation and scattering problems. Special interest will be also on solvers for large problems, and application of model based parameter estimation techniques to speed up field computations in time and frequency domains.

B06 - Transient fields and ultra wide band antennas, 7 Papers (ICP)

Saturday AM

Convenors: Ehud Heyman, Tel Aviv University, Israel, heyman@eng.tau.ac.il

Filippo Capolino, University of Siena, Italy, capolino@dii.unisi.it

Summary

True time domain radiation and reception has become important in applications ranging from impulse radar to ultra wideband radio to electronic warfare. This session will explore the theory that relates these varied applications and the systems that have been built to realize true pulsed radiation. Invited presentations will cover transient radiation and propagation theory and the relationship to frequency domain theory; methods and hardware for true time domain measurements; antennas and systems for UWB radio; impulse radar, target ID, and ground penetrating radar; and timed/UWB arrays, UWB SAR, and time reversal imaging. Papers are encouraged that explore true transient radiation physics, not just time domain numerical modeling

B07 - Wave Field Imaging for Homeland Security, 7 Papers (ICP)

Monday AM

Convenor: Karl Langenberg, University of Kassel, Germany, langenberg@uni-kassel.de

Juergen Detlefsen, Technical University Munich, Germany, detlefsen@tum.de

Summary

“Homeland Security” covers all aspects of scientific and engineering, which may contribute to ensuring the safety and security of persons on a public environment. As such, wave fields in a general sense; acoustic, elastic and electromagnetic waves in every frequency regime; can be relevant to the development of imaging systems to screen persons for concealed objects, to scan buildings to assess their integrity, to monitor the aging of materials non-destructively. Therefore, papers from rather distant disciplines are solicited in order to exchange ideas and to recognize common approaches.

BCD - Physical Limitations of Electromagnetic Metamaterials, 8 Papers (ICP)

Wednesday AM

Convenors: Ari Sihvola, TKK Electromagnetics Laboratory, Finland, ari.sihvola@tkk.fi

Arthur Yaghjian, Hanscom AFB, USA, a.yaghjian@verizon.net

Christophe Caloz, École Polytechnique, Canada, christophe.caloz@polymtl.ca

Summary

This session shall focus on the limitations and restrictions that basic principles of physics and engineering practicalities place upon the development of electromagnetic materials and their applications. Recent research on the design and use of various metamaterials has created a large amount of theoretical studies on the behavior and use of materials with unconventional material parameters such as negative permittivity and permeability or large anisotropies. On the other hand, fundamental principles such as causality, energy, and dispersion relationships as well as practical considerations such as losses, tolerances, and bandwidth may preclude the existence or practical realization of certain metamaterials and their applications. In this session, these limits will be charted.

BCK - Body Area Networks, including medical Application, 6 Papers (ICP)

Tuesday PM

Convenors: Yahya Rahmat-Samii, UCLA, USA, rahmat@ee.ucla.edu

Koichi Ito, Chiba University, Japan, ito.koichi@faculty.chiba-u.jp

Summary

Wireless systems, especially mobiles, require antennas with system-dependent requirements. They include operation near the human body, operation in a multi-path environment, extremely small size, space, beam and polarization diversity, dual-frequency operation, pattern reconfiguration, smart antennas and adaptive techniques. Unique quality factors, in contrast to the classical ones, are also introduced such as mean effective gain, correlation factor and efficiency in terms of volume, design techniques for antennas featured for mobile wireless systems, implementation of new concepts, cost-effective realization

of antennas and field-test results are of special interest. Introduction of latest projects such as ACE are introduced.

BK- Future Challenges of Computational Electromagnetics, 11 Papers (ICP)

Thursday AM

Convenors: Tapan Sarkar, University of Syracuse, USA, tksarkar@syr.edu

Magdalena Salazar Palma, salazar@tsc.uc3m.es

Summary

In the future the processors will be multicore. In addition the clock speeds are changing rapidly. They will have a tremendous impact on the computational electromagnetics. The objectives of this session are surveying the state of the art in computational electromagnetics and understanding what the future will bring.

BKF- Stochastic modeling and uncertainty management in electromagnetics, 6 Papers (ICP)

Thursday PM

Convenors: Wong Man-Fai, France Telecom, France, manfai.wong@orange-ftgroup.com

Joe Wiart, France Telecom, France, joe.wiart@orange-ftgroup.com

Summary

While electromagnetic modeling has made great progress, known deterministic data imply very accurate analyses. A great challenge of electromagnetic modeling is to take into

account stochastic processes (random media) or to manage uncertainties (lack of knowledge). Classical Monte-Carlo methods are unpractical in real life applications, thus specific techniques are needed.

2 - Poster Sessions

David Jackson, University Houston, USA, David.Jackson@mail.uh.edu

Aldo Petosa, Communications Research Centre, Canada, aldo.petosa@crc.ca

Summary

Contributed papers related to the terms of reference of the Commission

3 - Tutorial B

Transmission-Line Metamaterials: Fundamentals and Applications

Speaker: George Eleftheriades, University of Toronto, Canada, gelefth@waves.utoronto.ca

4 - General Lecture

Microwave Imaging in Medicine, Promises and Future Challenges

Speaker: Susan Hagness, University of Wisconsin-Madison, USA, hagness@ece.wisc.edu

COMMISSION C

This report was prepared by Andy Molisch, Commission C Chair 2006-2008.

1. Special interest group on Cognitive Radio

Due to the great increase of interest in software radio in the general scientific community, and among the URSI membership in particular, an ad-hoc "special interest group" for cognitive radio was established by the Commission-C chairman in late 2007. At the moment, discussions are done via an email reflector containing more than 20 names, exchanging information about relevant conferences and other events. More extensive scientific discussions, as well as planning of the activities for the next triennium, are planned for the Chicago GA.

2. Supported scientific conferences

The following meetings have been (will be) supported by Commission C in this triennium:

- EUSAR 2006 - European Conference on Synthetic Aperture Radar, Dresden, Germany, 16-18 May 2006
- International conference on Ultrawideband, Waltham, MA, USA, 24-27 September 2006
- ISAP 2006, Int. Symp. On Antennas and Propagation 2006, Singapore, 1-4 November 2006
- APMC 2006 - Asia-Pacific Microwave Conference, Yokohama, Japan, 12-15 December 2006
- ICMARS 2006-3rd Int. Conf. On Microwaves, Antenna, Propagation and Remote Sensing, Jodhpur, India, 20-22 December 2006
- Telecom & JFMMA, Fes, Morocco, 14-16 March 2007
- 12th Microcoll, Budapest, Hungary, 14-16 May 2007
- ETTC 2007, Toulouse, France, 12-14 June 2007
- ISSSE'07, Montreal, Canada, 30 July - 2 August 2007
- ISAP 2007, Int. Symp. On Antennas and Propagation 2007, Niigata, Japan, 20-24 August 2007
- ISRSSP'07 - International Symposium on Radio Systems and Space Plasma, Borovets, Bulgaria, on 2-5 September 2007
- ICEAA 2007, Torino, Italy, 17-21 September 2007
- APMC 2007 - Asia-Pacific Microwave Conference, Bangkok, Thailand, 11-14 December 2007

- 2nd International Conference on Wireless Communications in Underground and Confined Areas, Val-d'Or, Canada, 25-27 August 2008
- EMC Europe 2008, Hamburg, Germany, 8-12 September 2008

The following meetings will be supported in the next triennium:

- Microwave-08, Jaipur, India, in late November 2008
- EMC 2009, VIII International Symposium and Exhibition on Electromagnetic Compatibility and Electromagnetic Ecology, St Petersburg, Russia, 16-19 June 2009

3. Reports from the National Commissions

3.1 Spain

The main activity in the Spain URSI and particularly the Commission C is the Spain URSI Symposium that is celebrated each September in an Spanish city. The meetings of this triennium occurred in Valencia (2005), Oviedo (2006), and Tenerife (2007). This Symposium meets more than 300 papers and 400 people, mainly from Spain but some of the people comes from the Spanish America and from Portugal. Although the National Symposium covers all the commissions, commissions B and C are largely represented. Two prizes are organized to the best student paper. This meeting usually groups other activities like National Research Office project evaluation or Commissions social and organization meetings. More information can be obtained in the URSI web page <http://w3.iec.csic.es/ursi/english/index.htm>

3.2 United Kingdom

The main activity in the U.K. for Commission C was the participation in the National URSI symposium, which in 2007 took place in Portsmouth. It was held on 2-3 July 2007 and it covered all the various commissions. Looking at the program there were 20 papers, 9 posters and two invited papers. Commission C had 10 between papers and posters. Further details about the conference can be found at <http://ursi2007.ee.port.ac.uk/>. Prior to that i.e. in 2006 there was a similar meeting in Rutherford and Appleton Labs.

3.3 France

The covered topics by the commission are

- Radio communications and telecommunications
- Spectrum management
- Information theory, coding and modulation
- Signal Processing for communications and Image Processing

The C commission has 81 members.

3.3.1 General Assembly of New Delhi Participation

The C commission was represented by M. Bellanger Chairman and by J. Palicot vice-Chairman. The C commission contributed to the technical symposium significantly with 3 organised oral sessions.

- Jacques Palicot (Supelec) : Signal Processing for reconfigurable radio. The result with the presentations slides is on the link <http://www.rennes.supelec.fr/ren/rd/scee/> at the event bullet
- Cengiz Evci (Alcatel) : spectrum management
- Alain Sibille (Ensta) : UWB

These 3 conveners were also chairmen of their sessions. The sessions were running very satisfactory.

3.3.2 Cognitive Radio Days

The C commission was associated to four important days co-organized with the French research institute CNRS on cognitive radio subjects;

- **Journée radio cognitive** (GDR ISIS – URSI 30 juin 2005 – ENST, Paris)
This day was the first CR initiative in France, About 50 people attended this day. The presentations and the discussions were very interesting. The result with the presentations slides is on the link <http://www.rennes.supelec.fr/ren/rd/scee/> at the event bullet
- **Journée Scientifique Radiocommunications Haut Débit** (CNRS- DGA- ENSTA-URSI) 23 novembre 2005, ENSTA Paris
- **Vers Des Radiocommunications Reconfigurables Et Cognitives** (CNFRS-URSI), 28 et 29 mars 2006, C NAM, PARIS
These two days were very successful. The program with the papers is still available on the link <http://cnfrs.institut-telecom.fr/>, furthermore a special issue of the journal "Annals of Physics" was edited with extended version of the presentations.
- **Journée sur la Cognitive Radio** (CNRS GDR ISIS - URSI - ETSI.(19 octobre 2007), ENST Paris

The commission is involved in the CCCR group started end of 2007 for discussing the Cognitive Radio subject within C commission of URSI

We had our bureau election in 2007: Jacques Palicot has been elected as Chairman and A Sibille and JC Imbeaux were elected as vice-Chairmen.

The commission is involved in the preparation of the GAURSI 2008. We are convener or co-convener of 4 sessions.

3.4 Italy

The chairmanship of Commission C in Italy was handed over from Guido Tartara to Marco Luise (with Marco Lops from the University of Cassino as a deputy) officially in 2008, i.e., with some delay, due to issues with the Italian National Research Council (CNR, Consiglio Nazionale delle Ricerche) that is the official National interface with URSI.

3.5 Ukraine

The Ukrainian section of Commission C was a member of the organizing committee of the following Conferences

- VI-VIII INTERNATIONAL YOUNG SCIENTISTS CONFERENCES ON APPLIED PHYSICS, JUNE 2006-2008, National Taras Shevchenko university of Kiev.
- VI-VIII INTERNATIONAL CONFERENCES on ELECTRONICS AND APPLIED PHYSICS, OCTOBER 2006-2008, National Taras Shevchenko university of Kiev.

3.6 Taiwan

Research activities in wireless, networks and communications have been mainly focused on mobile, wireless, and optical systems, in recent three years. Several important landmarks of wireless, networks and communications research works are detailed (including references) in a report available upon request from Yuan-Kuang Tu, yktu@cht.com.tw.

3.7 India

The activities related to URSI are monitored in India through a joint National committee of COSPAR-URSI-SCOSTEP. During the above period the National committee members met twice, once in 2007 and 2008. The members of each commission made detailed presentations at these meetings and gave concrete suggestions for future program that need to be initiated to strengthen the R&D activities. In addition, suggestions were also made to change university curriculum for continuous upgrade in the technological skills. At least one conference was organized every year that is co-sponsored by URSI. The conferences supported during the period under review are:

- Indian Conference on “Microwaves, Antennas, Propagation and Remote Sensing, ICMARS-2005, Jodhpur, India, 2005.
- 3rd International conference on microwave, antennas, propagation and remote sensing, ICMARS-2006, Jodhpur, India, 2006.
- International Conference on Radio science ICRS-2008, Jodhpur, India, 2008.

Besides these activities, several other national and international conferences with active participation of

National committee members and International experts were held. These are:

- National Conference on Communications (NCC)
 - a. 2008: IIT Bombay, 1st - 3rd Feb. 2008
 - b. 2007: IIT Kanpur, 26th – 28th Jan. 2007
 - c. 2006: IIT Delhi, 27th – 29th Jan. 2006.
 - d. 2005: IIT Kharagpur, 28th – 30th Jan. 2005.
- The 10th Intl. Symposium on Wireless Personal Communications, Jaipur, Dec. 2007.
- Intl. Symposium on Ocean Electronics (SYMPOL – 2007), Kochi, Dec. 2007.
- Symposium on Ocean Electronics (SYMPOL – 2005), Kochi, Dec. 2005.
- Third Intl. Joint Conf. on Natural Language Processing, Hyderabad, 7-12th Jan, 2008.
- The Sixth Intl. Conf. on Advances in Pattern Recognition (ICAPR 2007), Kolkata, 2007.
- Indian Conf. on Computer Vision, Graphics, and Image Processing, Madurai, 2006.
- 3rd Intl. Conf. on Visual Information Engineering, Bangalore, 26-28th Sept. 2006.
- Indian Conf. on Medical Informatics and Telemedicine (ICMIT), Kharagpur, 2006.
- 3rd Indian Intl. Conf. on Artificial Intelligence, Pune, 2007.
- 4th Intl. Conf. on Natural Language Processing, Kanpur, 18-20 Dec. 2005.
- 5th Intl. Conf. on Natural Language Processing, Hyderabad, 4 – 6th Jan 2007.
- 6th Intl. Conf. on Natural Language Processing, Pune, 20 -22 Dec. 2008 (to be held).
- IEEE India Annual Conf. (INDICON – 2005), Chennai, 11-13 Dec. 2005.
- 13th Intl. Conf. on Advanced Computing and Communication (ADCOM 2005), Coimbatore, Dec. 2005.
- Workshop on Image and Signal Processing (WISP 2007), Guwahati, 28 -29 Dec. 2007.
- Workshop on Image and Signal Processing (WISP 2006), Madras, 2006.

3.8 Russia

- 1) Members of Commission C took part in organization and execution of three annual sci-tech conferences “Radiolocation, navigation, communication”, which were held in Voronez (Russia) April 2006-2008. Every conference gathered nearly 200-300 participants mainly from Community of Independent States (former USSR). Proceedings of these conferences were published in Russian.
- 2) Commission C took part in organization and execution of sci-tech conference “Innovations in radiotechnical information-telecommunication technologies” devoted to 60-th anniversary of Radiotechnical Institute by Academician A.L. Mints and Radioelectronics Faculty of Moscow Aviation Institute. This conference was held in Moscow 24-26 October 2006 in frames of Moscow

International Industry Fair (MIIF-2006). More than 150 specialists took part in conference, 7 plenary and 68 section reports were presented. Section reports were published in Russian.

- 3) Representatives of Commission C regularly attend workshop "Information technologies in radar science" being held twice a year on the basis of Bauman Moscow State University.
- 4) Two representatives of Commission C took part in International Symposium on Radio Systems and Space Plasma which was held in Sofia (Bulgaria) 2-5 September 2007.
- 5) Commission C, together with Russian Committee URSI, takes part in preparation to XXIX General Assembly in Chicago.

3.9 Canada

2007-2008 report: from minutes of annual CNC on April 20th, 2008

1. Efforts are on-going to bring a major IEEE conference to Canada through which URSI could gain visibility as a sponsor and/or co-organizer (i.e. the CNC). Two potential targets are the IEEE International Conference on Communications (ICC) and the IEEE Wireless Communications and Networking Conference (WCNC). WCNC is smaller than ICC but still significant (1000 attendees) and more focused on URSI's interest group. The Commission C Chair is currently interfacing with IEEE to bring WCNC to Canada within two to three years and he will solicit a letter of support from the CNC Chair in the fall of 2008. Further developments are thus expected in the late fall.
2. The Commission C Chair suggested that 'Best Student Paper Award' be presented at the Prompt R&D consortium's annual conference to be held next on November 20th, 2008. The CNC agreed and set the award level at 300\$.

COMMISSION E

This report was prepared by Flavio Canavero, Commission E Chair 2006-2008.

I. Terms of Reference

During the New Delhi URSI General Assembly, it was decided to update the terms of reference as follows: **Commission E - Electromagnetic Noise and Interference.**

The Commission promotes research and development in:

- a) Terrestrial and planetary noise of natural origin, seismic associated electromagnetic fields;
- b) Man-made noise;
- c) The composite noise environment;
- d) The effects of noise on system performance;
- e) The lasting effects of natural and intentional emissions on equipment performance;
- f) The scientific basis of noise and interference control, electromagnetic compatibility;
- g) Spectrum management.

During a business meeting of GA in New Delhi it was discussed on a possible change of name for Commission E, with the aim of better reflecting the challenges of new technologies. It was decided to discuss again at next GA in Chicago, if proposals come from National Delegates.

II. Working Groups

During the New Delhi URSI General Assembly, it was decided to slightly change the various working groups

(WG) in order to renew and update their field of interest. The new Working Groups are:

E.1. Terrestrial and Planetary Electromagnetic Noise Environment

Co-Chairs: M. Hayakawa (Japan), A.P. Nickolaenko (Ukraine), and C. Price (Israel).

Objectives: this WG deals with the study on the characteristics of electromagnetic noises taking place not only in the terrestrial, but also in the planetary environment. The most well-known noise is the atmospheric radio noise from the lightning discharges (so-called sferics in a wide frequency range from ULF to VHF). Some examples of topical subjects on sferics are (1) monitoring of global lightning activity as studied by high frequency noise and Schumann resonance phenomena in the ELF band and (2) ELF transients related with the optical emissions in the mesosphere due to the lightning. Higher frequency lightning emission provides us with the information on the fine structure of lightning electrical structure, while lower frequency noise provides us with the macroscopic nature of lightning. The noise coming from the ionosphere/magnetosphere will be discussed as well; micro pulsations in the ULF range, VLF/ELF emissions and HF emissions due to the plasma instabilities in the space. Also, our recent topic is the radio emission from the lithosphere, which covers again a wide frequency range from DC to VHF (or even more). The characteristics and generation mechanisms of those effects and also the seismic effect onto the ionosphere will be discussed. Finally, the radio noise environment on other planets (like Jupiter) will be our topic as well. The interaction of these natural noises with artificial

noises due to human activity is also another subject. Power line harmonic radiation penetrates into the ionosphere/magnetosphere and induces the particle precipitation into the lower ionosphere (this is a kind of pollution of the natural environment by human activity). Also, we discuss the interaction of natural environment with human activity.

· **E.2. Intentional Electromagnetic Interference**

Co-Chairs: M. Bäckström (Sweden), and W. Radasky (U.S.A)

· **E.3. High Power Electromagnetics**

Co-Chairs: C.E. Baum (U.S.A), and R.L. Gardner (U.S.A)

The subject of this working group is the physics and engineering associated with electromagnetic sources for which nonlinear effects associated with high-field regions must be avoided or included in the analysis and design. This includes (but is not limited to) EMP simulators, high-power narrowband and mesoband sources and antennas, and hyperband (impulse) sources and antennas. It also includes the environment near lightning channels and in nuclear EMP source regions. In some cases it includes the high-field regions on, or in targets. This committee actively encourages participation in scientific symposia related to this subject, including URSI and other societies (such as AMEREM/EUROEM, etc.)

· **E.4. Lightning Discharges and Related Phenomena**

Chair: Z. Kawasaki (Japan)

· **E.5. Interaction with, and Protection of, Complex Electronic Systems**

Co-Chairs: J.Nitsch (Germany), and J-P. Parmentier (France)

· **E.6. Spectrum Management**

Chair: T.Tjelta (Norway).

For more information on a group for “Radio Spectrum Management” The use of radio spectrum is a very hot issue today and a lot of discussion is taking place with respect to regulation and spectrum trading. For example, in Europe it seems that a general trend is to liberalise current regulation schemes for the benefit of business developments and users of wireless communication. From a scientific point of view a number of concerns can be raised and research is necessary to obtain better future solutions. A group in this area will work under the following objectives and activities:

Objective

- Utilization of the electromagnetic spectrum (for wireless communications and radio-based observations of the Earth and space
- Protection of radio-based services and spectrum sharing
- Activity protection of services
- Scientific passive and active observation of the

nature

- Radio-based services definitions of the International Telecommunication Union (ITU) seem inappropriate as service convergences is taking over
- The appropriate spectrum masks
- Spectrum use efficiency
- Monitor and control of spectrum use
- Activity spectrum sharing
- Reasonable spectrum sharing conditions
- Co-existence of radio systems
- Violation control

· **E.7. Geo-Electromagnetic Disturbances and their Effects on Technological Systems**

Chair: A. Viljanen (Finland)

· **E.8. Electromagnetic Compatibility in Wire and Wireless Communication Systems**

Co-Chairs: J. Gavan (Israel), and A.Zeddami (France)

· **Inter-Commission working group on Solar Power Satellites**

Chair: H. Matsumoto (Japan)

Secretary: K. Hashimoto (Japan)

Co-Chair for Commission E: Z. Kawasaki (Japan)

· **EGH. Seismo Electromagnetics (Lithosphere-Atmosphere-Ionosphere Coupling)**

Co-Chair for Commission E: M. Hayakawa (Japan)

III. Meetings

Most of the Commission E activities have been devoted to the organization of meetings and conferences and to the preparation of the Chicago General Assembly. Furthermore it must be outlined that, within the EMC conferences, an increasing number of sessions were devoted to applications in different domains as: automotive, railway system, power engineering, etc. and to EMC in wire and wireless communication system.

