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Contents

Front cover: The new URSI Board of Officers: from left to right in alphabetical order: S. Ananthakrishnan, M. Ando, Y. Antar, P. Cannon (President), U. Inan (Treasurer), P. Lagasse (Secretary General), P. Wilkinson.

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Editorial

AT-RASC is Coming!

URSI is establishing a new pattern in scientific conferences for radio scientists. There will now be three flagship conferences for radio scientists: one each year. Besides the triennial General Assembly and Scientific Symposium, and the triennial Asia-Pacific Radio Science Conference (AP-RASC, next held in 2016), in 2015 URSI will inaugurate the first triennial URSI Atlantic Radio Science Conference (AT-RASC), to be held May 18-25, 2015, at ExpoMeloneras Convention Centre, Gran Canaria (Canary Islands). This will be an open scientific conference with submitted papers in the areas of all 10 of the URSI Commissions. The deadline for paper submission is December 15, 2014, and a full call for papers appears in this issue. There will also be special programs for young scientists, a student paper competition, and programs for accompanying persons. I urge you to submit a paper to this conference, and to start now making plans to attend.

Our Papers

Cognitive radar is a concept for a whole new type of radar and mode of operation for radar. This potentially has both very significant benefits and very significant challenges. Anthony Martone examines these in detail in his paper. The paper begins with an in-depth analysis of the challenges facing radar today. These include both performance challenges, as well as challenges of operating in environments with ever-more-restricted spectral constraints. The principal components of a cognitive radar are then explained, and it is shown that there are six such components that go into making a radar cognitive. A generalized framework for cognitive radar, and the technologies required to support the components necessary for cognitive radar, are then introduced. These include reconfigurable hardware, multifunction radar target information processing, environmental sensors and spectrum sensing, and the decision processes. This paper provides an excellent introduction to a fascinating new approach to radar.

The invited paper by Meriem Mhedhbi, Nicolas Amiot, Stéphane Avrillon, Troels Pedersen, and Bernard Uguen won the student award at the French URSI national meeting. It reports results of a simulation of a radio link between two antennas mounted on a human body. The paper begins with a basic introduction to the concept of body-area networks. A two-level approach was used in the simulation. The first level simulated the overall motion of the body along a path. The second level simulated the detailed movements of the body. The method of modeling the body's motion using motion-capture data is described. A method of parameterizing and reducing the complexity of the model is described. The modeling of the antenna, and the integration of the antenna's pattern with the human-body model is explained. The simulations and their results are then presented. These involved a person walking along a path in a building, with a link from one hip to a wrist. The simulated results were shown to be in reasonable agreement with related published results. This paper is interesting because of the insight into the behavior of body-area networks, and also because of the techniques developed for the various aspects of the simulation.

The role of radio science in disaster management and mitigation is an area of intense interest to URSI (see the special sections on this topic in the June 2013 and March 2014 issues of the *Radio Science Bulletin*). This has also been an area of significant research for the US National Bureau of Standards and Technology (NIST), along with the National Telecommunications and Information Administration (NTIA) and the Department of Homeland Security (DHS), spanning 10 years. Some of the results of this research are reported in a series of three papers that will appear in this and the following two issues of the *Bulletin*. The first paper, by Christopher Holloway, Galen Koepke, Dennis Camell, William Young, and Kate Remley, appears in this issue. It deals with propagation measurements before, during, and after the collapse of three large buildings. The range of frequencies monitored, from 50 MHz to 1.8 GHz, spans bands in use by public-safety personnel and cell phones. The buildings are described in detail. They included a 13-story apartment building, a sports arena, and a convention center. The experimental setups are described in some detail. Radio-mapping measurements were taken for each site, in which a transmitter was moved throughout the building while the signal received at a fixed receiver outside the building was recorded. A mobile receiving system was moved around the building to record the signals from transmitters placed at fixed sites in the buildings. The transmissions were then recorded at fixed receiving sites outside the buildings during the collapse of the buildings. After the collapse, the mobile receiving system was moved over the same path as before the collapse, so that pre- and post-collapse received data could be compared. Experiments were also performed to test the concept of possibly using metallic debris that might extend through the collapsed building as a radiator to get a signal from inside to outside of the building. The results from all of these measurements provided important insights and understanding into the basic propagation potentially affecting emergency communications from inside to outside typical buildings. They also provided some basic guidelines regarding what levels of attenuation emergency radios may have to overcome in real-life situations. This is an important contribution to the field of radio science in disaster management.