Commission E has sponsored the following meetings

- Short Course: HPE 201-06 High-Power Electromagnetics: Environments, Interaction, Effects and Hardening 1-7 October 2006, Freiburg, Switzerland.
- The 4th International Beijing Symposium on EMC – 2007
- National Symposium on Environmental Electromagnetics and EMC, Beijing, 2007, Prof. Y.-G.Gao, Beijing Univ. of Posts & Telecommunications
- North American Radio Science Meeting, 22-26 July 2007, Ottawa, Canada, <http://ursi2007.ee.umanitoba.ca/>
- ICEAA '07, 17-21 September 2007, Torino, Italy, <http://www.iceaa.polito.it/>
- The Swedish Commission E, 23 members, usually arranges two meetings per year sometimes in collaboration with the Swedish IEEE EMC chapter. Every third year SNRV, which is the Swedish counterpart

of URSI, arranges a Nordic URSI conference denoted RVK (“Radio Science and Communication”). RVK has been arranged 19 times since the first time in Stockholm in 1949. the number of participants has been between 250 and 500.

- EUROEM 2008, 21-25 July 2008, Lausanne, Switzerland. Prof. Farhad Rachidi, <http://www.euroem.org/>

These meetings cover nearly all aspects of EMC and its applications.

IV. Reviews of Radio Science

Associate Editor for Commission E: Professor Christos Christopoulos

The following papers have been published or are in preparation:

- “An Overview of High-Power Electromagnetic (HPEM) Radiating and Conducting Systems” D.V. Giri, F.M. Tesche, Carl E. Baum. (In Press)
- “Electromagnetic Phenomena Associated with Earthquakes – Recent Progress” M. Hayakawa. (In Preparation)
- “EMC for Space Applications” A. Ciccolella. (In

Preparation)

V. Website

At the end of year 2005, the following website

<http://www.ursi.org/E/Homepage.htm>

was activated and hosted by URSI. The website is maintained by the Commission Vice Chair, Professor Christos Christopoulos.

The information of this website is structured under the following headings, corresponding to specific webpages:

- Introduction to URSI
- Terms of Reference of Commission E
- Officers
- Past Chairs
- National Delegates
- Meetings
- Guidelines and rules for URSI sponsorship of meetings
- Working Groups
- Reviews of Radio Science
- Commission E News and Reports
- Links to National Committees
- Job vacancies

COMMISSION G

This report was prepared by Professor Paul S. Cannon, Commission G Chair 2006-2008

1. In Memoriam

The following friends and colleagues from the URSI Commission G Community passed away during the triennium:

- Jean-Paul Villain (France)
- A P Mitra (India)
- Pietro Dominici (Italy)
- Tor Hagfors (Norway)
- Lyudmila Logvinova (Russia).
- Roy Piggott (UK)
- Paul Argo (USA).

2. Chair's Comments

2.1 General

I would like to give my thanks to the National Representatives. Moreover I would like to thank the GA conveners and WG leaders for their unstinting and timely help, and to thank my vice-chair Michael Rietveld and my

immediate past-chair Christian Hanuise for their excellent advice.

2.2 Funding

The URSI board provides to the Commission Chairs a sum of money at the start of each triennium, to be administered for the good of the community. During this triennium a sum of EUR9635 was made available. Approximately EUR5500 was spent in supporting various meetings, typically with 500 or 1000 Euros. The remaining EUR4135 has been used to support seven scientists, from a number of countries, to attend the General Assembly – this being our flagship meeting.

In addition – see below – USD5000 were made available to support the attendance of students at the meeting. After consultation, the Chair decided to make 5 awards, each of USD1000 to those students who submitted to the Student Paper Competition.

2.3 Electronic Communication:

The Commission now has a website hosted by URSI <http://www.ursi.org/G/Homepage.htm>, which is basic but hopefully sufficient – it is at least easy to maintain and keep up-to-date. My thanks go to Inge Heleu at URSI for posting updates as required.

Commission G also has an electronic mailing list, maintained by Dr Wilkinson (ursi-commission-g@ips.gov.au). Any member of the community can post to this mailing list. The mailing list membership is moderated by the Commission Chair. Currently, there are 416 addresses in the mailing list, which is a drop of ~300 from the report three years ago. This is probably due to it being used more and thereby dormant and unused email accounts have been identified. *There is an urgent need to increase the distribution, possibly through active use of national data bases.*

2.4 Chicago GA

Programme: Commission G has ~250 papers at the GA – an excellent turn out. The support is all the more gratifying given the plethora of other meetings being held this year. The Commission G tutorial paper is to be given by Dr Brian Wilson, on the subject of Data Assimilation, a new and exciting area for our community.

Paper Submission Process: This triennium URSI introduced a centralised paper submission process. This has certainly been a success and the Chair would like to register his thanks for the provision of this system

2.5 URSI Long Range Planning Committee

The LRPC decided to concentrate its attention on (i) enhancing the participation in URSI by new generations of young students and scientists, (ii) new topical initiatives and areas, and (iii) strengthening of Commissions that are not very active. The student paper competition has been introduced to progress (i). In respect to (ii), the Chair, Co-Chair and National Representatives of Commission G identified important emerging issues in two categories, Applied Science and Systems, and Science. The former include radar remote sensing from space and of space, high integrity GNSS navigation systems, assimilative models of electron density and scintillation, and engineering out the affects of the ionosphere in low frequency radio astronomy. The Science topics include increased emphasis on planetary ionospheres, anthropogenic effects (ionospheric modification by HF heaters and climate change), and plasmaspheric physics and models. As usual, significant opportunities for interaction exist with Commission F, H, and J.

2.6 Working Groups

Commission G working groups are the primary focus for active collaborative research. During the triennium 2005-2008, URSI Commission G has been active through a number of WGs - reports from these WGs are provided below,

WG G4 (Ionospheric Research to Support Radio Systems) has recommended that it should be disbanded – all other WGS recommend that they continue. WG G1 (Ionosonde Network Advisory Group) will be electing new officers at their meeting at the next GA.

3. Vice-Chairs Comments

The primary responsibility of the vice-chair is soliciting, and editing papers for the Radio Science Bulletin. In this triennium two papers have been published and a third is being prepared. This is a minimum number, averaging nearly one per year, and a greater number of papers is clearly desirable. Approximately one in three solicited authors agreed to prepare a paper so some redundancy is needed. The support of the wider community is required to suggest topics and authors to the next vice-chair. Thanks go to Dr Ross Stone (Editor) and to Dr Phil Wilkinson, (Associate Editor) for the final preparation of the papers.

The papers published were: “Space Weather Impacts of the Subauroral Polarization Stream”, by *Anthea Coster and John Foster*, RSB 321, June 2007 and “The impact of high resolution radar on meteor studies: the EISCAT perspective”, by *Asta Pellinen-Wannberg, Gudmund Wannberg, Johan Kero, Csilla Szasz and Assar Westman*, RSB no 324, March 2008.

In addition to the review papers, Commission G has also sponsored a collection of papers on the subject of ionospheric raytracing to remember the pioneering work of Jennifer Haselgrove. These papers will be published in the June and September 2008 of RSB.

4. Working Groups Reports

The following Working Groups reports have been prepared by the Working Group Chairs in cooperation with their co-chairs.

4.1 G1: Ionosonde Network Advisory Group

Chair: T. Bullett (USA)

Vice-Chair: L-A McKinnell (SA)

INAG Editor: P. Wilkinson (Australia)

INAG has maintained a constant membership of around 280. The main medium for contacting INAG members remains the Bulletin. During the last three years three Bulletins (INAG-66, 67 and 68) were produced, with a total of 11 articles. Most of these were in INAG’s traditional roles of announcements regarding ionosonde stations and brokering agreements on data exchange formats.

Ionosonde owners and operators still practice commendable levels of data sharing, although international fiscal and intellectual property pressures endanger this foundation. Ionosonde data continue to have widespread use in publications and presentations. There were about 30 journal articles and 50 presentations featuring ionosondes over this triennium.

As a result of INAG initiative, ionosonde data users have online access to raw ionogram data at WDC-A. In addition

to the standard scaled ionogram characteristics, the raw ionograms in native formats are available from NGDC at Boulder.

There has been a great deal of development of new generation ionosondes and data analysis software. While ionosondes that digitize at an intermediate frequency or baseband, such as the CADI, DPS-4 and the new AIS continue to be the most popular, this triennium saw the operation of the first fully digital ionosondes, which digitize at the radio frequency. These include the VIPIR (dynasonde) and DPS-4D.

The scientific possibilities afforded by these fully digital ionosondes are astounding. So are the volumes of raw data which they produce. Single high resolution raw ionograms from an 8 receiver system can approach 1 GByte. Some preliminary work on handling and exchanging raw data has begun, but more effort in this area is clearly needed. At the January 2008 US National Commission Radio Science meeting in Boulder, some of the lessons learned by the Incoherent Scatter Radar community were presented to INAG members by Dr. Frank Lind of MIT Haystack Observatory.

New ionogram automatic scaling software has also been developed. Adding to the familiar ARTIST and AUTOSCALE options are "Autoscala" (INGV), Dynasonde21 (Dynasonde Solutions) and Expert System for Ionogram Reduction (Space Environment Corp.). With these new choices comes an increasing need for standardization. To this end, INAG has endorsed the SAOXML data exchange format for information derived from ionograms. This format was described in INAG-66.

4.2 Studies of the ionosphere using beacon satellites

Chair: R. Leitinger (Austria)

Vice-Chairs: P. Doherty (USA); and P.V.S. Rama Rao (India)

The Beacon Satellite Group (BSG) is interdisciplinary, servicing science, research, applications, and engineering interests.

The Working Group was active in its traditional fields, namely compilation, exchange and dissemination of information, contact with and exchange of experience with various organisations of relevance (ITU-R study group 3, the European COST Actions, augmentation systems for GPS based satellite navigation, international and national advisory bodies, GPS data retrieval and archiving organisations, and others), providing advice on request. The work was partly carried out by correspondence, and partly through attendance of conferences and other meetings. Among the most important activities of the BSG are the Beacon Satellite Symposia. After a forerunner organised at the Max-Planck-Institut für Aeronomie at Lindau/Harz, Germany, in 1970 the series started in 1972 with the first Symposium at Graz/Austria and continued at time intervals between two and four years. Keeping the three year rhythm

the next meeting is planned for 2010. The proposed venue is the University Politecnica de Catalunya, UPC/gAGE, in Barcelona, Spain. This local host for this meeting will be Dr. Manuel Hernandez-Pajares, a member of the BSG.

The most recent **Beacon Satellite Symposium** held at Boston College from June 11-15, 2007 again ranks among the most successful ones. The details of this symposium are listed below:

Scientific Committee

- Ms. Patricia Doherty, Boston College, USA (Patricia.Doherty@bc.edu)
- Prof. P.V.S. Rama Rao, Andhra University, Visakhapatnam, India (palurirao@yahoo.com)
- Prof. Sandro Radicella, ICTP, Trieste, Italy (rsandro@ictp.trieste.it)

Local Organizing Committee

- Ms. Patricia Doherty, Boston College, USA
- Dr. Cesar Valladares, Boston College, USA
- Dr. Michael Mendillo, Boston University, USA

The statistics on the Beacon Symposium are as follows:

- Number of participants: 110
- Number of countries represented: 24
- Number of sessions: 15 (14 oral sessions and 1 poster sessions)
- Number of papers presented: 116 (86 oral presentations, 30 posters)
- Number of sponsors with substantial monetary support: 5 (Boston College, NSF, NASA, FAA, AFRL)

During the opening ceremony the participants were welcomed by Ms. Patricia Doherty and Prof. P.V.S. Rama Rao on behalf of the Beacon Satellite Studies group. Ms. Doherty and Prof. Sandro Radicella also extended a greeting from the group chair, Dr. Reinhart Leitinger. Dr. Leitinger suffered a stroke in March 2006 and continues to work toward recovery. His message included his wishes for a successful symposium with his hope to join us at a future meeting. The opening ceremonies continued with a formal welcome from Boston College by Dr. Arnie Shore, Associate Vice Provost for Research. Dr. Shore's warm welcome was combined with gratitude for bringing this unique scientific group to Boston College. Dr. Jules Aarons then presented an entertaining history of his experience studying the effects of the ionosphere on Beacon Signals.

BSS 2007 included sessions on new science initiatives with Beacon Satellites; where discussions on upcoming satellite missions, sensing instruments and multi-instrument networks generated much anticipation for a new era of studies using Beacon satellites. Other sessions addressed the specific topics of TEC and scintillation measurements and models; low-latitude equatorial depletions; space weather effects on Beacon signals and navigation augmentation systems; radio occultation techniques; tomographic imaging; remote sensing and general discussions. Social events included a welcome reception;

a cocktail party at The Castle sponsored by Boston University and a symposium dinner where Prof. Paul Cannon, Chair of URSI Commission G, addressed the participants with rousing support for the activities of the Beacon Satellite Group.

The Beacon Satellite Group is pleased and very grateful that due to substantial financial support from the NSF, NASA, FAA, AFRL and Boston College, it was possible to waive registration fees for students and provide travel support for over 22 participants from developing countries. This enabled participation for a wide audience with good representation from South America, India, Africa, Russia and other countries. Boston College also provided inexpensive accommodation for all participants. Although many young scientists were able to attend, the Beacon Satellite Group misses a “real” young scientist programme of URSI and urges Commission G to support such a program at the next symposium.

The Working Group wishes to continue its activities as an URSI Commission G Working Group in the future and has endorsed its present leadership. Since traditional and new activities are well within the terms of reference of the Working Group, it does not suggest a change of these terms.

4.3 G3: Incoherent scatter

Chair: W. Swartz (USA)

Vice-Chair: I. Haggstrom (Sweden)

4.3.1 Introduction

The global network of incoherent scatter radars (ISR) provides observations of fundamental properties of the atmosphere, ionosphere, and magnetosphere. Coordinating “World Day” (WD) experiments conducted by the ISRs and associated instrumentation is the major activity of the URSI Incoherent Scatter Working Group (ISWG). The ISWG publishes schedules of the World Days as part of the International Geophysical Calendar. Links to the current schedule as well as previous years schedules may also be found at: http://people.ece.cornell.edu/wes/URSI_ISWG.

In view of the ongoing activities in this field we ask URSI to keep this working group active.

4.3.2 World Days Facts

This report will include some facts about the World Days, how to request World Days for satisfying certain scientific objectives, and descriptions of the experiments carried out in the past three years and planned for the remainder of 2008.

- World Days provide for coordinated operations of two or more of the incoherent scatter radars (ISRs) for common scientific objectives. (Experiments that require only one radar should be set up separately and directly with those in charge of that ISR.)

- Note that the use of the ISRs is open to all qualified scientists, and the data are freely disseminated to a broad community of users for research and in the development and validation of models and instrumentation.
- World Days should be scattered throughout the calendar year.
- World Day data is to be promptly submitted to the CEDAR database and/or made available through other online databases as appropriate.

4.3.3 Process for Requesting World Day experiments

- Radar observing time is allocated (1) to individuals or groups through either formal or informal requests to the institutions responsible for operating the facilities, and (2) for World Day observations coordinated through a plan developed annually by the URSI Incoherent Scatter Working Group (ISWG).
- The high demand for ISR observations, in particular for extended and multi-radar operations, requires certain procedures to help ensure that the highest priority scientific research is addressed by the coordinated World Day schedule within the limits imposed by the cost and technical restrictions of ISR operations.
- The process begins with the development of a baseline schedule of general-purpose experiments that fall within the operating constraints of the radars. The baseline World Day schedule for 2009 and its updates will be available at http://people.ece.cornell.edu/wes/URSI_ISWG/2009WDschedule.htm or similar addresses in the future.
- If you are planning extended duration and/or multiple facility ISR experiments, you should review the baseline schedule carefully to determine whether your observational requirements can be met by the provisional baseline observations. If not, and if your experiment cannot be easily accommodated through requests to individual radar facilities, you will need to submit a proposal for additional or modified operations to the Chair of the ISWG (W. E. Swartz prior to the URSI GA in August 2008, or to I. Haggstrom afterwards). Instructions for preparing your request and a sample proposal are available at: http://people.ece.cornell.edu/wes/URSI_ISWG/SampleWDproposal.doc
- If you are unsure whether or not your experiment requires the submission of a proposal, please contact the ISWG Chair or any staff member of an ISR facility.
- When proposals are received, the ISWG Chair will initiate an interactive review process, enabling experimenters to provide additional input or arguments as needed. Every effort will be made to accommodate all requests.
- The ISWG will meet during the summer of each year to review all the proposals with the aid of external reviewers solicited by the Chair as appropriate. The group will then determine how the global network of ISRs can best satisfy the approved observational requests and will ensure that the experimental configurations, numbers of radars involved, time distribution and total time allocated

are appropriate for the specified science goals. This process will normally take place at, or during, the annual CEDAR meeting. The proposer's presence during this discussion is not required.

- Please feel free to consult with any facility staff member for clarification on this process for requesting ISR observing time within the World Day program.

4.3.4 Observations

International Polar Year: Continuation of year-long observations with the Jicamarca, Poker Flat, EISCAT Svalbard ISRs

Key Objectives:

- To provide an unprecedented data set with multiple applications.
- To provide correlative data for other instrumentation and models committed to the IPY.

Background Conditions: Anything that comes along.

ISRs Needed: ESR, and others as resources permit.

Parameters to Measure: Standard.

Contacts: Tony van Eyken.

TEC Mapping: ISR/GPS Coordinated Observations of Electron Density Variations

Key Objectives:

- To study latitudinal variations of the ionosphere in the American longitude sector.
- To examine time and latitudinal variations of electron content in the plasmasphere.
- To test the GPS TEC mapping function.

Background Conditions: A range of magnetic activity is preferred but not required. A summer week (5 days) with some magnetic activity to complement the measurements of 2007 March 1-5 (which was magnetically quiet). We plan similar experiments for years ahead so that we can pick up different months for different years.

ISRs Needed: All.

Parameters to Measure: Standard ISR basic parameters, e.g., Ne, Ti, Te and line-of-sight ion velocity V_o .

Inferred parameters, such as meridional thermospheric winds and local electric fields, are desirable at least for Millstone Hill.

Good height coverage and height/range resolution is needed. The idea is to have a good ISR profile for both the bottomside and topside. Our intent is to determine the plasmaspheric content from the difference between the GPS TEC and the integrated ISR electron content. Because of this, the value of the F2 peak, and of the electron density above and below it, are very important for our analysis. Using a single very long pulse to make ISR measurements may result in significant smearing effects and would cause measurements below 200 km to be unusable for our study. We suggest either a short pulse with a long dwell (integration) time or a long pulse with interleaved Alternating Code. A time resolution of up to 30 min is acceptable.

We will use Millstone Hill's zenith and MISA data, taken almost simultaneously, to test how the slant TEC is mapped to the vertical TEC. So both local measurements and wide coverage are requested. The elevation scan is preferred.

For high latitude sites, we prefer elevation scans towards the South. First, that would generate line-of-sight TEC that can be compared with GPS TEC (few GPS satellites are overhead or in the north at high latitudes). Second, in the American Sector, combined Millstone and Sondrestrom data could provide good latitudinal coverage over subauroral and auroral areas.

For other sites, vertical observations would be fine. We ask for high altitude measurements from Arecibo.

Contacts: Shun-Rong Zhang, Anthea Coster.

C/NOFS: Communications / Navigation Outage Forecasting System

The primary purpose of C/NOFS is to forecast the presence of ionospheric irregularities that adversely impact communication and navigation systems through

- (1) improved understanding of the physical processes active in the background ionosphere and thermosphere in which plasma instabilities grow;
- (2) the identification of those mechanisms that trigger or quench the plasma irregularities responsible for signal degradation; and
- (3) determining how the plasma irregularities affect the propagation of electro-magnetic waves.

A satellite was launched in April, 2008 into a low inclination (13°), elliptical ($\sim 400 \times 700$ km) orbit that is solely dedicated to the C/NOFS objectives. It is equipped with sensors that measure ambient and fluctuating electron densities, ion and electron temperatures, AC and DC electric fields, magnetic fields, neutral winds, ionospheric scintillations, and electron content along the lines of sight between C/NOFS and the Global Positioning System (GPS) satellite constellation. The orbit has a 45-day repeating precession. Complementary ground-based measurements including the Jicamarca and Altair radars are critical to the success of the mission. Coordination with the World Days periods starting in August 2008 will be expected. (Requests for additional UAF radar time beyond the currently scheduled World Days are to be made directly to the respective observatory staffs once orbital characteristics are known.)

Contacts: Odile de La Bedaujardiere, David Hysell, Wes Swartz

QP TIDs: Coordinated Study of Quasi-Periodic Medium-Scale Traveling Ionospheric Disturbances with Extended Latitude Coverage

Key Objectives:

- To determine whether gravity-wave induced medium-scale traveling ionospheric disturbances (MSTIDs) consistently observed at high geomagnetic latitudes under quiet geomagnetic conditions are at all related to the continuum of quasi-periodic thermospheric waves observed at both Arecibo and Millstone, and perhaps at AMISR Poker Flat.
- To firmly establish the geophysical parameter range over which these quasi-periodic MSTIDs—that currently appear to defy theoretical explanation—exist.

Background Conditions: Low to moderate geomagnetic activity, New Moon.

ISRs Needed: All except Jicamarca, for three 48-hour runs.

Parameters to Measure: Continuous or near-continuous vertical power profiles through the *E* and *F* regions (100-800 km) with the best time resolution possible. We must have 5 minute or better time resolution power profiles in order to properly filter the data to separate small amplitude waves from the normal variations of the ionosphere.

Secondary Parameters to Measure: Dual-beam ion velocities commensurate with the primary objective. .

Contacts: J.D. Mathews, F.T. Djuth, D. Livneh, I. Seker, M.P. Sulzer, C.A. Tepley, S.M. Smith, W.A. Bristow, J.C. Foster, and M. Nicolls.

Strat-Warming: Dynamics and Temperature of the Lower Thermosphere During Sudden Stratospheric Warming

Key Objectives:

- To measure neutral wind (zonal and meridional components) and electron and ion temperatures in the lower thermosphere before and during sudden stratospheric warming.
- To compare variations in temperature and winds to average variations observed by ISRs during the winter.
- To compare variations in temperatures and winds to mesospheric response as given by MF and meteor radars and lidars.
- To extend studies of stratospheric warming effects to the lower thermosphere and investigate possible coupling with the ionosphere.
- To examine the mechanisms responsible for variations in lower thermospheric dynamics and temperatures and investigate to what degree they can be related to sudden stratospheric warming.

Background Conditions: The observations need to be made before and during the sudden stratospheric warming. A 10-day campaign is requested, based on an alert to be issued either in January or February.

ISRs Needed: All, although the response at Arecibo and Jicamarca may be weak.

Parameters to Measure: LTCS mode - electron and ion temperatures from lowest possible altitude throughout the *F*-region, zonal and meridional components of neutral wind in the lower thermosphere (95-140km), *F*-region meridional wind. Temporal resolution can be sacrificed and data integration period increased in order to obtain data at lower altitudes.

Contacts: Larisa P. Goncharenko, Irfan Azeem, William Wardr.

Synoptic:

Key Objectives: These synoptic experiments are intended to emphasize wide coverage of the *F*-region, with some augmented coverage of the topside or *E*-region to fill in areas of the data bases that have relatively little data.

Contacts: Wes Swartz, Jan Sojka.

LTCS (Lower Thermosphere Coupling Study): Tidal Variability

Contact: Larisa P. Goncharenko

M-I Coupling (Magnetosphere-Ionosphere Coupling): Storm and Substorm Effects on the Middle- and Low-Latitude Ionosphere

Contact: Chaosong Huang

GPS-Radar (Global Plasma Structuring-Radar Experiment): Thermal plasma coupling between low, mid, and high latitudes

Contact: John Foster

Meteoric Ions (Global observations of ionization created by the Perseids and Leonids)

Contact: Ingemar Haggstrom

CPEA (Coupling Processes in the Equatorial Atmosphere)

Contacts: Shoichiro Fukao, Project Leader, Sunanda Basu, Janet Kozyra

MST (Studies of the Mesosphere, Stratosphere, and Troposphere)

Contacts: Gerald Lehmacher, Erhan Kudeki, Jorge L. Chau

World Month (Searching for Long Period Effects)

Contacts: Tony van Eyken, Larisa P. Goncharenko, and Wes Swartz

4.4 G4: Ionospheric Research to support radio systems

Chair: M. Angling (United Kingdom)

Vice-Chair: C. Coleman (Australia)

URSI Commission G Working Group 4: Ionospheric Research to Support Radio Systems was formed at the Maastricht General Assembly. The intention was that the group should have wide objectives, and should seek to maintain an overview of ionospheric research related to radio systems. A website for the working group is located at: <http://www.ips.gov.au/IPSHosted/wg4/index.html>. In addition to a general information role, the group has attempted to sponsor two projects that were felt of general importance. The areas selected were data assimilation and propagation predictions for digital radio.

The data assimilation project aimed to provide a consistent set of input and test data that could be used to facilitate comparative testing between models. There has been little uptake of this idea. Apart from the initial studies identified in the report given to the last GA, the only known use of this test set has been by QinetiQ and AFRL in an unpublished study.

With regards the other project, a model of ionospheric scatter has been formulated and a method developed to estimate the effect of multipath and Doppler on digital waveforms. The model is largely based in existing ITU recommendations applicable to self interference. A draft amendment to ITU-R Rec533 has been submitted to ITU.

This has been achieved largely through the personal efforts of Les Barclay with some assistance from IPS and QinetiQ.

The group has not been as active as hoped and it is not clear that this is likely to change in the near future. It is therefore recommended that the group should be shut down, whilst noting that its technical area remains well covered by the Ionospheric Effects Symposium and the IET Ionospheric Radio Systems and Techniques conference.

4.5 GF: Middle atmosphere

Co-Chair for Commission G: J. Röttger (Germany)
Co-Chair for Commission F: C.H. Liu (China, SRS)

The International School on Atmosphere Radar at the National Central University in Taiwan ISAR-NCU over three weeks in October 2007 demonstrated the wide student interest in learning about MST and incoherent scatter radar. Lecturers from several countries were present with the students mainly from developing countries. A report was published in the URSI Radio Science Bulletin and we appreciated sponsoring and financial support by URSI.

A further school of this kind, ISAR-NCU 2008, is being prepared on remote sensing by passive and active sounding methods using radio waves for studies of the ionosphere and atmosphere. This school will be held at the National Central University in Chung-Li, Taiwan in October 2008. The majority of funding will come from Taiwan and some further support and sponsoring by URSI has been applied for. This school is again directed towards students from developing countries and the Asia Pacific region.

In December 2007 the 11th MST radar workshop MST-11 was held in Tirupati, India. More than 100 participants attended. The proceedings have been published by the National Atmosphere Research Laboratory of India in Gadanki and a short journal publication is on its way in *Annales Geophysicae*. The next MST radar workshop MST-12 is planned for May 2009 in Canada.

The existence and performance of the URSI Joint Working Group GF was very helpful in the preparation and for the final decision in Germany to remain in the EISCAT Scientific Association. The membership was transferred end of 2006 from the Max-Planck-Gesellschaft to the Deutsche Forschungsgemeinschaft.

In view of the ongoing activities in this field we ask URSI to keep this working group active.

4.6 GH: Active experiments in plasmas

Co-Chair for Commission G: K Groves (USA)
Co-Chair for Commission H: B. Thidé (Sweden)

The 2005-08 period has been an exciting time for active experiments in space, marked by the completion and first utilization of a new world class high power, high frequency

(HF) heating facility and significant progress in understanding heating physics driven by experimental results. As a result, the Active Experiments in Plasmas community has been, literally, active.

A relatively new heating facility established near Gakona, Alaska under the High Frequency Active Auroral Research Program (HAARP) by the U.S. Air Force Research Laboratory and the Naval Research Laboratory was completed in July 2007. Since the facility's completion more than 1000 hours of reliable operations have been performed, primarily to investigate HF-induced generation of ELF/VLF radiation. The HAARP facility consists of 144 crossed-dipole antenna elements fed independently by 20 kW transmitters producing a peak effective radiated power (ERP) of 3.6 GW across a broad range of frequencies (2.8-10 MHz). Because each element is powered and controlled independently, the system offers extremely flexible control of transmitted phase, amplitude and frequency opening up vast new possibilities for waveform selection and excitation of plasma wave modes. Additional information concerning the HAARP facility can be found at www.haarp.alaska.edu.

Prior to completion (2006 to mid-2007) the facility was operated at lower power in a number of campaigns to investigate the heating characteristics as a function of magnetic aspect angle and frequency. Particularly interesting results were obtained heating near the 2nd gyro-harmonic of the local magnetic field where dramatic enhancements of optical emissions were observed. The first international campaign with the new facility was conducted during the period from Feb-Mar 2008. Focused on the generation of artificial irregularities, it consisted of approximately 35 experiments conducted by a similar number of investigators from the US and the international community. Preliminary analysis shows that spectacular optical emissions were observed and many new results are anticipated. A second campaign period is anticipated in October 2008; specific dates will be announced to the community when they are established.

Additionally, an effort to restore a two-frequency heater capability at Arecibo Observatory in Puerto Rico is funded and underway. The Arecibo heater will deploy a sub-reflector screen and use the 270 meter dish as the primary reflector and should achieve better performance at both 5.1 MHz and 8.175 MHz, approximately 80 MW ERP, than the previous Arecibo heating facility near Isote,. Coupled with the sensitive incoherent scatter radar at the facility it promises to enable exciting new high resolution studies on the micro-physics of high power wave-plasma interactions in space at mid-latitudes.

A number of new investigations in 2006-08 were conducted with the EISCAT heating facility located at Tromsø, Norway by participants from numerous countries including the UK, Finland, Norway, Sweden, Germany, Japan, Russia and Ukraine. Topics studied include the dependence of Langmuir turbulence signatures on geomagnetic field aspect angle as

observed by the EISCAT incoherent scatter radars, the excitation of short-scale irregularities associated with upper hybrid processes using coherent backscatter radar (CUTLASS) and short-wave broadcast station carriers, as well as the interaction of powerful HF pump waves with natural phenomena such as auroral processes, magnetic pulsations, ion outflow, and polar mesospheric summertime echoes (PMSE). Indeed, a new 50 MHz coherent backscatter radar was installed to further support these studies at longer wavelengths. A major campaign was conducted in 2006 to investigate the directional dependence of stimulated electromagnetic emissions (SEE) using HF interferometry. Opportunities to perform new optical experiments were limited to some extent by the occurrence of solar minimum during the 2005-08 period, but these activities are expected to increase significantly during the next three years.

The Sura heating facility near Vasilsursk, Russia reports a number of new results from campaigns conducted in 2006 and 2007. Studies combining in situ observations from the Demeter satellite and ground-based tomographic reconstructions have demonstrated large scale HF-induced density variations mapping hundreds of kilometers along the geomagnetic field. Both negative and positive density perturbations were observed, ranging from $\pm 10-20\%$ in relative amplitude. Propagation effects detected by satellite-based VLF observations corroborate the formation of these HF-induced large-scale ducts. These results merit further theoretical and modeling investigation to provide quantitative descriptions of ducting phenomena.

Some of these results were presented at the VII International Suzdal URSI Symposium on Modification of the Ionosphere by Powerful Radio Waves held near Moscow in October 2007. The meeting was well-attended, with approximately 25 oral and 30 poster presentations covering a wide range of heating-related topics as well as phenomena driven by intense natural electric field sources, such as lightning. Much progress in understanding nonlinear thermal parametric instabilities and their role in plasma heating, structuring and electron acceleration was reported, as was further insight into the nature of wave-plasma interactions at magnetic zenith and gyroharmonics and the critical contributions of upper- and lower-hybrid waves to HF-induced turbulence and striation-formation.

Given the on-going development of new facilities and the recent impressive results from existing heaters, expectations for future progress in understanding high power HF-space plasma interactions are very high. The 2005-08 time period has been very productive and it is anticipated that there will be many new significant results in the next reporting period. The Active Experiments in Plasmas group wishes to continue as an URSI Working Group in the forthcoming triennium.

4.7 FG: Atmospheric Remote Sensing using Satellite Navigation Systems

Co-Chairs: Dr. Bertram Arbesser-Rastburg (F) and Dr. Cathryn Mitchell (G)

We considered holding a special conference as had been

held in Matera in 2003. However, due to the large number of meetings already scheduled in the period 2006-2007 we opted for a special session at the International Beacon Satellite Symposium, 2007 held in Boston, USA.

The session welcomed papers that had an applications emphasis or had connections between the ionosphere and troposphere. It promoted very lively discussions, particularly relating to the precise techniques that are used in GPS receivers to measure scintillations.

Details of the papers given are below.

10:50 AM

Study of Equatorial Spread F Irregularities at Indian Low Latitude Using Multi-Technique Observations K. N. Iyer, H.P. Joshi, Mallini Aggarwal, A.K. Patra and Smitha V. Thampi

11:10 AM

A Review of Ionospheric and Tropospheric Scintillation and its Effect on Global Navigation Satellite Systems at L- and C- Band R. Watson, C.N. Mitchell and M.J. van de Kamp

11:30 AM

The Coherent Ionospheric Doppler Receivers: Past, Present and Future J. York, C. Slack, T. Garner, T.L. Gaussiran II and D. Munton

11:50 AM

Precise Ionospheric Measurements with GPS S. Ganguly, L. Dyrud, A. Jovancevic and A. Brown

12:10 PM Investigations of GPS Scintillations Using Digital Storage Receivers P. Kintner and A. Cerruti

Future: The importance of the working group topic is on the increase. There are now potentially four navigation systems (GPS, GLONASS, Galileo and COMPASS) that will come into increasing importance in the next few years. A special conference for the working group will be considered in the next period, probably in early 2010.

In view of the ongoing activities in this field we ask URSI to keep this working group active.

4.8 URSI/COSPAR on International Reference Ionosphere (IRI)

Chair: B.W. Reinisch (USA)

Vice Chair for COSPAR : Martin Friedrich (Austria)

Vice Chair for URSI: Lida Triskova (Czech Republic);

Secretary: D. Bilitza (USA),

The main event during the reporting period was the release of the new and improved version of the model, IRI-2007. This latest version includes several new options and new parameters:

- (a) two new options for the topside electron density profile (a correction based on topside sounder data developed

- by Bilitza, USA and the NeQuick-model of Radicella, Italy and Leitinger, Austria),
- (b) a Neural-Network model for the electron density in the auroral E-region based on the work of McKinnell, South Africa and Friedrich, Austria using EISCAT incoherent scatter radar measurements and rocket data,
- (c) plasmaspheric electron temperatures are included for the first time (Akebono model of Kutiev, Bulgaria and Oyama, Japan),
- (d) a much improved model for the topside ion composition (Triskova and Truhlik, Czech Republic), and for the first time a specification of spread F probability (de Souza, Brazil).

During the 2006 General Assembly of the Committee on Space Research (COSPAR) in Beijing, China, a special IRI-related session was held entitled "Modeling the Solar Activity Variations of Ionospheric Parameters (session C4.2)". Close to 60 papers were presented during the 2-day session including oral and poster presentations. Of special interest is the good correlation of topside parameters with indicators of solar variation like the F10.7 radio flux when allowing for a 1-2 day delay.

A special IRI workshop was held in October of 2006 in Buenos Aires, Argentina focusing on an improved representation of total electron content (TEC) with IRI. The meeting was exceptionally well organized by Dr. M. Mosert and her team from CASLEO, San Juan with help from the ionospheric groups from the Universidad Nacional of Tucuman and La Plata. Excellent global coverage was represented by participants from Argentina, Czech Republic, Italy, USA, Spain, Russia, Austria, Peru, Cuba, South Africa, Brazil, Nigeria, and Mexico, making use of many different data sources: ionosondes, GPS, incoherent scatter radars, TIMED, DMSP, Hinotori, Akebono, and a few other satellites. Presentations showed how on one hand the data from the Global Navigation Satellite Systems (GNSS) can benefit the representation of TEC with IRI both in terms of model improvements as well as real-time updating, and on the other hand showed how usage of the IRI model helps to initiate and fine-tune the GNSS data mapping techniques. A more detailed description can be found at http://iri.gsfc.nasa.gov/docs/iri_06_report.html.

For its 2007 Workshop the IRI team joined forces with the European Cooperation for the Mitigation of Ionospheric Effects on Radio Systems (COST 296) one of the major pan-European projects in ionospheric physics supported by the European Cooperation in the Field of Scientific and Technical Research (COST). The special focus of this combined IRI/COST workshop was a better representation of the forcing from below and from above in ionospheric models with special emphasis on the IRI model and regional European models. Naturally the workshop had a strong orientation towards application of ionospheric models and specifically on their effects on radio systems. The 1-week

meeting was held in Prague, Czech Republic in July 2007, expertly organized by the Local Organizing Committee of the Institute of Atmospheric Physics (Drs. Lastovicka, Buresova, Sauli, Truhlik, Triskova) and attended by 103 participants from Africa, Asia, Europe, and North and South America giving 67 oral and 50 poster papers. An article summarizing workshop results was published in the Space Weather journal (Bilitza, D., B. Reinisch, and J. Lastovicka (2008), Progress in Observation-Based Ionospheric Modeling, Space Weather, 6, S02002, doi:10.1029/2007SW000359).

All three IRI meetings received financial support from a number of international and national organizations including travel support from URSI for key speakers.

Refereed papers from the IRI meetings are slated for publication in the Journal of Advances in Space Research. A combined issue with ~30 papers from the Beijing and Buenos Aires meetings is now complete and will be published in the near future. Editing work is under way for selected papers from the Prague meeting which will be published in two issues because of the large number of contributions. Two JASR issues with papers from earlier IRI workshops were published during this reporting period:

- (1) Bilitza D., B. Reinisch, (eds.), Advances in Specifying Plasma Temperatures and Ion composition in the Ionosphere, Advances in Space Research, Volume 37, Number 5, 2006.
- (2) Reinisch B., D. Bilitza, and D. Altadill (eds.), New Satellite and Ground Data for IRI and Comparison with Regional Models, Advances in Space Research, Volume 39, Number 5, 2007.

In view of the ongoing activities in this field we ask URSI to keep this working group active.

4.9 Other Working Groups

Other Working Groups in which Commission G is active are reported on the lead Commission reports. These include:

- Inter-commission Working Group on Solar Power Satellites
Co-Chair for Commission G: M. Rietveld (Norway)
- EGH: Seismo Electromagnetics (Lithosphere-Atmosphere-Ionosphere Coupling)
Co-Chair for Commission G: S. Pulinets (Russia)
- URSI/IAGA Inter-union working group on VLF/ELF Remote Sensing of the Ionosphere and Magnetosphere (VERSIM)
Co-Chair for URSI Commissions G and H: Janos Lichtenberger (Hungary)

5. Sponsored meetings

5.1 Mode A sponsorship

Commission G offered Mode A (no additional funds) support to the following meetings:

- Advanced School on Space Weather, ICTP, Trieste, Italy, 2 May 2006
- Characterising the Ionosphere, Fairbanks, Alaska, USA, 12-16 June 2006
- IRST - Ionospheric Radio Systems and Techniques, 18-21 July 2006, London, UK A EUR 0
- ISROSES - International Symposium on Recent Observations and Simulations of the Sun-Earth System, Varna, Bulgaria, 17-22 September 2006
- EuCAP 2006 - European Conference on Antennas and Propagation, Nice, France, 6-10 November 2006
- Workshop on the future of ionospheric research for satellite navigation and positioning: its relevance for developing countries, ICTP, Trieste, , 27 November - 8 December 2006
- STIINTE - Solar-Terrestrial Interactions : Instrumentation and Techniques, Sinaia, Romania, 4-16 June 2007
- BSS 2007 - Beacon Satellite Symposium 2007, Boston College, Chestnut Hill, MA, USA 11-15 June 2007
- Rarotonga Energetic Particle Workshop 2007, Rarotonga (Cook Islands), 5-10 August 2007
- STAMMS2 - Spatio-Temporal Analysis of Multimoint Measurements in Space, Orléand, France, 24-28 September 2007

- From Planets to Dark Energy: the Modern Radio Universe, Manchester, UK, 1-5 October 2007
- Scientific and Fundamental Aspects of the Galileo Programme, Toulouse, France, 2-4 October 2007
- IES2008 - 12th International Ionospheric Effects Symposium, Alexandria, Virginia, USA, 6-8 May 2008
- 37th COSPAR Scientific Assembly, Montreal, Canada, 13-20 July 2008

5.2 Mode B sponsorship

Meetings sponsored under Mode B received (limited) funding from Commission G, and other Commissions in some cases.

- Joint URSI-COSPAR session on the IRI (3 half-day sessions), 16-23 July, Beijing, China, 2006
- Vertical coupling in the atmosphere/ionosphere system, Varna, Bulgaria, 18-22 September 2006
- ISAR-NCU - International School of Atmospheric Radar, Chung-Li, Taiwan, 9-27 October 2006
- IRI Workshop 2006 - New Measurements for Improved IRI TEC Representation, Buenos Aires, Argentina, 16-20 October 2006
- MST 11, International Workshop on Technical and Scientific Aspects of MST Radar, Gadanki, Tirupati, India, 11-15 December 2007
- IRI/COST296 Workshop on Ionosphere Modelling, Forcing and Telecommunications, Prague, Czech Republic, 10-14 July 2007
- 10th International VLF Seminar, Zvenigorod, Moscow Region, Russia, 12-15 November 2007
- ISEA-12, Heraklion, Crete, Greece

COMMISSION H

This report was prepared by Professor Richard B. Horne, Commission H Chair 2006-2008

1. In Memoriam

The following friends and colleagues passed away during the last three years:

- Roger Gendrin
- Victor Trakhtengerts
- James Van Allen
- William W L Taylor

They made significant contributions to the science supported by Commission H and will be remembered warmly.

2. Commission H web site

During the last three years the Commission H website has been updated significantly. The web site now contains introductory material and references to Commission H business. I would like to thank the editor, Ondrej Santolik, for all his hard work. The web site can be found at <http://www.ursi.org/H/index.html>.

3. Meeting Support

Each Commission has a budget for supporting meetings during the triennium. The budget for Commission H was EUR 11,000 which included a carry-over of EUR 2,000 from the last triennium. The Commission received 21 requests for support, and was able to provide financial support for 12 meetings based on scientific relevance, and

geographical spread. The following meetings were supported financially with between EUR 500 - 1,500:

- 11th Workshop on the Physics of Dusty Plasmas, Williamsburg, Virginia, USA, 28 June - 1 July 2006
- BG-URSI School and Workshop on Waves and Turbulence Phenomena in Space Plasmas, Bulgaria, 1-9 July 2006
- COSPAR Scientific Assembly, Beijing, China, 16-23 July 2006, in particular session D3.1 on multiscale magnetospheric processes including simulations and theory
- ISROSES - International Symposium on Recent Observations and Simulations of the Sun-Earth System, Varna, Bulgaria, 17-22 September 2006
- 2nd VERSIM Workshop 2006, ELF/VLF Radio Phenomena, Sodankylä, Finland, 26-30 September 2006
- IRI Workshop 2006 - New Measurements for Improved IRI TEC Representation, Buenos Aires, Argentina, 16-20 October 2006
- ISSS8 - 8th International School for Space Simulations, Kauai, Hawaii, USA, 25 Feb - 3 March 2007
- STIINTE - Solar-Terrestrial Interactions : Instrumentation and Techniques, Sinaia, Romania, 4-16 June 2007
- Rarotonga Energetic Particle Workshop 2007, Rarotonga (Cook Islands), 5-10 August 2007
- 10th International VLF Seminar, Zvenigorod, Moscow Region, Russia, 12-15 November 2007
- 3rd VERSIM/URSI-IAGA workshop, Tihany, Hungary, 15-20 September 2008
- International Magnetosphere-Ionosphere Coupling Workshop, Espoo, Finland, 28 July 2 August, 2008.

Commission H also provided support in mode A (non financial aid), which means they can use the URSI badge to help promote the meeting, for the following meetings:

- International Symposium on Space THz Technologies, Paris, France, 10-12 May 2006
- Astrophysics in the LOFAR era, Emmen, the Netherlands, 23-27 April 2007
- 12th Microcoll, Budapest, Hungary, 14-16 May 2007
- IRI/COST296 Workshop on Ionosphere Modeling, Forcing and Telecommunications, Prague, Czech Republic, 10-14 July 2007
- International Symposium on Radio Systems and Space Plasma, Borovets, Bulgaria, on 2-5 September 2007
- ICEAA 2007, Torino, Italy, 17-21 September 2007
- STAMMS2 - Spatio-Temporal Analysis of Multimoint Measurements in Space, Orléans, France, 24-28 September 2007
- 12th International Ionospheric Effects Symposium, Alexandria, Virginia, USA, 6-8 May 2008
- 37th COSPAR Scientific Assembly, Montreal, Canada, 13-20 July 2008

4. Working Group Activities

- **VERSIM.** URSI/IAGA VLF/ELF remote Sensing of the Ionosphere and Magnetosphere (VERSIM) URSI Rep: H. Janos Lichtenberger
The VERSIM working Group has been very active over the last three years. They continue to provide a yearly newsletter to over 100 scientists from 26 Countries. VERSIM have run workshops in 2004, 2006, and 2008. Details of the newsletter, meetings and other information are all online at the webpage, <http://www.physics.otago.ac.nz/versim>
- **HEJ: Supercomputing in Space Radio Science.** Co-chair for Commission H: Y. Omura (Japan)
Plasma simulations are an essential tool for studying waves in plasmas. URSI has been supporting a series of meetings known as the International School for Space Simulations since the 1st meeting in Kyoto in 1982. During the last three years the 8th ISSS meeting was held in Hawaii to train the next generation of space scientists. The next meeting ISSS-9, is scheduled in summer 2009. More information about the meetings and activities can be found on the new web site: <http://www.iss9.uvsq.fr>
- **EGH: Seismo-Electromagnetics.** Co-chair for Commission H: M Parrot (France)
Since the URSI GA in 2005, the members of the WG have organized several dedicated sessions either in collaboration with EMSEV (Puerto Vallarta, 2005; Agra, 2006) or during international meetings (AGU, 2005, 2006, 2007; EGU, 2006, 2007, 2008). New data coming from the expanding GPS network and from the Earth observation satellites at different wavelengths have been presented. A special International Workshop devoted to the satellite DEMETER was organised in June 2006 in Toulouse. This workshop was attended by 125 geophysicists from 27 countries (including people working in seismology, tectonics, volcanism, EM emissions, ionosphere modelling ...). The DEMETER mission will continue until the end of 2009, and several countries are now proposing to have satellites to follow on from DEMETER.
- **ABDFGHJK: An inter-commission working Groups on Solar Power Satellites:** Co-chair for Commission H: N. Shinohara (Japan),
Work on solar power satellites continues to be an active area of research, particularly in Japan. During the last three years URSI published its first white paper on Solar Power Satellites, in Radio Science Bulletin, June, 2007.
- **GH1 Active experiments in Space Plasmas:** Co-Chair for Commission H: B Thide (Sweden)

5. Publications

The Vice Chair is responsible for soliciting and editing review papers for the Radio Science Bulletin. Over the last three years Commission H has been the most active of all the commissions and six review papers were published:

- Lembege et al., Kinetic and nonlinear processes in space plasmas, RSB, September 2005
- Decreau et al., The Cluster fleet explores waves in the magnetosphere, RSB, December, 2005
- Koons and Fennel, Space Weather effects on communications satellites, RSB, March, 2006
- Green and Boardson, Kilometric continuum radiation, RSB, September, 2006
- Amatucci, A Review of laboratory investigations of space plasma waves, RSB, December, 2006
- Chaston, Sources for dispersive shear Alfvén waves in the magnetosphere: A Review, RSB, March, 2007

A further four review papers are in progress. Thanks go to the Vice Chair, Yoshi Omura, for all his work in continuing this successful activity for Commission H.

6. Long Range planning Committee

A meeting of the Long Range Planning Committee was held in Belgium in 2007. The topics discussed included

1. Encouraging new generations of scientists to participate in URSI
2. Identifying new scientific areas
3. Strengthening Commissions that are not very active

A new student paper competition was introduced to address item 1 (see below), and additional money was allocated to each Commission to support non US students attending the GA. To address (2), Commission H identified energy supplies, satellite propulsion (e.g., ion thrusters), protection of satellites (radiation effects on electronics) and power and communications systems (i.e., Space Weather), and solar variability and climate change (e.g., via wave-driven energetic particle precipitation). Use of satellite constellations (small, micro-, nano-) to measure wave properties (temporal and spatial) and plasma wave applications involving other planets and solar physics were also recognized as new opportunities. Furthermore, as energy supplies becomes higher up the political agenda, both the development of nuclear fusion and solar power satellites are seen as possible areas of renewed emphasis, with involvement of several other Commissions (e.g., B, E, F, G, J, and K).

7. URSI General Assembly, Chicago, 2008

7.1 Scientific Sessions

Preparations for the URSI GA are one of the major activities of the Chair and Vice Chair during the triennia. Taking forward the proposals for sessions made at the GA in India, and after negotiations with other Commissions, a number of sessions had to be merged to fit into the new programme. Commission H arranged 10 H led scientific sessions, and contributed to 3 sessions led by other Commissions. 178 papers (82 oral and 96 poster) were accepted for the H led scientific sessions with a further 28 oral, and more than 28 poster papers for the joint sessions led by other commissions. This gives a total (including joint sessions) of 234 papers which compares favourably with 183 papers (89 oral and 94 poster) at the last GA in New Delhi. Overall the number of papers is up.

7.2 Papers

- H1. Dynamics of the plasmasphere using wave techniques: 7 oral 5 poster
- H2. Observations of waves and coherent structures in space plasmas: 10 oral 17 poster
- HG1a. Wave particle interactions, and radiation belt remediation: 8 oral 11 poster
- HG1b. Wave particle interactions and radiation belt remediation: 6 oral 11 poster
- H3. Open session and latest results: 10 oral 6 poster
- H4. Kinetic processes at boundary layers: 11 oral 8 poster
- HG2. Dusty plasmas: 6 oral 4 poster
- H5. Wave experiments in laboratory plasmas and applications to space: 7 oral 4 poster
- HGE. Seismo-electromagnetics: 10 oral 26 poster
- HBDGJK. Solar power satellites: 7 oral 4 poster
- GHE. Modification of the ionosphere and magnetosphere: 7 oral 21 poster
- GH. Radio sounding techniques for the ionosphere and magnetosphere: 11 oral 7 poster
- EGH. Terrestrial and Planetary Electromagnetic disturbances and effects: 10 oral
- H Tutorial. Wave Acceleration and Loss Processes at the Earth and Planets: 1 tutorial
- HSR. Special Review, Roger Gendrin: 1 oral

7.3 Medals and Awards

Every three years URSI calls for nominations for medals and awards to recognise outstanding contributions to URSI science. At this year's GA URSI has announced awards to two scientists that have been closely associated with Commission H:

- Booker Gold Medal to Prof. H. Matsumoto with the citation: *"For his outstanding contributions to the understanding of nonlinear plasma wave processes, promotion of computer simulations in space plasma physics and international leadership in plasma wave research"*.

- Appleton Prize to Prof. U. Inan, with the citation “*For fundamental contributions to understanding of whistler-mode wave-particle interaction in near-Earth space and the electrodynamic coupling between lightning discharges and the upper atmosphere*” (with approval from the Council of the Royal Society)

Congratulations to the recipients, it is good to see their scientific contributions recognised.

7.4 Young Scientist Support

For the General Assembly, URSI has a programme of financial support for young scientists. For the 2008 GA in Chicago URSI is supporting 119 young scientists with funds to cover their lodging and also provided a daily allowance. This includes 12 young scientists from Commission H. Five of these young scientists were from developing countries, or East European countries, and received an additional grant from URSI to cover part of their travel.

7.5 Student Paper Competition

This year URSI has instigated a student paper competition at the 2008 GA in Chicago to encourage students in all areas of URSI related science. There are five prizes ranging from US\$ 1,500 for first prize down to US\$500 for fifth prize. The entrants must be full-time University students from any country, present a paper at URSI, and submit a full length paper in Radio Science format via the web site at the time

of abstract submission. Four student papers were submitted through Commission H from the USA, Czech Republic, Russia and France. After refereeing, one of these papers has been selected for the final round of the competition where the students will present their work just before the GA.

7.6 Commission H Student Paper Competition

At the last GA in India 2005, up to US\$ 5,000 was made available to each Commission to support non USA students to attend the GA in Chicago. This was to encourage more students to attend URSI. After discussion, Commission H decided to allocate this money to the best student papers, after the full refereeing round. Commission H was thus able to support four students for travel and subsistence.

7.7 Vice Chair Election

The call for nominations for new Vice Chair was sent out in early December 2007. Four excellent candidates have now been nominated and postal voting is in progress. One candidate will be elected at the first Commission H business meeting, which will be held on the first Monday evening of the GA in Chicago.

Finally, I would like to record my thanks to the Vice Chair, Yoshi Omura, to the Commission H National Representatives, and the Working Group Representatives, who have contributed to the success of Commission H over the last 3 years.

COMMISSION J

This report was prepared by Professor Richard Schilizzi, Commission J Chair 2006-2008

1. Commission J Statement of Accounts

- *Budget:* €11000 (€9000 grant for 2005-8 triennium + €2000 carry-over from 2002-5)
\$5000 (special grant for travel support to the General Assembly)
- *Expenditure:* €7000 Mode B meeting support
€3450 travel support to General Assembly
\$5000 travel support to General Assembly
- *Balance carried forward:* €550

2. Meeting Support

Two meetings were given financial support by Commission J during the triennium:

- “Astrophysics in the LOFAR era”, Emmen, The Netherlands, April 07
- “From Planets to Dark Energy: the Modern Radio Universe”, Manchester, UK, October 2007

3. Publications in the Radio Science Bulletin

- “Enhancing the Sensitivity of Radio Telescopes Using Fiber-Optic Networks”, Roshene McCool, Ralph Spencer, Suresh Kumar, Ron Beresford, Steven Durand, Yasuhiro Koyama, Steve Parsley, Alan Whitney, and Peter Maat, *Radio Science Bulletin*, No. 317, June 2006, pp. 9-18.
- “Advances in Radio Astrometry” E. B. Fomalont and H. Kobayashi, *Radio Science Bulletin*, No. 318, September 2006, pp. 13-29.
- “Mitigation of Radio-Frequency Interference”, M. J. Kesteven, *Radio Science Bulletin*, No. 319, March 2007, pp. 9-18
- “Square Kilometre Array”, P. J. Hall, R. T. Schilizzi, P. E. Dewdney, T. W. J. Lazio (about to be submitted)
- “Phased arrays in Radio Astronomy”, A. van Ardenne (Commission J Tutorial, 2008), in preparation
- “Paths to Discovery in Radio Astronomy”, R. D. Ekers (in preparation)

4. URSI General Assembly, Chicago, August 2008

4.1 Scientific Sessions

A full program of talks and posters has been prepared on the following topics:

- Future Large Telescopes
- Aperture and focal plane arrays in radio astronomy,
- Mm and sub-mm radio astronomy
- Radio Frequency Interference, problems and solutions (joint with Commission F)
- Observatory reports
- Low frequency radio astronomy and the ionosphere (joint with Commission G)
- Radio astronomy in space and on the Moon; and
- Signal processing, calibration, and imaging in radio astronomy

Ninety one oral presentations and 116 posters will be presented - a total of 207 papers - an increase of 49 over the 2005 General Assembly.

Thanks to the convenors for their organization of the sessions, and to S. Ananthakrishnan for his organization of the poster sessions, including the Special Poster Session on the Giant Metre-wave Radio Telescope.

Jim Cordes will give one of the three General Lectures at the General Assembly entitled "Pulsars, General Relativity and Gravitational Waves", and Arnold van Ardenne will give the Commission J Tutorial entitled "Phased Arrays in Radio Astronomy".

4.2 Medals and Awards

This year, Commission J members were honoured with two of the five URSI Awards. Jack Welch will receive the Balthazar van der Pol Gold Medal, and Alan Rogers will receive the John Howard Dellinger Gold Medal. Congratulations to both these distinguished scientists!

4.3 Young Scientist Support

Following a call for proposals for travel support, nine young scientists were selected to receive grants supporting their travel to the General Assembly.

5. Inter Union Committee for the Allocation of Frequencies, IUCAF (Chair: Wim van Driel)

5.1 Introduction

The Scientific Committee on Frequency Allocations for Radio Astronomy and Space Science, IUCAF, was formed in 1960 by its sponsoring Scientific Unions, URSI, the IAU, and COSPAR. Its brief is to study and coordinate the requirements of radio frequency allocations for passive (i.e., non-emitting) radio sciences, such as radio astronomy, space research and remote sensing, in order to make these

requirements known to the national and international bodies that allocate frequencies. IUCAF operates as a standing inter-disciplinary committee under the auspices of ICSU, the International Council for Science. IUCAF is a Sector Member of the International Telecommunication Union (ITU).

5.2 Membership

In the period following the 2005 URSI General Assembly, the IUCAF membership was:

URSI

S. Reising (Com F), USA
U. Shankar (Com J), India
W. Swartz (Com G), USA
A. Tzioumis (Com J), Australia
W. van Driel (Com J; Chair), France

IAU

H. Chung Korea
R.J. Cohen [† 11/2006], United Kingdom
D.T. Emerson, USA
M. Ohishi, Japan
K.F. Tapping, Canada
A. Tiplady, South Africa

COSPAR

J. Romney, USA
at large:
W.A. Baan, Netherlands
K. Ruf, Germany

IUCAF also has a group of Correspondents, in order to improve its global geographic representation and for issues on spectrum regulation concerning astronomical observations in the optical and infrared domains.

5.3 International meetings

Since the 2005 URSI General Assembly, IUCAF has been represented by its members and correspondents in the following international meetings:

- 11/2005 ITU-R Working Party 7D (radio astronomy), Geneva, Switzerland
- 04/2006 ITU-R Task Group 1/9 (Compatibility between passive and active services), Geneva, Switzerland
- 07/2006 36th COSPAR Scientific Assembly, Beijing, China
- 08/2006 XXVIth General Assembly of the International Astronomical Union, Prague, Czech Republic
- 08/2006 ITU-R Working Party 7D (radio astronomy), Geneva, Switzerland
- 09/2006 ITU-R Task Group 1/9 (Compatibility between passive and active services), Geneva, Switzerland
- 09/2006 Space Frequency Coordination Group meeting SFCG-26, Bonn, Germany
- 02/2007 ITU-R Working Party 7D (radio astronomy), Geneva, Switzerland
- 02/2007 ITU-R Conference Preparatory Meeting, Geneva, Switzerland

- 09/2007 Space Frequency Coordination Group meeting SFCG-27, Maspalomas, Spain
- 10/2007 ITU World Radiocommunication Conference WRC-07, Geneva, Switzerland
- 04/2008 ITU-R Working Party 7D (radio astronomy), Geneva, Switzerland

IUCAF has face-to-face committee meeting before each of these meetings, with the purpose of discussing issues on the agenda of the meetings in preparation for the public sessions. During these sessions ad-hoc meetings of IUCAF were held to discuss further its strategy.

Although such face-to-face meetings have been convenient and effective, throughout the year much IUCAF business is undertaken via e-mail communications between the members and correspondents.

Additionally, many IUCAF members and Correspondents participated in numerous national or regional meetings (including CORF, CRAF, RAFCAP, the FCC etc.), dealing with spectrum management issues, such as the preparation of input documents to various fora.

5.4 Contact with the Sponsoring Unions and ICSU

IUCAF maintains regular contact with its supporting Scientific Unions and with ICSU. The Unions play a strong supporting role for IUCAF and the membership is greatly encouraged by their support.

URSI: IUCAF members have played an active role in the redaction of the URSI White Paper on Solar Power Satellites (SPS). IUCAF's objective was to ensure that it presents a balanced discussion of the SPS technology, including an evaluation of the risks involved, in particular to radio science. Unwanted radio emissions from SPS systems must be suppressed sufficiently to avoid interference with other radio services and applications, in accordance with the provisions of the Radio Regulations of the ITU.

IUCAF members have been actively involved in the work of the URSI Scientific Commission on Telecommunication (SCT), whose brief is to form a liaison in matters of spectrum management between URSI and the International Telecommunication Union (ITU).

For the 2008 URSI Scientific Assembly, IUCAF has been organizing its open meeting during session J07, and IUCAF members have been actively involved in the organization of the session on Solar Power Satellites. Each year, IUCAF members also actively participated in national URSI meetings.

IAU: In view of a the possibility of including frequency allocations in the infrared and optical wavelength domain in the ITU-R Radio Regulations, which form the framework for international spectrum management, IUCAF continued its consultations with members of the optical/infrared astronomy community.

The IUCAF Chair, W. van Driel, is a member of the Organizing Committee of IAU Commission 50 on the Protection of Existing and Potential Observatory Sites, IUCAF member A. Tzioumis is Chair of the Working Group on Radio Frequency Interference of IAU Division X (radio astronomy), and IUCAF member M. Ohishi chairs the Working Group on Astrophysically Important Spectral Lines of Division X.

COSPAR: Pursuing its brief, IUCAF continued its activities towards strengthening its links with other passive radio science communities, in particular in space science, and defining a concerted strategy in common spectrum management issues. At the 2006 COSPAR Scientific Assembly, IUCAF organized an open session on its activities and potential links with COSPAR, and at the 2008 COSPAR Scientific Assembly, IUCAF will organize Scientific Event E110 on "Spectrum Management and COSPAR: Keeping Passive Radio Observations Free of Interference".

5.5 Protecting the passive radio science services

At the ITU, in the period 2005-2007 the work in the various Working Parties of interest to IUCAF was focused largely on the preparations for WRC-07, the ITU World Radiocommunication Conference, which lasted for 4 weeks, from October 22nd to November 16nd, in Geneva, Switzerland. WRC-07 was attended by well over 3000 delegates from over a 180 nations and accredited organizations, including 7 IUCAF members and correspondents, and 9 other astronomers and astronomical spectrum managers.

The main goal of a WRC is the revision of the ITU Radio Regulations, which define the worldwide framework for spectrum management, including protection criteria for the radio astronomy service from unwanted emissions into its allocated frequency bands. WRCs are held every 3 to 4 years, and its agenda items are adopted at the previous WRC.

Of greatest relevance to IUCAF was an agenda item on the protection of the radio astronomy service and the Earth exploration-satellite (passive) service from unwanted emissions of active services in adjacent and nearby bands. This has resulted in an update of the tables of threshold levels used for consultation between the passive and active radio services in Resolutions 738 and 739. Of particular, and long-standing, concern to IUCAF was the case of the 1610.6-1613.8 MHz band, which contains important spectral lines of the interstellar OH molecule. It was decided that "The protection of the radio astronomy service in the 1 610.6-1 613.8 MHz band is ensured and will continue to be in accordance with the bilateral agreement between the Russian Federation, the notifying administration of the GLONASS/GLONASS-M system, and IUCAF, and subsequent bilateral agreements with other administrations." Among the preliminary agenda items adopted for the next WRC in 2011, the one most relevant to radio astronomy concerns the use of the radio spectrum

between 275 and 3000 GHz. No allocations for the use of this frequency band will be made at WRC-11, but the radio astronomy community has to identify a list of specific bands of interest.

IUCAF member M. Ohishi is Chair of ITU-R Working Party 7D (radio astronomy) and IUCAF member H. Chung is Vice-chair of ITU-R Study Group 7 (Science Services).

IUCAF members participated actively in the Task Force on Regulatory Issues of the international Square Kilometre Array (SKA) project, advising on criteria for a Radio Quiet Zone for this future giant global radio telescope.

5.6 IUCAF-sponsored meetings

IUCAF organizes and sponsors international meetings on spectrum management and RFI mitigation. Following the first Summer School in Spectrum Management for Radio Astronomy, held in Green Bank, USA, in 2002, and the second School held in Castel San Pietro, Italy, in 2005, IUCAF has been working towards its 2009 Summer School on Spectrum Management for Passive Radio Sciences, planned to be held in Korea.

5.7 Publications and reports

IUCAF has a permanent web address, <http://www.iucaf.org>, where the latest updates on the organization's activities are made available. All contributions to IUCAF-sponsored meetings are made available on this website.

5.8 Conclusion

IUCAF interests and activities range from preserving what has been achieved through regulatory measures or mitigation techniques, to looking far into the future of high frequency use and giant radio telescope use. Current priorities, which will certainly keep us busy through the next years, include the use of satellite down-links close in frequency to the radio astronomy bands, the coordination of the operation in shared bands of radio observatories and powerful transmissions from downward-looking satellite radars, the possible detrimental effects of ultra-wide band (UWB) transmissions and high-frequency power line communications (HF-PLC) on all passive services, and studies on the operational conditions that will allow the successful operation of future giant radio telescopes.

IUCAF is grateful for the moral and financial support that has been given for these continuing efforts by ICSU, COSPAR, the IAU, and URSI. IUCAF also recognizes the support given by radio astronomy observatories, universities and national funding agencies to individual members in order to participate in the work of IUCAF.

6. Global Very Long Baseline Interferometry Working Group (Chair: Jon Romney)

This triennium began with an action to re-create the GVWG's Terms of Reference, which had been lost over the

years since the Group was established in 1990. Fortunately, the archives of one long-term member yielded a copy of the original memorandum by R. D. Ekers, which was found to coincide quite well with current practice and areas of interest. New Terms of Reference, based on modern conditions, were drafted and accepted by both URSI and IAU (see <http://www.ursi.org/J/workinggroup.htm>).

Simultaneously, GVWG membership was renewed through a poll of all previous members, who were asked either to confirm their continued membership or to propose replacements. The new membership was selected with an eye toward balanced representation in both a geographic sense, and in terms of expertise. Geographic balance was based on three longitude regions: Asia & Australia, Europe & Africa, and the Americas. Expertise available among current GVWG members spans areas including scientific studies in astrophysics, astrometry, and geodesy; and techniques including e-VLBI and Space VLBI. (See <http://www.ursi.org/J/workinggroup.htm> for the names of the GVWG members.)

It was not possible for the GVWG to meet as a group until the end of this triennium, at the current General Assembly of URSI. It is not clear whether the past practice of holding GVWG meetings during General Assemblies of these international Unions remains tenable, but other options are also problematic, in view of the diversity of interests among the membership, and the graduation of VLBI beyond the specialized-technique category for which periodic international "VLBI meetings" were appropriate.

Among the three basic tasks specified in the GVWG's Terms of Reference, work was concentrated in the Space VLBI area during this triennium, in preliminary work related to the VSOP-2 mission. This effort was carried out by the Chair individually at this early stage. Guidance, developed in consultation with the Chair of Commission J (who is a past Chair of GVWG), was provided to the mission in two areas: on compiling a suitable list of ground radio telescopes (GRTs) whose participation would be valuable to the mission, and on issuing invitations to the institutions operating those telescopes. As of this date, a substantial list of suitable GRTs exists, but the invitations have not yet been issued by the mission. The mission itself strongly favours GRT coordination through the GVWG, but agreement on this has not yet been reached with the major GRT networks. An overall resolution of this issue will have to be a major focus for the Group early in the coming triennium.

The Chair was appointed, on an ex-officio basis, as a member of the VISC-2 mission advisory committee, and participated in that group's first face-to-face meeting in Bonn in May 2008, in a limited meeting during this GA, and in a number of VISC-2 teleconferences. After 6 years in the job, the Chair tendered his resignation at the end of this triennium.

7. Reports from National Committees

7.1 Australia (David DeBoer)

URSI activities centre around the Workshop on Applications for Radio Science (WARS) conference and participation in the Delhi General Assembly. The last WARS was held at the Gold Coast of Queensland 11-12 February 2008 and was well attended by government and industry. The focus was on the new instruments for radio astronomy, with the ASKAP and MWA instruments under development.

7.2 Brazil (Pierre Kaufmann)

- The solar submillimeter-wave telescope (SST) receivers and reflector were upgraded improving overall gain by a mean factor of ten. This program is carried jointly by Mackenzie Presbyterian University, Brazil and Complejo Astronomico El Leoncito, Argentina.
- Geodetic VLBI observations with the 12-m radio-telescope were carried regularly out at Northeast Space Radio Observatory, Eusébio (near Fortaleza), Ceará State, sponsored partially by a contract between Mackenzie and NASA, in cooperation with Brazil National Space Research Institute (INPE).
- The upgrade of Mackenzie 13.7-m Itapetinga telescope, Atibaia, São Paulo State, was completed. It continues to be operated within an agreement with INPE.
- At São José dos Campos, São Paulo State, INPE operates a solar radio spectrograph and develops a large decimeter-wave interferometer.

7.3 China (Yihua Yan)

- In China, the Five-hundred-meter Aperture Spherical telescope (FAST) project has been approved by the central government in 2007.
- Two new antennas, one 40m antenna in Kunming and one 50m antenna in Beijing, were built in 2006 to form the Chinese VLBI Network, and a data processing center was established recently in Shanghai.
- A huge array of 10160 2-meter log periodic antennas for measurement of the 21 cm mission from reionization epoch has been set up in Xinjiang, west China.
- The Chinese Spectral Radiotelescope (CSRH), which consists of a 0.4-2 GHz array of 40 4.5m antennas and 2-15 GHz array of 60 2m antennas, is being built in a radio quiet zone in Inner Mongolia, China, to achieve high spatial, temporal and spectral resolutions and high sensitivity in dm-cm bands.

7.4 France (André Deschamps)

- 1) Operations
 - First cosmic ray detection with logarithmic antennas
 - VLB interferometry around 60 MHz (LOFAR)
 - Participation in SKA project
 - Participation in ALMA project (Channel 7 and 8 prototypes, very large band auto-correlators)
 - HERSCHEL / HIFI Channel 1
- 2) Meetings and Workshops
 - Organization of the workshop « Pulsars » (Jan 2006,

May 2007)

- Preparation and organization of ISSTT 2006 (Paris, May 2006)
 - SKA meetings (Paris 2006-2007)
- 3) URSI representation
 - ANFR (French Agency for Frequency Regulation, Paris). New rules for suppression of taxes for scientific frequency bands in France. Inscription of radio astronomy bands up to 270 GHz to the BR at Geneva.
 - ITU (Geneva). URSI representation at WRC07, and WP7D.
 - RSPG (Brussels). Participation in sessions on “Scientific Use of Radio Spectrum” and “SRR at 24 GHz”

7.5 India (Subramaniam Ananthakrishnan)

- The GMRT was used for more than 200 scientific proposals, both national and international. Among these studies the highlights are the following: detection of a 61.86 millisecond pulsar using GMRT in the supernova remnant G21.5-0.9 and inferring a characteristic age of ~4900 years for this pulsar which has the second highest spin-down luminosity after the Crab pulsar, discoveries of three new pulsars, three new HI 21 cm absorption systems towards damped Lyman-alpha candidates at $z > 1$ and one new double-double radio galaxy (NCRA); extensive studies of rotation and hence dark matter studies in the smallest known galaxies and follow up of X-ray binaries, extragalactic supernovae, and magnetars as targets of opportunity which helped in constraining models of their radio emissions.
- The shape of the density turbulence spectrum of cometary plasma in the comet 73P/Schwassmann-Wachmann 3-B from the observations of the occultation of a compact radio source by its plasma tail, using the Ooty Radio telescope, was reported;
- Study of Gamma ray burst afterglow for almost five years showing the deceleration of the expanding fireball from an initial ultra-relativistic phase to a non relativistic one has been reported.
- Development of a radically new model for the formation and temporal evolution in pulsar wind nebulae, identification of the existence of collimated particle beams from pulsars’ magnetic poles and demonstration of free precession of the central compact object to account for many aspects of the time variability have also been reported.

7.6 Italy (Roberto Ambrosinin)

- Commission J in Italy has supported meetings and research activities in the framework of the national participation in some of the most important international projects such as ALMA, SKA, LOFAR and Herschel.
- The Commission is participating also in the research activity carried out for the development of the Sardinia Radio Telescope (SRT). This instrument based on novel technologies such as active surface and flexible frequency

coverage, up to 100GHz, is expected to be completed by the end of 2009.

7.7 Japan (Hideyuki Kobayashi)

- URSI Commission J in Japan had two workshops related to the ALMA project and the future plans for Japanese astronomy.
- Commission J sent a recommendation letter supporting the next space VLBI mission to Japanese space agency, JAXA. The mission was approved in 2007 as Astro-G mission.
- Commission J supported on-going projects, ALMA, VERA, ASTE, NANTEN, and Nobeyama.

7.8 Netherlands (Arnold van Ardenne)

- The Dutch national URSI committee now operates under the auspices of the KNAW, the national academy of science, thereby improving its scientific status and visibility.
- It has set up a foundation for the purpose of organizing scientific meetings and symposia and has co-organized yearly workshops two of which have been together with the Belgian national committee. Commission J members gave presentations on new technical and scientific developments in radio astronomy. National Committee member, Wolfgang Wild, moved to ESO/ALMA to become European Project Manager.
- NOVA/SRON developed the ALMA band 9 receivers.
- The European SKA design study (SKADS) coordinated by ASTRON through the national chairman of Commission J, successfully passed its Mid-term review in 2007 and has now entered its last year. Its activities emphasize the use of Phased arrays for radio instruments, in particular for the SKA. SKADS has made important contributions to the technical and scientific potential of the SKA. An associated EC-funded Marie Curie program also coordinated by the URSI Committee chairman, has been successful in interesting many young engineers and scientists in radio astronomy. It is hoped that many will participate in the development and use of instruments like LOFAR and the SKA.
- A new program called Apertif involves the development of focal plane arrays for the Westerbork Synthesis telescope in close cooperation with similar developments in Canada and Australia.
- A continuation of the RadioNet collaboration in the seventh EC Framework Program has been approved. It is now being led by ASTRON.
- For VLBI, the European xPRoS program, led by JIVE in the Netherlands, was approved.

7.9 Peru (Walter R. Guevara Day)

- Two antennas systems have been built at VLF radio frequencies and installed in locations of Lima and Piura to observe solar activity using a variation of phase in the D layer. This is an international project called SAVNET leading by "Centro de Radioastronomia y Astrofisica de Mackenzie" (CRAAM) of Brazil, PI is Dr. Jean Pierre Raulin, and this is part of the activities associated with the International Heliophysical Year 2007-2009.

- Three courses in VLF propagation waves and Solar Physics are now offered, as well as courses in Solar Radiophysics at "Universidad Nacional Mayor de San Marcos" and the National Commission for Aerospace Research and Development (CONIDA).
- seminars on solar radio astronomy have been offered to undergraduate and graduate students in Solar Radioastronomy.
- Recently, the Geophysical Institute of Peru (IGP) is implementing a radio telescope for galactic and extragalactic research. This antenna was donated by a Spanish company (Telefonica) and developed by the National Astronomical Observatory of Japan.
- The Catholic University of Peru proposes to build a radio telescope for astronomical observation.
- Finally CONIDA are continuing with the SAVNET project on solar radiophysics with the construction proposed of two VLF system to be installed on ICA and Moquegua, which are integral parts of the network SAVNET. The construction of a solar radio telescope at high frequencies is also proposed.

7.10 Portugal (Luis Cupido)

- participation in the national URSI symposium (also with Spanish participation) where radio astronomers provided a small session of oral presentations and posters.
- participation in the URSI national meetings in preparation of the national symposium for 2008, and encouragement for the submission of articles to the GA;
- contact has been made with all people involved in research on radio astronomy in Portugal and they are now fully aware of the URSI existence and Portuguese representation.

7.11 Russia (Igor Zinchenko)

Radio astronomical activities in Russia included development of new facilities and upgrade of existing ones, development of new methods and astrophysical studies of various objects.

The main results can be summarized as follows:

1. Facilities and methods

The following developments have taken place:

- Completion of the national VLBI network "Quasar". The system comprises 3 stations based on 32-m antennas. It is included in the international IVS network and performs measurements for astrometry and geodynamics, in particular in the framework of the CONTO5 program;
- A new broadband 16-channel receiver for the RATAN-600 radio telescope;
- For the "Radioastron" mission, a new hydrogen maser frequency standard and new methods of multi-frequency VLBI measurement analysis;
- At the 64-m Kalyazin radio telescope, a new data acquisition system with time resolution of 10 ns and 10 hours recording time. Super-giant pulses from the pulsar in the Crab nebula were detected (5-6 MJy with 20-30 ns duration);

- The proposal of a new precise astronomical time scale based on measurements of the sample of reference pulsars at Arecibo and Kalyazin observatories;
- VLBI radar Doppler measurements of the 2004 $\tilde{\text{D}}$ 14 asteroid were performed.

2. *Extragalactic studies*

- A non-Gaussian component in CMBR anisotropy was found.
- Statistical studies of the spectra and structure of several tens thousands radio sources in the flux range from 1 Jy to several mJy were performed in preparation for the Radioastron and Planck missions.
- Radio flares from AGN at millimeter waves correlated with optical activity were observed.

3. *Galactic studies*

- A series of pulsar studies was performed at Pushchino observatory. In particular, radio pulses from the X-ray pulsar 1RXS J2143.7+065419 at 111 MHz were detected. This strongly constrains possible models of these objects.
- Interstellar turbulence was studied on the basis of the scintillation measurements of extragalactic radio sources. Several components in interstellar plasma are identified with different levels of turbulence.
- Studies of the structure and kinematics of star forming regions by observations of molecular radio lines and dust emission provide new data on radial profiles of physical parameters and small scale clumpiness in these regions.
- Transition frequencies for several important interstellar molecules (C18O, 13CO, HNC, HCN, OCS, etc.) were improved using laboratory and radio astronomical measurements. Typical uncertainties are ~ 1 m/s.
- Studies of interstellar molecular masers were performed in several observatories. In particular, rapid fluctuations of water masers were detected (tens of percent on the time scale of 5-10 min in W33B). Methanol masers associated with low mass protostars were found. Very narrow (~ 30 m/s) emission features were detected in 9.9 and 104 GHz methanol masers which indicated an unsaturated regime with a gain > 100 .

4. *Solar research*

- Inductive interaction of coronal magnetic loops was found from modulation of microwave emission of solar flares.
- Parametric resonance between 5 min photospheric oscillations and acoustic waves in coronal magnetic loops was found by observations of several corresponding frequencies.
- From observations of solar flares at NAOJ NRO it was found that the electron injection happens at the bottom of the magnetic loop.
- The amount and properties of hot and cold plasma in active regions were studied with the Pulkovo radio telescope.

7.12 South Africa (Justin Jonas)

- The SKA has become the main focus for radio astronomy in South Africa, particularly since Southern Africa has

been shortlisted together with Australia as a suitable SKA site.

- A radio astronomy reserve has been created in the Karoo region that is protected from radio interference by an Act of parliament. This reserve includes the SKA core site proposed by South Africa, and will be the site for the 80 dish MeerKAT array, a technology and science pathfinder for the SKA.
- The Hartebeesthoek Radio Astronomy Observatory (HartRAO) continues its programme of pulsar, molecular spectroscopy and VLBI science, and real-time eVLBI experiments with the EVN were conducted for the first time in 2008 using the JIVE correlator.

7.13 Taiwan (ROC) (Paul Ho)

- The Submillimeter Array (SMA), a joint project between Smithsonian Astrophysical Observatory (SAO) and the Academia Sinica Institute of Astronomy and Astrophysics (ASIAA), became operational in November 2003 on Mauna Kea, Hawaii. Taiwan contributed two of the 8 six-meter antennas together with all its associated receivers and instrumentations. In 2008, the SMA remains the only submm interferometer in the world, and is the fore-runner to the Atacama Large Millimeter/submillimeter Array (ALMA) under construction in Chile.
- The Array for Microwave Background Anisotropy (AMiBA), a project led by Taiwan, became operational in October 2006 on Mauna Loa, Hawaii. The AMiBA is a 7-element platform-mounted interferometer operating at 3mm to study the structure of the cosmic background radiation.
- Taiwan is also a partner with Japan and North America on the ALMA project, and operates the East Asia Front End Integration Center in Taiwan and contributes the equivalent of 2 ALMA antennas to the North American effort.
- Astronomers in Taiwan also make use of all the frontier international radio instruments, including the Nobeyama Radio Observatory, Arizona Radio Observatory, the Very Large Array, the Very Long Baseline Array, the Green Bank Telescope, the Australian Telescope, the IRAM 30 m telescope and the IRAM interferometer, the Odin submillimeter satellite, the Giant Meterwave Radio Telescope.

7.14 Turkey (Mehmet Özel)

There are two main groups active in radio astronomy in Turkey:

- (1) Erciyes University Astronomy Dept. established in 2000 with 3 senior (director: Assoc.Prof.Dr. I.Kucuk) and several junior level staff and researchers. They are presently building a 15m size radio telescope in Kayseri, which will basically be an educational facility to observe at 5-50 GHz frequencies.
- (2) Çanakkale University Astrophysics Research Center, which has diverse interests including radio astronomy. RA group includes 2 senior (M.E.Özel, Edwin Budding) a junior scientist (Naci Erkan). Recently, the Australian

Radio Telescope Facility (ATCA) is used to observe the active cool binary star system CC Eri as a part of an international multisite-multifrequency observing campaign - which includes photometric, x-ray and (4.8 and 8.6 GHz) radio observations simultaneously. Results were published recently (Budding et al., ASS, 304,13-16, 2007). The group continues follow up observations of the system and other similar systems.

7.15 USA (Dave Woody)

- US Commission J had very successful winter meetings in Boulder Colorado in January 2005 and 2008. The attendance at the commission sessions averaged ~60 for both meetings and ~30 commission J members attended the business meetings
- There was a successful joint North American Science meeting with CNC-URSI Canada in Ottawa in August 2007.
- A new vice chair, Richard Bradley from NRAO, rbradley@nrao.edu, was elected at the January 2008 meeting. The current vice chair, Jim Cordes from Cornell, will become the chair for the January 2009 meeting.
- Six new members were nominated and elected in USNC-URSI commission J at the January 2005 meeting and six more at the January 2008 meeting.

8. Other

An electronic distribution list has been in use for the whole triennium as a means of communicating with the more than 400 Commission J members. The Commission J webpage on the URSI website has not been actively used, but contains a useful compendium of information on the Commission.

Commission J members under the leadership of Wim van Driel, Mike Davis and Masatoshi Ohishi provided substantial comment on drafts of the URSI White Paper on Solar Power Satellite systems.

I would like to thank Jon Romney for his work over the past 6 years in leading the GSWG.

I would also like to take this opportunity to thank my vice-chair, Prof. Subramaniam Ananthakrishnan for his valuable advice, hard work, and support, and wish him every success in the coming triennium.

COMMISSION K

This report was prepared by G. D’Inzeo, Commission K Chair 2006-2008

1. Overview

In the last three years, Commission K and its members have been active in:

- a) publishing articles in the Radio Science Bulletin,
- b) sponsoring scientific meetings,
- c) organizing and funding a major international symposium (July 2007),
- d) preparing a white paper on Wireless Communication and Health,
- e) running two business meetings in June 2006 and June 2008 at the annual Bioelectromagnetics Society Meeting,
- f) developing a draft of commission strategic directions and g) preparing for the General Assembly of Chicago (9 specific sessions, and one poster session, 2 joint sessions lead by Commission K with Commissions A and E and B and E respectively, one tutorial and one lead by Commission B and one lead by Commission B with Commission F for a total of 103 oral presentations and 31 poster presentations).

2. Contributions to the Radio Science Bulletin

2.1 Published Invited Reviews

- Ahlbom, A., Feychting, M, and Lonn, S., 2005. Mobile Phones and Tumor Risk: Interpretation of Recent Results. *Radio Science Bulletin*. 314: 30-33.
- Lin, J. 2005. Interactions of Wireless Communication Fields with Blood-Brain Barrier of Laboratory Animals. *Radio Science Bulletin*. 315: 33-38.

2.2 Invited Reviews in Preparation

(Waiting for Guglielmo D’Inzeo email)

2.3 Radio – Frequency Radiation Safety and Health:

- Lin, J. 2005. Radio-Frequency Radiation Safety and Health. *Radio Science Bulletin*. 315: 44-46.
- Lin, J. 2006. Radio-Frequency Radiation Safety and Health. *Radio Science Bulletin*. 316: 42-44.
- Lin, J. 2006. Radio-Frequency Radiation Safety and Health. *Radio Science Bulletin*. 318: 67-68.
- Lin, J. 2006. Radio-Frequency Radiation Safety and Health. *Radio Science Bulletin*. 319: 67-68.
- Lin, J. 2007. Radio-Frequency Radiation Safety and Health. *Radio Science Bulletin*. 320: 48-49.

- Lin, J. 2007. Radio-Frequency Radiation Safety and Health. *Radio Science Bulletin*. 321: 54-55.
- Lin, J. 2007. Radio-Frequency Radiation Safety and Health. *Radio Science Bulletin*. 322: 41-42.
- Lin, J. 2008. Radio-Frequency Radiation Safety and Health. *Radio Science Bulletin*. 324: 41-42.

2.4 Published Commission K Tutorial Lecture:

- Vecchia, P. 2006. Assessment of Health Effects Associated with Electromagnetic Fields by WHO, IARC, and ICNIRP. *Radio Science Bulletin*. 318: 30-33.

3. Sponsoring Scientific Meetings

The following scientific meetings received non-financial i.e. moral support from Commission K.

- International Symposium on Space THz Technologies (ISSTT), Paris, France: May 10-12, 2006
- International Conference on Ultrawideband, Waltham, MA, USA September: 24-27, 2006
- VIIth International Symposium on Electromagnetic Compatibility and Electromagnetic Ecology, St. Petersburg, Russia June 26-29, 2007
- 2007 Asia-Pacific Microwave Conference, Bangkok, Thailand: December 11-14, 2007
- ICMARS-2006, Jodhpur, India: December 20-22, 2006
- Millimeter Waves in Medicine and Biology, Moscow, Russia: April 2-5, 2007
- The Sixth International Kharkov Symposium on Physics and Engineering of Microwaves, Millimeter and Submillimeter Waves (MSMW'07), Kharkov, Ukraine: June 25-30, 2007
- Electromagnetic Compatibility EMC Europe 2008, Hamburg, Germany: September 8-12, 2008
- Microwave-08, Jaipur, India: November 2008
- 20th International Zurich Symposium on Electromagnetic Compatibility, Zurich, Switzerland: January 12-16, 2009
- Electromagnetic Compatibility – EMC-2009, St. Petersburg, Russia: 2009

4. International Symposium Held July 22-26, 2007, Ottawa, Canada

URSI International Commission K and CNC-URSI ran four symposia associated with the North American URSI Meeting in Ottawa, Canada, July 22-26, 2007 (see <http://ursi2007.ee.umanitoba.ca/Home.html>). Two were associated with Commission E CNC and US-NC. Three of the four sessions had an overarching theme: toward visualization of electromagnetic brain stimulation through electromagnetic brain imaging and mapping.

The first session (K2) focused on Neuronal Stimulation by both inductive and capacitive coupling including presentations on theory, simulations and/or experimentation.

The third session (EK2) was a joint session on Electromagnetic Brain Imaging and Mapping with Commission E and focused on brain MRI, photo-acoustic imaging and current density imaging as well as brain mapping with EEG and electrical impedance tomography. The fourth session (K3) brought together the ideas in K2 and EK2 and covered Bioelectromagnetic Brain Imaging and Mapping of Effects from Electromagnetic Stimulation.

The second session was also with Commission E and this session (EK1) focused on breast imaging using microwaves - a very exciting, new and exploding field for URSI.

The success of these sessions allowed Commission K to decide on including similar sessions at the URSI GA08 in Chicago. These sessions especially the ones on Breast Imaging, Brain Imaging and imaging the effects of EMF brain stimulations have been oversubscribed suggesting that imaging will be a new large part of Commission K activities in the future.

The cost of this Symposium was about \$40,000 CAN/USD. This was raised from the \$8,000 EU available from URSI/Comm K, \$5,000 CAN from a research grant from CIHR, \$2,000 CAN for students from CNC/URSI and the remainder was generously provided by the Lawson Health Research Institute.

5. White Paper on Wireless Communication and Health

Dr. Bernard Veyret is preparing this white paper, requested by URSI. He has identified the authors for the different sections and will have a draft of the white paper ready for the general assembly in August 2008.

6. Two Meetings of National Representatives of Commission K*

- 9 June 12, 2006: A meeting was held in Cancun, Mexico at the 2006 Bioelectromagnetics Meeting.
- 10 June 9, 2008: A meeting was held in San Diego, California at the 2008 Bioelectromagnetics Meeting.

* Minutes of these two meetings can be found at <http://www.ursi.org/K/Index.htm>

7. URSI Commission K Emerging Issues, Prepared by Bernard Veyret and Frank Prato

The driving issue behind the creation of Commission K was health risk assessment mainly related to mobile telephony.

Since then, several emerging issues of heavy societal impact have been encompassed by the terms of reference for Commission K, especially in view of the still rapid development of wireless communication technologies and the emergence of the areas of “bioengineering” as a new area of emphasis at so many institutions, with new Departments of Bioengineering, Medical Imaging, Molecular Imaging and Molecular Biology being created. It is significant in this regard that the chair ship of Commission K has alternated between world leaders in risk assessment and biomedical engineering and imaging over the last 4 cycles.

While the underlying opportunities and applications in this connection are extremely broad, and cannot possibly be all addressed by URSI, or any other single organization, the relatively small but important component of the research thrusts of such departments, namely ‘Electromagnetic Effects in Biology & Medicine’ can be uniquely and most effectively captured by URSI.

The main emerging issues are today the new EMF-emitting devices (e.g., WiFi, Wimax, RFID) linked with dosimetric and standardization issues, and the biomedical applications of biomedical imaging (e.g., very high field MRI, microwave imaging, thermal imaging, near infrared imaging, optical imaging and hybrid imaging including optical/acoustic and microwave/acoustic), electrical mapping (e.g., electrical encephalography or EEG and electrical magneto encephalography or EMG) and electrical simulation (e.g., direct electrical stimulation and inductive non-invasive stimulation). It must be acknowledged in this regard that Commission K members must remain current in employing the latest in technology no matter where in the spectrum of these disciplines they work. For example they must use the latest in molecular biology regardless of whether research is in the traditional area of risk assessment (e.g. use of gene c-DNA arrays) or biomedical (e.g. developing reporter probes for molecular imaging).

Realization of such opportunities should be a new thrust of URSI, especially in view of their societal importance. In that context, significant interaction with other Commissions do exist already, namely commission A (e.g., field and SAR metrology), commission B (e.g., numerical methods and modeling of electromagnetic propagation in tissues, EM and statistics), commission E (e.g., development of EMI standards), commission F (e.g., terahertz propagation in tissue), and commission H (electromagnetics in conducting media).

In order to strengthen its role in health risk assessment and standard setting, commission K has built strong links with WHO and ICNIRP.¹

Hence Commission K has two important roles to play within URSI. The risk assessment role is that of “hand maiden” to the other commissions where, for example, Commission K members use the latest tools to test for safely

of a new wireless technology. The second role is where Commission K leads and asks other commissions to lend their expertise to develop new technologies such as the understanding of EM field transmission characteristics for microwave breast imaging. It is this second role that has the capacity of explosive growth but it is also the area most likely to be taken over once it reaches a level of commercialization for medical application by large well funded medical imaging societies. However Commission K can achieve a novel niche by leveraging the strengths of the other URSI commissions.

8. Preparations for GA08, August 9-15, 2008, Chicago:

Commission K will lead in 11 specific sessions and one poster session. This includes one session with Commissions B and E on microwave breast imaging and one with commissions A and E on exposure assessment of new emerging technologies. Commission K has combined with Commission B on a session with the title “Future Challenges of Computational Electromagnetics” and with Commission B and F with the title “Stochastic Modeling and Uncertainty Arrangement in Electromagnetics”. All 13 of these oral sessions have been filled and in addition there are a total of 31 posters and 1 Commission K Tutorial on Wireless Communication and Health. Hence there are a total of 134 Commission K presentations with 31 of these being posters.

9. Nomination of Dr. Shoogo Ueno for the Balthasar Van der Pol Gold Medal of URSI Society

Dr. Shoogo Ueno was nominated for a Gold Medal of the URSI Society. Although Dr. Ueno was more than deserving for an extensive career in research, teaching and administration his nomination, through no fault of his own, was not successful. Dr. Ueno has served our community unselfishly as a former Chair of Commission K and President of BEMS. Although not successful, Commission K members would like Dr. Shoogo Ueno to realize that his associates and colleagues hold him in the greatest regard.

10. Student Support at URSI

Commission K had \$5,000 US for student support and decided to use it to offset student travel costs by giving \$300 US to each of the 16 students.

Three Commission K students received Young Scientific Awards.

One Commission K student’s manuscript was selected in the 10 finalists for the URSI student paper competition: “*International Commission on Non-Ionizing Radiation Protection*”.

XXIXth General Assembly



NEWLY ELECTED OFFICERS, 2009-2011 TRIENNIUM

Following the elections at the XXIXth General Assembly in Chicago, IL, USA, the Officers of the Board and the Scientific Commissions for the 2009-2011 triennium are as given below:

Board 2009-2011

President: Gert Brussaard (the Netherlands)

Vice-Presidents:

- Dr. Yahia M.M. Antar (Canada)
- Prof. Martti Hallikainen (Finland)
- Prof. Umran Inan (USA)

Secretary General: Prof. Paul Lagasse (Belgium)

Past President: Prof. François Lefeuvre (France)

Chairs 2009-2001

Commission A: Dr. P. Banerjee (India)

Commission B: Prof. K.J. Langenberg (Germany)

Commission C: Prof. T. Ohira (Japan)

Commission D: Prof. F. Kaertner (USA)

Commission E: Prof. C. Christopoulos (UK)

Commission F: Dr. M. Chandra (Germany)

Commission G: Prof. M. Rietveld (Norway)

Commission H: Dr. Y. Omura (Japan)

Commission J: Prof. S. Ananthkrishnan (India)

Commission K: Prof. G. D'Inzeo (Italy)

Vice-Chairs 2009-2011

Commission A: Dr. W.A. Davis (USA)

Commission B: Prof. G. Manara (Italy)

Commission C: Prof. M. Luise (Italy)

Commission D: Dr. S. Tedjini (France)

Commission E: Dr. A.P.J. Van Deursen (The Netherlands)

Commission F: Dr. Roger H. Lang (USA)

Commission G: Prof. J.D. Mathews (USA)

Commission H: Dr. O. Santolik (Czech Republic)

Commission J: Dr. Donald C. Backer (USA)

Commission K: Dr. M. Taki (Japan)

The next URSI General Assembly will be held in Istanbul, Turkey, 13-20 August 2011.

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YOUNG SCIENTIST PROGRAM

The Young Scientist Program for the 2008 URSI GA was very successful due to a historic high number of applicants and due to the high quality of the applications. In total there were 279 applicants.

URSI selected 100 applicants coming from non US-countries. On top of this, the US National Committee sponsored 25 US Young Scientists allowing a selection of a total of 124 Young Scientists:

AUSTRALIA

Dr. Jean-Michel Le Floch
Dr. Maxim, A. Voronkov

AUSTRIA

Dr. Nicolai Czik

BELARUS

Dr. Pavel Siamashka

BELGIUM

Mr. Jürgen De Zaeytjij

BRAZIL

Ms. Glaucia C. Balvedi

CANADA

Mrs. Robyn Fiori
Mr. Colin Gilmore
Mr. Shulabh Gupta
Mr. Amir Hajiaboli
Mr. Symon Podilchak
Dr. Ning Yang

CHINA

Mr. Bin Chen
Ms. Jinghua Li

Ms. Dan Shi
Dr. Wei Wang
Ms. Yan Wang

COTE D'IVOIRE

Mr. Niangoran Mene

CROATIA

Mr. Sinisa Skokic
Mr. Michal Cifra
Mr. Daniel Kouba
Mr. Frantisek Nemecek

EGYPT

Ms. Amina El-Zein
Dr. Mohamed Eldosoky

FRANCE

Mrs. Emmanuelle Conil
Ms. Rym Feliachi
Dr. Geraldine Garcia
Ms. Souhir Gdoura
Mr. Anthony Ghiotto
Mr. Boubacar Kante
Mr. Adel Metref

GERMANY

Ms. Sandra Knoerzer
Mr. Qiang Li
Mr. Tobias Renk
Mr. Holger Thye
Mrs. Yvonne Weitsch
Mr. Karl Will

INDIA

Mr. Gijo Augustin
Mr. Mukul Das
Dr. Amar Kakad
Ms. Harsupreet Kaur
Dr. Karanam Kishore Kumar
Mr. Vinod Kumar
Dr. Abhijit Mitra
Mr. Joseph Ojo
Dr. Suman Sharma
Mr. Yatendra Singh
Mr. Tulasi Ram Sudarsanam

IRAN

Mr. Mohammad Khorrami

ISRAEL

Mr. Emil Winebrand

ITALY

Dr. Ilaria Catapano
Dr. Giancarlo Cerretto
Dr. Flavia Grassi
Dr. Caterina Merla
Dr. Simone Paulotto

JAPAN

Dr. Yuki Ashihara
Dr. Hidekatsu Jin
Dr. Takeshi Morimoto
Dr. Tomoaki Nagaoka
Dr. Kotaro Niinuma
Mr. Kensuke Sasaki
Mr. Sachiko Yamaguchi-Sekino
Mr. Jianping Zheng

NETHERLANDS

Ms. Anne Roc'h
Dr. Shanmugha Sundaram
Mr. Ousmane Sy

NEW ZEALAND

Mr. Rory Gamble

NORWAY

Dr. Rico Behlke

PAKISTAN

Ms. Madeeha Ashfaq

PERU

Mr. Jesus Dalmau
Mr. Henry Pinedo

POLAND

Dr. Adam Lamecki

RUSSIAN FEDERATION

Mr. Alexander Laktyunkin
Dr. Dmitry Mansfeld
Mr. Artyom Nickishov

Ms. Maria Sergeeva
Mr. Timopheyy Shevgunov
Dr. Elena, Skorodumova
Mr. Yuri Yasukevich

SINGAPORE

Dr. Chengwei Qiu

SOUTH AFRICA

Ms. Sherry Bremner
Mr. John Bosco Habarulema
Mr. Chrispin Mulangu
Mr. Patrick Sibanda

SPAIN

Mr. Yuri Alvarez Lopez
Ms. Aránzazu Sanchis Otero

SWEDEN

Mr. Christian Sohl
Dr. Sarah Loughran
Mr. Felix Vega

TAIWAN

Dr. Chien-hung (Charles) Lin

TURKEY

Dr. Cumali Sabah
Mr. Celal Alp Tunc

UKRAINE

Mr. Volodymyr Byelobrov
Mr. Yuriy Cherniak

UNITED KINGDOM

Dr. Chan See
Mr. Peiqing Xia
Dr. Dawei Zhou

UNITED STATES

Dr. Serhat Altunc
Dr. Hakan Bagci
Prof. Reyhan Baktur
Dr. William Barott
Prof. Nader Behdad
Dr. Stanley Briczinski
Dr. Chen Chen
Dr. Timothy Chevalier
Dr. Chia-Chin Chong
Dr. Vincent Fish
Prof. Dongning Guo
Dr. Songming Hou
Prof. Gregory H Huff
Dr. Ningyu Liu
Prof. Vitaliy Lomakin
Dr. Hans-Peter Marshall
Prof. Shayan Mookherjea
Dr. Robert Moore
Dr. Michael Nicolls
Dr. Olga Pechony
Dr. Bogdan Popa
Dr. Anup Prasad
Dr. Shing Yang
Dr. Heng Yang
Dr. Caglar Yardim

Chair: Professor Andy Molisch
Vice-Chair: Dr. Takashi Ohira

1. Welcome to URSI General Assembly in Chicago

The commission held open business meetings on 11th and 13th, August 2008. The following persons were present at least at one meeting, but mostly at both: Takashi Ohira (Chair); Kenji Itoh (Japan); Sana Salous (UK); Robert Bultitude (Canada); Marek Amanowicz (Poland); Jacques Palicot (France); Alain Sibille (France); Maurice Bellanger (France); Andrew Parfitt (Australia). At the opening of the first business meeting, the Chair welcomed everyone to the meeting and attendees introduced themselves.

2. Election of the next Vice-Chair

Four candidates, Marco Luise (Italy), Robert J.C. Bultitude (Canada), Palicot Jacques (France), and Igor V. Zavislyak (Ukraine), for the next Vice-Chair were nominated. Marco Luise was elected as a result of 14 points against runner up of 12 points.

3. Commission Editor for the new Radio Science Bulletin

Although Marco Luise, new vice chair, did not attend the meetings, he later indicated his willingness to serve as Commission Editor for RSB.

4. Review of the Last Triennium

The chair reported the activity of Commission C in this triennium as follows:

4.1 International Events Sponsored by URSI/URSI-C

- (i) General Assembly (URSI-GA2008)
- (ii) International Symposium on Signals Systems and Electronics (ISSSE2007)
- (iii) International Symposium on Radio Systems and Space Plasma (ISRSSP2007)

4.2 Website: <http://www.ursi.org/C/Index.htm>

4.3 Radio Science Bulletin (RSB)

Associate Editor: Takashi Ohira

The following two papers were published.

- [1] T. Kaizer et al, "Ultra-wideband wireless systems: A broad overview," RSB320, pp.25-40, March 2007.
- [2] E. Taillefer and J. Cheng, "Reactance-domain signal

processing for adaptive beamforming and direction-of-arrival estimation: An overview," RSB323, pp.14-25, Dec. 2007.

4.4 The Terms of Reference: "Radio-Communication Systems and Signal Processing"

The Commission promotes Research and Development in:

- a Radio-Communication and Telecommunication Systems;
- b Spectrum and Medium Utilization;
- c Information Theory, Coding, Modulation and Detection;
- d Signal and Image Processing in the area of radio science.

The design of effective radio-communication systems must include scientific, engineering and economic considerations. This Commission emphasizes research into the scientific aspects, and provides enabling technologies to other areas of radio science.

5. Role of National Representatives of "C"

Further enhancement of the national and international activity of Commission C should strongly be prompted for the next triennium. While National Representatives are desired to have close contact with Commission C, Commission C also is encouraged to try to cooperate with radio scientists in each country in parallel to National Representatives

6. Plan for the Next Triennium

6.1 Meetings and Symposia

- (i) General Assembly (URSI-GA2011)
August 2011, Venue: Istanbul, Turkey
- (ii) International Symposium on Signals Systems and Electronics (ISSSE2010)
Sponsors: Commissions C and D
Organizer candidate: Prof Wei Hong, China South East Univ.
- (iii) Asia-Pacific Radio Science Conference (APRASC2009)
Local organizer: Prof Toshimi Okada, University of Toyama Prefecture

6.2 Website: <http://www.ursi.org/C/Index.htm>

6.3 Radio Science Bulletin (RSB)

The commission continues to contribute to RSB.

Marco Luise, Associate Editor, will call for papers.

6.4 Development of New National Members

Through our activities, the commission is willing to recruit new national members.

7. National Representatives Roster

Following is the national representatives of the commission. If there is a change for next triennial, it should be contacted to Takashi Ohira.

ARGENTINA:	Prof. A. QUIJANO
AUSTRALIA:	Prof. A.J. PARFITT
AUSTRIA:	Prof. S.J. BAUER
BELGIUM:	Prof. L. VANDENDORPE
BRAZIL:	Prof. H. WALDMAN
BULGARIA:	Prof. B.B. SHISHKOV
CANADA:	Mr. C. DESPINS
CHILE:	Dr. R. FEICK
CHINA (CIE):	Dr. Zhi-Hua WANG
CZECH:	Prof. D. BIOLEK
DENMARK:	Dr. K.J. LARSEN
EGYPT:	Prof. S.E. ELKHAMY
FINLAND:	Mr. J. AURINSALO
FRANCE:	Dr J. PALICOT
GERMANY:	Dr. W. MATHIS
GREECE:	Prof. N. KALOUPSIDIS
HUNGARY:	Dr. L. NAGY
INDIA:	Dr. S.K. KOUL
IRELAND:	Dr. L. DOYLE
ISRAEL:	Dr. S. LITSYN
JAPAN:	Prof. S. KOMAKI
NETHERLANDS:	Dr. F.M.J. WILLEMS

NEW ZEALAND:	Dr. P.T. GOUGH
NORWAY:	Prof. B. FORSSELL
PERU:	Dr. M. F. SARANGO
POLAND:	Prof. M. PIEKARSKI
PORTUGAL:	Prof. J.N. LEITAO
RUSSIA:	Dr. A.B. SHMELEV
SLOVAKIA:	Prof. P. FARKAS
SOUTH AFRICA:	Dr. D.D. MASHAO
SPAIN:	Prof. M. S. PEREZ
SWEDEN:	Dr. E. ENGLUND
SWITZERLAND:	Prof. M. RUBINSTEIN
TAIWAN:	Dr. Y-K TU
TURKEY:	Dr. E. PANAYIRCI
UKRAINE:	Prof. V.V. DANILOV
UK:	Prof. S. SALOUS
USA:	Dr. D. PALMER

8. Wrap Up

- (1) Joint sessions will be organized in next GA
- (2) Ideas and topics will be collected to chair
- (3) Students are important for promote our activities.
- (4) We will make advertisement on website
- (5) Special commission C student award should be considered.
- (6) Make invited student papers on RSB
- (7) Prepare specific call for papers

BUSINESS TRANACTED BY COMMISSION D

Chair: Dr. Frédérique de Fornel
Vice Chair: Franz X. Kärtner

Commission D Business meetings were held by Dr. Frédérique de Fornel (Chair) on the following two days:
Meeting 1: Monday, August 11th, 17:20-18:40 @
Meeting 2: Wednesday, August 13th, 17:20-18:20

The following issues were discussed and decided upon.

1. Triennial Activity for 2005 – 2008

Pr. Frédérique de Fornel reported on:

1. Commission D has supported several new areas of research related to the Nanosciences and thus, a few issues have emerged. The URSI community in this area is still too dispersed. Commission D needs a concerted effort to have a common action plan together with the other commissions and scientific organizations active in this area.
2. The emergence of Nanotechnology in the domain of RFID has changed sensor technology. Increasingly collaboration with other commissions, active in this area becomes important.

3. Microwave and millimeter wave imaging is a research area in full development.

The following conferences were supported by Commission D during the triennium 2005-2008:

1. APMC 2006 Asia-Pacific Microwave conference , Yokohama, Japan, 12-15 December 2006.
2. Telecom& JFMMA, Fes, Morocco, 14-16 March 2007.
3. Zurich 2007, München, Germany, 24-28 September 2007
4. Metamarerial's 2007, The first International Congress on Advanced Electromagnetic Materials for Microwaves and Optics, Rome, Italia, 22-24 October 2007.
5. ISSSE 2007, Montreal, Canada, 30 July- 2 August 2007.
6. EMC 2009 VIII International Symposium and Exhibition on Electromagnetic Compatibility and Electromagnetic Ecology, St Petersburg, Russia, June 2009

2. New Chair and Vice Chair for 2008-2011

Election of the new Vice-Chair

Two candidates were presented :

1. Smail Tedjini, Professor
Department of Electrical Engineering
Grenoble-inp/lcis
Grenoble, France

2. Josef Lazar, PhD
Institute of Scientific Instruments
Academy of Sciences of the Czech Republic
Brno, Czech Republic

Voting was held for the incoming Commission D Vice-Chair 2008 – 20011. The successful candidate was: Smail Tedjini

3. Appointment of Commission D Editor for Review of Radio Science

URSI Publication: Commission D Editor for RSB will be, Prof. S. Tedjini (incoming Vice-Chair)

4. Scientific Program of Next General Assembly

The tentative topics of interest to Commission D for the General Assembly 2011 are:

- RFID Technology and Applications
- Signal Processing Antennas, jointly with Commissions B and C
- Modeling of High Frequency Devices and Circuits
- Electronic Analog to Digital Conversion and Mixed Signal Systems, jointly with Commission C
- Photonic Analog to Digital Conversion
- Microwave Optical Links
- Low Noise Microwave Generation
- Optical Frequency Metrology jointly with Commission A
- Optical Devices and Guided Waves
- Plasmonics
- Metamaterials
- Terahertz technology
- MEMS and NEMS Components
- Micro- and Nanophotonics
- Numerical Methods and Modeling in Integrated Optics
- Hyperspectral Sensing and LIDAR

BUSINESS TRANSACTED BY COMMISSION E

Chair: Flavio Canavero (Italy)
Vice Chair: Christos Christopoulos (UK)

1) Terms of reference

After some discussion, Commission E voted the following amended version of ToR.

Commission E - ELECTROMAGNETIC ENVIRONMENT AND INTERFERENCE.

The Commission promotes research and development in:

- (a) Terrestrial and planetary noise of natural origin, seismic associated electromagnetic fields;
- (b) Man-made electromagnetic environment;
- (c) The composite noise environment;
- (d) The effects of noise on system performance;
- (e) The effects of natural and intentional emissions on equipment performance;
- (f) The scientific basis of noise and interference control, electromagnetic compatibility;
- (g) Spectrum management.

2) Working Groups

The Commission E activities are based on the work conducted by the working groups (WG). After some

discussion, Commission E voted the following amended list of WG.

2.1 Working Groups 2008-2011

- E.1. Terrestrial and Planetary Electromagnetic Noise Environment
Co-Chairs : M. Hayakawa (Japan), A.P. Nickolaenko (Ukraine) and C. Price (Israel), K. Hattori (Japan);
- E.2. Intentional Electromagnetic Interference
Co-Chairs : W. Radasky (USA) and M. Bäckström (Sweden);
- E.3. High Power Electromagnetics
Co-Chairs : C.E. Baum (USA) and R.L. Gardner (USA);
- E.4. Lightning Discharges and Related Phenomena
Chair : Z. Kawasaki (Japan);
- E.5. Interaction with, and Protection of, Complex Electronic Systems
Co-Chairs : F. Sabath (Germany) and J-P. Parmentier (France);
- E.6. Spectrum Management
Chair : T. Tjelta (Norway);
- E.7. Geo-Electromagnetic Disturbances and Their Effects on Technological Systems
Chair : A. Viljanen (Finland);
- E.8. Electromagnetic Compatibility in Wire and Wireless Communication Systems
Co-Chairs : J. Gavan (Israel) and A. Zeddami (France);

Also, Commission E designated its representatives to WG jointly operated with other Commissions as follows:

2.2 Joint Working Groups

- Inter-commission working group on Solar Power Satellites
Co-Chair for Commission E: Zen Kawasaki (Japan), Jacques Gavan (Israel)
- EGH. Seismo Electromagnetics (Lithosphere-Atmosphere-Ionosphere Coupling)
Co-Chair for Commission E : M. Hayakawa (Japan)

3) Sponsorship of Conferences

Commission E sponsors on average twelve meetings in the period between general assemblies. At the business meetings it was decided that a more proactive approach should be adopted focussing on the sponsorship of at least one major conference in Europe, the Americas and Asia. For these targeted meetings the intention is to organise and lead a session under the URSI label. The Commission will continue to respond positively to requests to sponsor other meetings relevant to its terms of reference. A provisional list of

meetings to be sponsored in the next three-year period is given below. This list will be continuously updated and will appear in the Commission's web page:

- International Conference on Electromagnetics in Advanced Applications (ICEAA09), Torino, Italy, Sept 14-18, 2009.
- EMC Europe, Wroclaw, Poland, 13-17 Sept. 2010.
- EMC Europe Workshop "Materials in EMC Applications", Athens, Greece, 11-12 June 2009.
- Asia-Pacific EMC Week, Beijing China, 12-16 Apr 2010.

National Representatives are invited to inform the Chair well in advance of meetings suitable for sponsorship in order to be able to plan a budget for future years.

4) Vice Chair Election

Prof Alexander P J van Deuren (Technical University of Eindhoven, Netherlands) was elected as Vice-Chair. He will also serve as the Commission E Editor of the Radio Science Bulletin.

If you wish to receive the Radio Science Bulletin in the next URSI triennium 2009-2011 please read this

For the next triennium individuals will get the option to receive the RSB electronically (this will be done by sending an e-mail with a link to the latest issue) or to receive a paper copy. The first option costs 40 Euro and the second option 100 Euro. For more details see the application form on the back cover of this issue.

Everyone who attended the last URSI GA in Chicago, IL, USA (August 2008) had 40 Euro included in the registration fee (and will receive an electronic version of the RSB downloadable from the URSI web site from March 2009 onwards) except for those who checked a box for a second type of registration fee that costs 60 Euro more. They will still receive a hard copy of the Bulletin.

EMTS 2010

**International Symposium
on Electromagnetic Theory**



Commission B

**Berlin, Germany
August 16 – 19, 2010**

www.emts2010.de

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Estrel Conference Center

Sonnenallee 225
D-12057 Berlin
www.estrel.de

Professional Conference Organizer:
Copernicus Gesellschaft mbH
www.copernicus.org

Conference Chair:
Karl J. Langenberg
Universität Kassel
D-34109 Kassel, Germany
Phone +49 561 804 6368
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Local Organizing Committee Chair:
Ludger Klinkenbusch
Christian-Albrecht-Universität zu Kiel
D-24143 Kiel, Germany
Phone +49 431 880 6252
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CONFERENCE REPORTS

INTERNATIONAL CONFERENCE ON ELECTROMAGNETICS IN ADVANCED APPLICATIONS (ICEAA '07)

Torino, Italy, 17 - 21 September 2007

The International Conference on Electromagnetics in Advanced Applications (ICEAA) has been held every two years in Torino, Italy, since 1989. The tenth edition, ICEAA'07, held September 17-21, 2007, attracted over three hundred participants from thirty-six countries. In decreasing order of number of papers presented, the ten top countries were the USA, Italy, Germany, France, The Netherlands, the UK, Israel, Iran, Japan, and Turkey. The conference received about five hundred submissions, which were subjected to a rigorous review process, resulting in a rejection rate exceeding forty percent. The proceedings containing the two hundred and seventy-five accepted papers were published as a CD-ROM and, for the first time in the history of the conference, were posted on IEEE Xplore (IEEE Catalog Number: 07EX1603C; ISBN: 1-4244-0767-2).

Organized by the Politecnico di Torino and the Italian National Research Council (IEIIT-CNR), ICEAA has the IEEE Antennas and Propagation Society as its principal technical cosponsor, other technical cosponsors being URSI, and the ED and MTT Societies of the IEEE. Financial support was provided by the Istituto Superiore Mario Boella and by the Torino Wireless Foundation, both headed by Prof. Rodolfo Zich, past Rector of the Politecnico, who was the founder of ICEAA back in 1989. The organization of ICEAA'07 was articulated around an Organizing Committee chaired by Prof. Roberto D. Graglia of the Politecnico di Torino, and a Scientific Committee chaired by myself (Prof. P. L. E. Uslenghi of the University of Illinois at Chicago).

The scientific program of ICEAA'07 consisted of thirty-four technical sessions, averaging eight papers each. Seventeen of these sessions were special sessions on the following topics (organizers in parentheses):

- "Radiation and Scattering of Waves: A Tribute to Prof. L. B. Felsen" (V. Galdi and E. Heyman)
- "Wireless Communications: Antennas, Propagation, and Component Technologies" (D. Erricolo and M. F. Iskander)
- "Evolutionary Numerical Techniques" (Y. Rahmat-Samii and R. E. Zich)
- "Numerical Methods for Solving Maxwell's Equations in the Frequency Domain" (A. Buffa and J.-F. Lee)
- "Advances in Time Domain CEM" (E. Michielssen)
- "Adaptive Waveform Technology for Futuristic Communications, Radar and Navigation Systems" (D. Erricolo and C. M. Wicks)
- "Novel Techniques Including Parallelization Schemes for the Solution of Electromagnetic Radiation and Scattering Problems" (R. Mittra)
- "Post-CMOS Logic: All-Magnetic Information-Processing Systems" (V. Metlushko)
- "Analytical and Analytical-Numerical Methods in Electromagnetics" (P. D. Smith)
- "Diffraction Problems for the Detection of Man-Made Objects Hidden in Complex Environments" (R. D. Graglia)
- "Intentional EMI" (C. E. Baum)
- "Advances and Applications of the Finite Element Method" (L. C. Kempel)
- "Dielectric Resonator Antennas" (S. A. Long)
- "Issues and Inherent Limitations in UWB System Design" (W. Wiesbeck)
- "Computational Electromagnetics" (R. D. Graglia and D. R. Wilton)
- "Advances in Bioelectromagnetics: Safety Assessment and Medical Applications" (G. Lazzi)
- "Reflectarray Antennas" (A. Freni, P. Pirinoli, and R. E. Zich).

The seventeen ordinary sessions covered a wide variety of topics: MIMO antenna systems; inverse scattering and remote sensing; frequency-selective surfaces; EMC/EMI/EMP; radar cross section and asymptotic techniques; electromagnetic properties of materials; radar imaging; wireless communications; microwave antennas and arrays;

printed and conformal antennas; electromagnetic theory and nanotechnology applications; active and smart antennas; electromagnetic measurements; optoelectronics and electromagnetic devices; integral-equation methods; finite methods; and electromagnetic applications to biomedicine.

Two very interesting full-day short courses were offered. The first one, devoted to “Sommerfeld-Malyuzhinets Technique in Modern Diffraction Theory,” was taught by Prof. Mikhail A. Lyalinov of St. Petersburg University, Russia, with the support of a NATO Science for Peace project involving four countries: Italy (R. D. Graglia), Israel (E. Heyman, A. Boag), Russia (V. M. Babich, M. A. Lyalinov), and the United States (P. L. E. Uslenghi). The second short course, on “Multiple Antenna Systems – From SISO to MIMO,” was hands-on and taught by Prof. Werner Wiesbeck of Karlsruhe University, Germany.

The opening ceremony was attended by a number of dignitaries. It paid special tribute to the memory of Leo Felsen, who had actively participated in all previous editions of ICEAA, was a member of its Scientific Committee, and wrote a poem for each ICEAA meeting that later appeared in the *IEEE Antennas and Propagation Magazine*. The technical sessions, held in a modern air-conditioned conference center, lasted four days. There were never more than four in parallel, allowing ample time for spirited discussions among participants. The catered and long-lasting luncheons, included in the registration fee and abundantly complemented by excellent wines and delicious

desserts, provided an ideal setting for networking among participants, and left everyone in a sunny mood for the afternoon sessions.

The social high point of the conference was the official reception and gala dinner, held at a castle (Castello di San Giorgio) in the pre-Alps near Torino. (On a personal note: this castle was built centuries ago by one of my ancestors, but unfortunately not a single penny of those riches drifted down to my generation.) The outdoor reception was followed by a gala dinner inside the castle. Reception and dinner were included in the registration fee.

Two other evening social events were conducted during the conference: a wine-tasting party was held at the oldest restaurant in Torino, the Ristorante del Cambio, which was celebrating its 250th year of existence, and a chocolate-tasting party (Torino’s renowned chocolate products are exported all over the world). Both events were thoroughly enjoyed by all who attended them.

According to the opinions manifested by participants, ICEAA was the best scientific conference they ever attended, in terms of the quality of its technical and social programs, and of the beauty of its venue and surrounding areas. The ICEAA Organizing Committee, and in particular its Chair, Roberto Graglia, should be complimented for setting up such a precious event. The next ICEAA Conference will be held in Torino on September 14-18, 2009; detailed information may be found on the conference Web site: <http://www.iceaa.net>.

Piergiorgio L. E. (George) Uslenghi
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REPORT ON THE 37TH SCIENTIFIC ASSEMBLY OF THE COMMITTEE ON SPACE RESEARCH (COSPAR 2008)

Montreal, Canada, 13 - 20 July 2008

The 37th Scientific Assembly of the Committee on Space Research (COSPAR), which was “50 Anniversary Assembly”, was held in Montreal from 13-20 July 2008. The conference venue was the Palais des Congress de Montreal. The Scientific Program was chaired by Professor Jean-Pierre St.-Maurice from the University of Saskatchewan, Saskatoon, Canada while Dr Gordon G. Shepherd, the Canadian National Representative to COSPAR, was the Local Executive Committee Chair.

The organized Scientific Events covered the topics related to eight Scientific Commissions and nine Panels of present COSPAR Scientific Structure. At the same time, six COSPAR Interdisciplinary Lectures, six Lunch Time Lectures, as well as six spatial 50th Anniversary Lectures were given. Two COSPAR Associated Events were organized on the occasion of this Scientific Assembly; namely, as it is a custom, the Academy Day (The International

Academy of Astronautics prepared Program) and the Expert Meeting on Global Navigation Satellite System (GNSS) and Services organized by the International Committee on Global Navigation Satellite System (ICG). Traditionally, the COSPAR Scientific Commission and Panel Open Business Meeting for challenging programmatic purpose were held.

COSPAR is now on the track of implementation of challenges formulated as a result of the reflection with respect to its 50th Anniversary and future. The 37th COSPAR Assembly in Montreal was the occasion to review the results of this effort and to look for next steps. COSPAR in the new political international environment would not like to restrict its activity to managing only the space community Scientific Assembly and being “a platform of mutual understanding”. COSPAR, with its virtual assets-intellectual

capital of international space community organised as Associates, can much more effectively control the future of science. The COSPAR Membership in 2008 read as: National Scientific Institutions - 44, International Scientific Unions - 13, Associated Supporters- 5, and individual Associates - 5755.

The organisational formula and structure of COSPAR Assembly still evolve to meet the expectations and produce added value for Participants, i.e.

- As was mentioned above COSPAR offers its Meeting floor for Associated Events.
- **COSPAR Scientific Advisory Committee (CSAC)** was established to evaluate the proposed activity in scientific and international context, such as:
 - the establishment of new Panel on Exploration
 - COSPAR's joining the Group on Earth Observation as Participating Organization and
 - co-chairing the GEO Science and Technology Committee, as COSPAR Commission A is able to provide real science advice and a vision of why and how to observe. Scientific Commission A has participated very actively in recent meetings of the GEO-STC, and COSPAR will host the next meeting.
 - recommendation that COSPAR has to participate more actively in the environmental modeling work, currently underway at the International Standards Organization, in order to ensure that the final product of this exercise will incorporate the best science.
 - encouraging young space scientists on outstanding paper Awards
 - pinpoint strategic interests of COSPAR.
- **Advanced in Space Research** COSPAR flagship journal has become the regular scientific journal registered in SCI since 2008, with the Impact Factor rise up to 0.7 in the recent years.
- **COSPAR Capacity Building** Workshops were defined as the strategic track of COSPAR activity. They are organized according to the request of the scientists of the country interested in – it is them who have to propose the subject and venue. In the last two years, four Workshops were organised, which gives the total number of nine workshops prepared by COSPAR up till now.
- **The COSPAR Capacity Building Fellowship** Programme was open to participants of Capacity Building workshop to provide for 2-4 – week visit for carrying out joint research in the group of famous laboratories collaborating with COSPAR in this subject.
- **COSPAR 2008 in Montreal was the first test-bed for implementation of the International Space Education Board Program for COSPAR.** The Student Program included meetings with famous individuals of space community organized by cooperating Agencies (NASA, ESA, JAXA, CSN), as well as presentation of posters and active participation in the sessions.
- COSPAR'S INFORMATION BULLETIN – **SPACE RESEARCH TODAY** is published regularly by ELSEVIER and presents the current issues of space research community.

The Programs of Scientific Events of 37th COSPAR Congress related to Scientific Commissions C- “Upper Atmospheres of the Earth and Planets Including Reference Atmospheres”, D- “Space Plasmas in Solar System, Including Planetary Magnetospheres” and Panel on Space Weather seem to be the most interesting to URSI Community as their subjects relate to physical layer of radio systems and science involved.

The 750 papers (244 selected to be posters) presented in the frame of Commission C focused on results of numerous satellite programs like Champ, Grace and COSMIC constellation and ground based incoherent scatter radars, the SuperDARN radars and a global network of GPS receivers. URSI/COSPAR Task Group on International Reference Ionosphere (IRI) as well as COSPAR/URSI Task Group on Reference Atmospheres, including ISO WG4 organized their meeting and session. Thus, questions related to the development of reference atmospheres including the Earth (CIRA) and ISO standards related to Space Environment were well presented. What should be stressed in this context is The Resolution recommended by Commission C regarding the adaption of New COSPAR International Reference Atmosphere (CIRA08). COSPAR notes this Resolution and invited URSI to review and to approve and adopt CIRA08 jointly with COSPAR. The Council of COSPAR notes also, with respect to another Resolution of Commission C, that “As a major facility used by a number of scientific disciplines in the US, the Arecibo Observatory is an important component of the chain of radio telescopes in the international VLBI network,...” and “requests the appropriate agencies to take it into account in decisions on the future of the observatory“

There were 605 abstracts submitted to sessions of Commission D (219 of them were presented as posters). The subjects covered included space plasma in solar system, the transition events from Sun to the Heliosphere including multispacecraft imaging and in situ observation, multiscale magnetospheric processes-theory, simulation and multipoint observation; coupled large and small scale processes in space and solar physics. The correlated multipoint observations and multiscale processes were in the focus of many presentations. Traditionally, Sub-commission C/D on Theory and Observations of Active Experiments organised its 1,5-day-sessions mainly focused on the HF radio waves interaction with ionospheric plasma.

The Panel on Space Weather has organized 2-day-session preparing for the Next Solar Maximum. The Session received 75 accepted abstracts, 43 of which were poster presentations. The presented papers cover all space weather issues, including Sun to Earth simulation selected space weather events, state of art in space weather observational activities, analysis and comparison of magnetic forecast techniques. The reports on activity of ISES Regional Warning Centres were presented to session participants.

The Associated Event-ICG Expert Meeting on Global Navigation Satellite Systems and Services organized by the United Nations for Outer Space Affairs as four-sessions-meeting gathered participants involved in GNSS applications. The first session was devoted to the presentation of ICG (International Committee on Global Navigation Satellite System) Working Group Overviews, the second one to the Overview of Global Navigation Satellite Systems, while the third was related to Compatibility

and Interoperability at the User Equipment level. The last session facilitated a discussion between providers and users/producers on the subject of compatibility among the navigation satellite systems.

In summary it can be concluded that 2500 abstracts submitted to the 37th COSPAR Assembly paved the way to the future of space science.

COSPAR SESSION C41 UPDATING IONOSPHERIC MODELS WITH GROUND AND SPACE DATA

Montreal, Canada, 13 - 20 July 2008

A 2-day session on the Updating of Ionospheric Models with Ground and Space Data was held during the 2008 Scientific Assembly of the Committee on Space Research (COSPAR) in Montreal, Canada. The session was organized by the joint COSPAR-URSI Working Group on the International Reference Ionosphere (IRI) and was divided into oral and poster sessions with the oral sub-sessions being focused on 'Updating Ionospheric Models', 'TEC Data and Models', 'F-peak Mapping', 'Topside Modeling', 'Storm Modeling', 'New Inputs for IRI', and 'Solar Cycle Effects'. A business meeting of the IRI Working Group was also convened during the COSPAR meeting. We briefly report on the papers presented and the resulting decisions for the next update of the IRI model.

what is found for the bottomside scale height; the values for H_m derived from topside and bottomside side profiles differ by a factor between 1 and 3 depending on season and time of day. Using COSMIC occultation data Liu et al. (IGG, Beijing, China) study scale heights at 400km altitude and find a noontime maximum most notably near the magnetic equator. They also note the presence of a significant longitudinal structure in the equatorial sector. Ratovsky et al. (ISZF, Irkutsk, Russia) studied scale heights derived from Irkutsk incoherent scatter radar (ISR) measurements and also see significant diurnal structure similar to the Millstone Hill and Arecibo ISRs. The new IRI-2007-Corrected option reproduces the daytime variation but overestimates nighttime scale heights. They also observed significant differences to the F-peak scale heights deduced from digisonde bottomside measurements.

Electron Density Profile

The IRI electron density profile is normalized to the F-peak density and height and the profile above and below is determined by several characteristic bottomside and topside parameters. A major improvement of the representation of the IRI bottomside profile will be achieved with the introduction of the analytical model of Altadill et al. (Ebro Observatory, Spain). Their model is based on ionosonde data and shows a more accurate and continuous description of annual and seasonal variations than the current IRI model which uses step-wise interpolation and only a limited set of ionosonde inputs.

Topside modeling is benefiting from the large volume of new topside profiles that has become available through the Alouette/ISIS data restoration effort at GSFC (Benson, Bilitza) and also from the Vary-Chap approach developed by Reinisch and Huang (U Mass Lowell, USA). This approach uses a height-varying scale height function that describes the transition from the O^+ dominated F-region to the H^+ & He^+ dominated upper topside. Important parameters in this approach are the starting scale height at F-layer heights (H_m) and the transition height h_t . Reinisch et al. (UML, USA) deduce H_m from ISIS-2 topside sounder profiles and noted only small diurnal variations contrary to

Mapping the F-peak Density and Height

A special IRI task force team is working towards new models for the F-peak density and height. The models currently used in IRI and other models are more than two decades old, the most widely used model, the CCIR model, dates in fact back to the sixties. A new modeling effort is long overdue and can take advantage of a much increased volume of ionosonde data, although still heavily biased towards the Northern mid-latitudes. The team has made an effort to locate and encourage all data providers to participate in the mapping effort. As base model the group will use the Neural Network model developed by McKinnell (HMO, Hermanus, South Africa) and Oyeyemi (University of Lagos, Nigeria). Newest results of this model with special focus on the equatorial ionosphere and the Equatorial Ionization Anomaly (EIA) were presented by McKinnell and Oyeyemi. The mapping group intends to work closely with the Radio-propagation working group of the International Union of Telecommunications (ITU) that is supporting the worldwide radio and telecommunication community and agencies with advice on ionospheric predictions.

New Inputs for IRI

Of special interest is a better description of the day-to-day ionospheric variability. This item is very high on the priority list of IRI members and users. A first-order model based on a large volume of ionosonde data was developed by Araujo-Pradere et al. (U Colorado, Boulder, USA) describing the variability during quiet-time as well as storm-time conditions. With the inclusion of satellite data it is planned to extend his model to the topside and widen the solar activity range. Zhang and Holt (MIT, USA) determined the variability for the whole profile at mid-latitudes based on the long record of ISR measurements from Millstone Hill and St. Santin and developed a model that describes the variability at different altitudes, seasons, and solar activities. The STORM model of Fuller-Rowell et al. (U Colorado, Boulder, USA) is used for the description of storm effects on the F2 peak density. Results of a comparative analysis of European ionosonde data show that the STORM model captures quite effectively the negative phases of the summer ionospheric storms, while electron density enhancement during winter storms and the changeover between the different storm phases is reproduced with lower accuracy (Buresova et al., IAP, Prague, Czech Republic).

New efforts are underway to improve the description of the auroral E-region ionosphere. Data from the TIMED GUVI (Zhang et al., JHU/APL, USA) and SABER (Mertens et al., NASA/LRC, USA) instruments are used to describe auroral boundaries, their changes with magnetic activity, and the influence of auroral protons and magnetic storms on the E peak density and height. Comparisons during a TIMED pass over Sondrestrom showed that the SABER-deduced densities agree well with the ISR measurements. An new and essentially continuous data source for this region and altitude range was presented by Lattek, Singer et al. (LIAP, K hlungsborn, Germany) noting that electron density profiles in the altitude range 55 km to 90 km can be obtained with the MF Doppler radar near Andenes, Norway.

A systematic study of the Equatorial Ionization Anomaly (EIA) with CHAMP data at 440 km altitude revealed a strong intensification with increasing solar activity in the post-sunset sector, but only moderate variations during noontime. In addition, it was found that the crest regions are generally more sensitive to solar activity than the equatorial trough, and that the crest's variation is seasonally dependent. IRI reproduces the noontime variations very well for all solar activity levels, but underestimates the EIA strength in the post sunset sector (Stolle et al., GFZ, Potsdam, Germany). Watanabe et al. (U. Hokkaido, Sapporo, Japan) discussed the longitudinal 4-peak structure as seen with CHAMP data that may be the result of diurnal atmospheric tides driven by weather in the tropics. IRI shows longitudinal maxima but not all 4 peaks are well developed.

An adaptive ray-tracing model was discussed by Al-Ubaidi (Baghdad University, Baghdad, Iraq).

Comparisons and Model Evaluation

De La Beaujardiere et al. (AFRL, USA) evaluated the impact of GNSS data on data assimilation models including the PMod developed at AFRL and the GAIM developed by the University of Southern California /Jet Propulsion Lab. Their results show that both models overestimated TEC relative to the Jicamarca ISR and that the GAIM derivations of NmF2 and hmF2 can be degraded rather than improved, when COSMIC occultation data are assimilated. Other papers during the IRI sessions also noted the problems in deducing accurate peak parameters from the integral GNSS measurements. Comparisons with ionosonde data show that the techniques are getting better but still have significant error margins in areas of steep ionospheric gradients.

Comparisons with GPS-TEC maps over Taiwan indicate that IRI-2007 overestimates TEC when F10.7 is less than 150, and underestimates TEC when F10.7 is larger than 200 (Kakinami et al., NCU, Chung-Li, Taiwan). A regional ionospheric model for the Brazilian sector was developed by Souza et al. (INPE, Brazil) based on results from the Sheffield University Plasmasphere Ionosphere Model (SUPIM). The model includes the F3 layer often observed at equatorial latitudes. The model will be helpful in improving IRI at equatorial latitudes.

Plasma Temperatures

A major IRI task still pending is the inclusion of solar activity variations for the plasma temperature models. A large volume of insitu satellite measurements is being applied by Bilitza (GMU/GSFC, USA) and Truhlik (IAP, Prague, Czech Republic) towards this goal. Most difficult is the F-region altitude range during daytime where the electron temperature increases, decreases, or stays constant with increasing solar activity depending on the season, time of day and latitude. During equinox the temperature decreases at mid-latitudes but increases everywhere else. During summer mid-latitude temperatures increase while winter temperatures decrease and the temperatures at low latitude are almost constant during solstice. A first model based on these results was presented benefiting also from input from Richards (GMU, USA) Field-Line Interhemispheric Plasma (FLIP) model for times and areas where no data were available or where data were inconclusive. Significant discrepancies were, for example, found between simultaneous DMSP insitu and Millstone Hill incoherent scatter radar measurements of electron temperature (Truhlik et al., IAP, Prague, Czech Republic). At low solar activities (= low electron densities) the DMSP temperatures exceeded the ISR measurements by up to a factor of 2.

Ion Composition and Drift

Park et al. (KAIST, Dae-jeon, Korea) compared DMSP F15 measurements of O^+ and H^+ , of the low latitude nighttime topside ionosphere during the period of 2000-2004 with IRI predictions. The IRI variations with solar activity show a saturation effect at high solar activities not seen in the data and most likely induced by the correlation with electron density (IRI describes the percentage ion composition and assumes charge neutrality: total ion density = electron density). The IRI model overestimates the hydrogen ion density and underestimates the oxygen ion density and these effects are more pronounced when F10.7 is high. Combining DMSP data at 840 km with Komsat data at 600 km Min (KAIST, Daejeon, Korea) studied the seasonal and solar activity variations of O^+ , H^+ , and He^+ densities over a wider altitude range. They note that during nighttime topside H^+ densities do not show significant variations with solar activity but are strongly influenced by season, which is in contrast to the oxygen ions, which show a more pronounced variation with F10.7 than with season.

Su and Chen (NCU, Chung-Li, Taiwan) studied the solar flux effect on longitudinal/seasonal variations of ion density structures at the 600-km low-latitude ionosphere as observed by the ROCSAT-1 satellite.

Abdu et al. (INPE, Brazil) studied the effects of solar activity on the equatorial vertical ion drift with digisonde data from Sao Luis and Fortaleza pointing out discrepancies with the current IRI drift model. A similar effort by Oyekola and Oluwafemi (Covenant University, Nigeria) used ionosonde data from Ouagadougou, Burkina Faso. On average, the values of daytime and nighttime ionosonde-derived vertical drifts are smaller by about a factor of four than measurements in other equatorial regions using different experimental techniques. Both efforts note that the diurnal variation is dominated by the characteristic morning peak and evening prereversal enhancement (PRE) velocities. Seasonal and solar cycle effects are prominent near the dusk sector with an increase of PRE from solar minimum to maximum. The average equinoctial evening prereversal enhancement increases by almost a factor of three from low to high flux.

New Members, Publications, and Future Workshops

Four new members were elected to the IRI Working Group: (1) Eduardo Araujo-Pradere, of the University of Colorado in Boulder, USA is one of the authors of the STROM model now used in IRI and is very active in modeling ionospheric variability based on the long record of ionosonde measurements; (2) Elijah Oyeyemi of the University of Lagos in Lagos, Nigeria is working on the new NN model for the F-peak density; (3) Dalia Buresova of the Institute of Atmospheric Physics in Prague, Czech Republic was one of the main local organizers of the very successful 2007 IRI-COST Workshop in Prague and her scientific interest is in the ionospheric variability of the region below the F-peak; (4) Andrzej Krankowski of the University of Warmia and Mazury in Olsztyn, Poland is an expert in GPS-TEC mappings and is currently the Chair of the Ionosphere Working Group of the International GNSS Service (IGS).

Refereed papers from the IRI meetings are slated for publication in the Journal of Advances in Space Research. The latest issue was published as Number 4 of Volume 42 including papers from the IRI session during COSPAR-2006 in Beijing, China and from the 2006 IRI Workshop in Buenos Aires, Argentina. Editing work is under way for the papers from the Prague IRI Workshop. Because of the large number of contributions the papers will be distributed over two issues of Advances in Space Research.

The next IRI Workshop is now planned for the week of November 2 – 6, 2009 in Kagoshima, Japan and will be organized by Shigeto Watanabe of Hokkaido University in Sapporo, Japan. There will also be a special IRI Task Force Activity on the Real-Time IRI in Boulder (or Colorado Springs) on May 4-6, 2009; this is the week following the Space Weather Week. The meeting will be organized by Tim Fuller-Rowell and Eduardo Araujo-Pradere of the University of Colorado in Boulder, USA. The IRI team has submitted a session proposal for the 2010 COSPAR General Assembly in Bremen, Germany on the topic of the Representation of the Auroral and Polar Ionosphere in IRI.

Access to IRI is now also available through the Community Coordinated Modeling Center (CCMC) at <http://ccmc.gsfc.nasa.gov/>, and the Virtual Model Repository (VMR) is using IRI for data-model comparisons. More information about the IRI project and access to the IRI Fortran code, web interface, and related links can be found on the IRI homepage at <http://IRI.gsfc.nasa.gov/>.

URSI CONFERENCE CALENDAR

URSI cannot be held responsible for any errors contained in this list of meetings.

June 2009

EMC-2009 - VIII International Symposium and Exhibition on Electromagnetic Compatibility and Electromagnetic Ecology

St. Petersburg, Russia, 16-19 June 2009

Contact : St.Petersburg State Electrotechnical University "LETI" , 5, Prof. Popov Street, St. Petersburg, 197376, Russia, Underground Station "PETROGRADSKAYA", Phone: +7 812 234-48-40, Fax: +7 812 234-46-81, E-mail: discone@mail.wplus.net, Web: <http://www.eltech.ru/emc>

October 2008

ISAR-NCU 2008

Chung-Li, Taiwan, 6-18 October 2008

Contact: E-mail: isar2008@csrnr.ncu.edu.tw, Web: <http://isarncu.ncu.edu.tw/ISAR/index.htm>

November 2008

Microwave 2008 - International Conference on Recent Advances in Microwave Theory and Applications

Jaipur, India, 21 - 24 November 2008

Contact: Dr. Deepak Bhatnagar, Department of Physics, University of Rajasthan, Jaipur, 302004, India, Fax +91 1412 702645, E-mail: dbhatnagar_2000@rediffmail.com, Web: www.uniraj.ernet.in/~microwave

January 2009

EMC Zurich 2009

Zurich, Switzerland, 12-16 January 2009

Contact: Dr. Pascal Leuchtman, ETH Zurich, ETZ K94, CH-8092 Zurich, Switzerland, Fax +41 44-632 1647, Leuchtman@ifh.ee.ethz.ch, Web: <http://www.emc-zurich.ch>

February 2009

International Workshop on Chorus Plasma Waves

La Jolla, CA, USA, 18-20 February 2009

Contact: Bruce Tsurutani, Jet Propulsion Laboratory MS 169-506, 4800 Oak Grove Dr., Pasadena, CA 91109, USA, Fax: +1 818 354 8895, E-mail: bruce.tsurutani@jpl.nasa.gov

May 2009

MST 12 - 12th Workshop on Technical and Scientific Aspects of MST Radar

London, Ontario, Canada, 17-23 May 2009

Contact: Wayne Hocking and Toshitaka Tsuda, Co-chairs, MST workshop series, Web: <http://www.mst12.com/>

URBAN 2009 - Data fusion and Remote Sensing in Urban areas

Shanghai, China, 20-22 May 2009

Contact : Shanghai Association for Science and Technology (SAST), No.47 Nanchang Road, Shanghai 200020, China (SAST), Tel: 86-21-6358 0841-207, Fax: 86-21-6327 1590, E-mail: urban-urs2009@163.com, Web: <http://www.urban-remote-sensing-2009.org.cn>

September 2009

ICEAA'09 - International Conference on Electromagnetics in Advanced Applications

Turin, Italy, 14-18 September 2009

Contact: ICEAA 07, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, Italy, Fax: +39-011-564-5199, e-mail: gspinasanta@corep.it, Web: <http://www.iceaa.net/>

October 2009

International Conference on Radar

Bordeaux, France, 12-16 October 2009

Contact: SEE / CONGRESS DEPARTMENT, Béatrice Valdayron - Valérie Alidor - Caroline Zago - Morgane Melou, Fax: + 33 (0)1 56 90 37 08, E-mail : radar2009@see.asso.fr, Web: <http://www.radar2009.org>

April 2010

AP-EMC 2010 - Asia-Pacific EMC Symposium

Beijing, China, 12-16 April 2010

Contact: Web: <http://www.apemc2010.org>

August 2010

EMTS 2010 - International Symposium on Electromagnetic Theory (Commission B Open Symposium)

Berlin, Germany, 16-19 August 2010

Contact: EMTS 2010, Prof. Karl J. Langenberg, Universität Kassel, D-34109 Kassel, Germany, Tel. +49 561 804 6368, E-mail: info@emts2010.de, Web: <http://www.emts2010.de>

URSI cannot be held responsible for any errors contained in this list of meetings.

News from the URSI Community



NEWS FROM A MEMBER COMMITTEE

NIGERIA FIRST NATIONAL CONFERENCE ON RADIO SCIENCE FOR NATIONAL DEVELOPMENT AND SECURITY

Obafemi Awolowo University, AOU Campus, Ile-Ife, Nigeria, 3-5 December 2008

The Nigerian Union of Radio Science (NURS), an affiliate of International Union of Radio Science (URSI) and the foremost professional association for radio scientists, engineers and technologists in Nigeria, announces her first annual conference at the African Regional Centre for Space Science and Technology Education (ARCSSTEE), Obafemi Awolowo University, (OAU) Campus, Ile-Ife, Nigeria, from 3 to 5 December 2008.

The NURS initiative is to raise Nigerian research capacity, promote participation of Nigerian organizations and identify co-operation opportunities in fields of mutual interest in Universities, Industry and the Military. The goal is to increase mutual R&D potential and network relevant Nigerian stakeholders.

National Organizing Committee

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Viktor Chukwuma	victorchukwuma@yahoo.com

Themes

Thematic priorities for NURS 2008 are:

- Radio Communication as tool for economic development
- Space weather
- Radio Communication in the Tropics
- The Military and Radio Science
- Secure Environment for Citizens and Business

Exhibition and Posters

Nurs 2008 features an Exhibition, which provides the opportunity to showcase research results and applications through technology demonstrations, whether funded commercially or at national level or by States. While some space will be offered for posters, most of the Exhibition will be reserved for innovative technology demonstrations.

Demonstration stands are reserved for live technology demonstrations, but can feature early prototypes or a pre-commercial launch to a highly targeted, knowledgeable community.

Participation in the Exhibition is rewarding, as it provides a valuable opportunity to make international contacts and to build relationships with potential partners or clients from around the country.

To maximize demonstration and networking opportunities for exhibitors, coffee breaks will be held in the Exhibition area.

Presentation of Papers at the Conference

The deadline for abstract submissions ended on October 23. The conference language is English and submissions must be for technical papers and business or government or military case studies within the scope of NURS.

Papers presented at the meeting shall undergo a review process and shall be published as a special publication of the African Regional Centre for Space Science and Technology Education.

The Journal of Atmospheric and Solar-Terrestrial Physics

SPECIAL OFFER TO URSI RADIOSCIENTISTS

AIMS AND SCOPE

The *Journal of Atmospheric and Terrestrial Physics* (JASTP) first appeared in print in 1951, at the very start of what is termed the "Space Age". The first papers grappled with such novel subjects as the Earth's ionosphere and photographic studies of the aurora. Since that early, seminal work, the Journal has continuously evolved and expanded its scope in concert with - and in support of - the exciting evolution of a dynamic, rapidly growing field of scientific endeavour: the Earth and Space Sciences. At its Golden Anniversary, the now re-named *Journal of Atmospheric and Solar-Terrestrial Physics* (JASTP) continues its development as the premier international journal dedicated to the physics of the Earth's atmospheric and space environment, especially the highly varied and highly variable physical phenomena that occur in this natural laboratory and the processes that couple them. The *Journal of Atmospheric and Solar-Terrestrial Physics* is an international journal concerned with the inter-disciplinary science of the Sun-Earth connection, defined very broadly. The journal referees and publishes original research papers, using rigorous standards of review, and focusing on the following: The results of experiments and their interpretations, and results of theoretical or modelling studies; Papers dealing with remote sensing carried out from the ground or space and with in situ studies made from rockets or from satellites orbiting the Earth; and, Plans for future research, often carried out within programs of international scope. The Journal also encourages papers involving: large scale collaborations, especially those with an international perspective; rapid communications; papers dealing with novel techniques or methodologies; commissioned review papers on topical subjects; and, special issues arising from chosen scientific symposia or workshops. The journal covers the physical processes operating in the troposphere, stratosphere, mesosphere, thermosphere, ionosphere, magnetosphere, the Sun, interplanetary medium, and heliosphere. Phenomena occurring in other "spheres", solar influences on climate, and supporting laboratory measurements are also considered. The journal deals especially with the coupling between the different regions. Solar flares, coronal mass ejections, and other energetic events on the Sun create interesting and important perturbations in the near-Earth space environment. The physics of this subject, now termed "space weather", is central to the Journal of Atmospheric and Solar-Terrestrial Physics and the journal welcomes papers that lead in the direction of a predictive understanding of the coupled system. Regarding the upper atmosphere, the subjects of aeronomy, geomagnetism and geoelectricity, auroral phenomena, radio wave propagation, and plasma instabilities, are examples within the broad field of solar-terrestrial physics which emphasise the energy exchange between the solar wind, the magnetospheric and

ionospheric plasmas, and the neutral gas. In the lower atmosphere, topics covered range from mesoscale to global scale dynamics, to atmospheric electricity, lightning and its effects, and to anthropogenic changes. Helpful, novel schematic diagrams are encouraged. Short animations and ancillary data sets can also be accommodated. Prospective authors should review the *Instructions to Authors* at the back of each issue.

Complimentary Information about this journal:

<http://www.elsevier.com/locate/JASTP?>

<http://earth.elsevier.com/geophysics>

Audience:

Atmospheric physicists, geophysicists and astrophysicists.

Abstracted/indexed in:

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Curr Cont Sci Cit Ind
Curr Cont/Phys Chem & Sci
INSPEC Data
Metoro & Geostrophys Abstr
Res Alert

Editor-in-Chief:

T.L. Killeen, National Centre for Atmospheric Research, Boulder, Colorado, 80307 USA

Editorial Office:

P.O. Box 1930, 1000 BX Amsterdam, The Netherlands

Special Rate for URSI Radioscientists 2003:

Euro 149.00 (US\$ 149.00)

Subscription Information

2002: Volume 65 (18 issues)

Subscription price: Euro 2659 (US\$ 2975)

ISSN: 1364-6826

CONTENTS DIRECT:

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Information for authors



Content

The *Radio Science Bulletin* is published four times per year by the Radio Science Press on behalf of URSI, the International Union of Radio Science. The content of the *Bulletin* falls into three categories: peer-reviewed scientific papers, correspondence items (short technical notes, letters to the editor, reports on meetings, and reviews), and general and administrative information issued by the URSI Secretariat. Scientific papers may be invited (such as papers in the *Reviews of Radio Science* series, from the Commissions of URSI) or contributed. Papers may include original contributions, but should preferably also be of a sufficiently tutorial or review nature to be of interest to a wide range of radio scientists. The *Radio Science Bulletin* is indexed and abstracted by INSPEC.

Scientific papers are subjected to peer review. The content should be original and should not duplicate information or material that has been previously published (if use is made of previously published material, this must be identified to the Editor at the time of submission). Submission of a manuscript constitutes an implicit statement by the author(s) that it has not been submitted, accepted for publication, published, or copyrighted elsewhere, unless stated differently by the author(s) at time of submission. Accepted material will not be returned unless requested by the author(s) at time of submission.

Submissions

Material submitted for publication in the scientific section of the *Bulletin* should be addressed to the Editor, whereas administrative material is handled directly with the Secretariat. Submission in electronic format according to the instructions below is preferred. There are typically no page charges for contributions following the guidelines. No free reprints are provided.

Style and Format

There are no set limits on the length of papers, but they typically range from three to 15 published pages including figures. The official languages of URSI are French and English: contributions in either language are acceptable. No specific style for the manuscript is required as the final layout of the material is done by the URSI Secretariat. Manuscripts should generally be prepared in one column for printing on one side of the paper, with as little use of automatic formatting features of word processors as possible. A complete style guide for the *Reviews of Radio Science* can be downloaded from <http://www.ips.gov.au/IPSHosted/NCRS/reviews/>. The style instructions in this can be followed for all other *Bulletin* contributions, as well. The name, affiliation, address, telephone and fax numbers, and e-mail address for all authors must be included with all submissions.

All papers accepted for publication are subject to editing to provide uniformity of style and clarity of language. The publication schedule does not usually permit providing galleys to the author.

Figure captions should be on a separate page in proper style; see the above guide or any issue for examples. All lettering on figures must be of sufficient size to be at least 9 pt in size after reduction to column width. Each illustration should be identified on the back or at the bottom of the sheet with the figure number and name of author(s). If possible, the figures should also be provided in electronic format. TIF is preferred, although other formats are possible as well: please contact the Editor. Electronic versions of figures *must* be of sufficient resolution to permit good quality in print. As a rough guideline, when sized to column width, line art should have a minimum resolution of 300 dpi; color photographs should have a minimum resolution of 150 dpi with a color depth of 24 bits. 72 dpi images intended for the Web are generally *not* acceptable. Contact the Editor for further information.

Electronic Submission

A version of Microsoft *Word* is the preferred format for submissions. Submissions in versions of T_EX can be accepted in some circumstances: please contact the Editor before submitting. *A paper copy of all electronic submissions must be mailed to the Editor, including originals of all figures.* Please do *not* include figures in the same file as the text of a contribution. Electronic files can be sent to the Editor in three ways: (1) By sending a floppy diskette or CD-R; (2) By attachment to an e-mail message to the Editor (the maximum size for attachments *after* MIME encoding is about 7 MB); (3) By e-mailing the Editor instructions for downloading the material from an ftp site.

Review Process

The review process usually requires about three months. Authors may be asked to modify the manuscript if it is not accepted in its original form. The elapsed time between receipt of a manuscript and publication is usually less than twelve months.

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APPLICATION FOR AN URSI RADIOSCIENTIST

I have not attended the last URSI General Assembly, and I wish to remain/become an URSI Radioscientist in the 2009-2011 triennium. Subscription to *The Radio Science Bulletin* is included in the fee.

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