Our Other Contributions

We have the triennial reports of several of the URSI Commissions in this issue. We also have the reports from the business meetings of some of the Commissions, held at the Beijing GASS. These include descriptions of the accomplishments and status of the Working Groups of the Commissions, and the activities in the Member countries of each of the Commissions.

Editor-in-Chief of *Radio Science*

The AGU is conducting a search for a new Editor-in-Chief of the URSI logo journal, *Radio Science*. A call for candidates appears in this issue. If you have an interest in this position, or would like to nominate someone for it, now is the time to respond.

The GASS

URSI had an outstanding General Assembly and Scientific Symposium in Beijing. A very big thank you goes to Qinjian Lou, the Local Conference Chair; Xiaolan Xu, the Conference Secretary General; Zixue Zhou, the Chair of the Local Organizing Committee; Runhua (Forest) Lin, the Secretary General of the LOC; Yimin (Lucy) Zhang, Wenting (Cynthia) Lian, Hong Luo, Qianyi Li, Yuhua Jiao, Huijun Wang, Huicong Ning, and Yuanjun Qin of the LOC; Ayhan Altintas, Coordinator of the Scientific Program, and Jian Wu and Yihua Yan, Associate Coordinators of the Scientific Program; and Paul Lagasse, Peter Van Daele, Inge Heleu, and Inge Lievens of the URSI Secretariat. These are the people who made it all work so well.

The URSI Council decided that the 2017 XXXIInd URSI GASS would be held August 19-26, 2017, in the Palais des Congrès, Montréal, Canada. I look forward to seeing you there.

Call for Papers

1st URSI Atlantic Radio Science Conference (URSI AT-RASC)

18 - 25 May 2015

ExpoMeloneras Convention Centre, Gran Canaria

Important deadlines

Paper submission
December 15, 2014

Notification
February 28, 2015

Early bird registration
March 31, 2015

Conference start
May 18, 2015

The newly established triennial URSI Atlantic Radio Science Conference (URSI AT-RASC) is the 3rd URSI flagship conference besides the triennial URSI General Assembly and Scientific Symposium and the triennial AP-RASC conference (AsiaPacific Radio Science Conference).

This 1st URSI Atlantic Radio Science Conference will have an open scientific program composed of submitted papers within the domains covered by all ten Commissions of URSI:

Commission A: Electromagnetic Metrology
Commission B: Fields and Waves
Commission C: Radiocommunication and Signal Processing Systems
Commission D: Electronics and Photonics
Commission E: Electromagnetic Environment and Interference
Commission F: Wave Propagation and Remote Sensing
Commission G: Ionospheric Radio and Propagation
Commission H: Waves in Plasmas
Commission J: Radio Astronomy
Commission K: Electromagnetics in Biology and Medicine

Paper submission Deadline: December 15, 2014

Authors must submit an abstract (minimum of 250 words) electronically by December 15, 2014. Each registered author may present no more than two papers. Organizers of special sessions should send a request to the appropriate commission Chair(s) by October 18, 2014 - details are found on the URSI website. Detailed information on Paper Submission as well as Travel Information will become available through the URSI website: www.at-rasc.org in September 2014. Papers presented at this 1st URSI AT-RASC will be submitted for posting to IEEE Xplore.

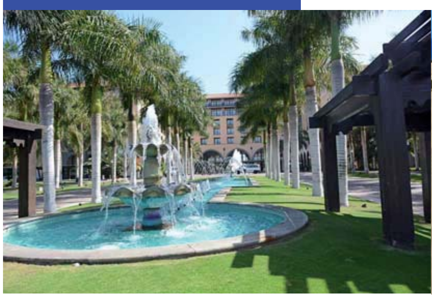
In addition, there will be special programs for young scientists, a student paper competition and programs for accompanying persons.

Technical Programme Committee: Prof. P.L.E. Uslenghi, Chair; Prof. P.S. Cannon, Vice-Chair; Dr. W.R. Stone, Publications

Organizing Committee: Prof. P. Lagasse, Chair, Prof. P. Van Daele, Vice-Chair

www.at-rasc.org

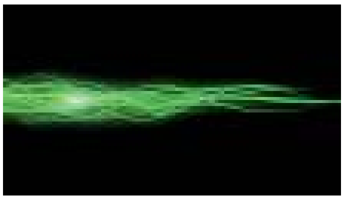
Contact:
uslenghi@uic.edu



Topics of interest

Commission A – Electromagnetic Metrology
Antennas, Atomic-based mechatronics, Bioeffects and medical applications, EMC and EM metrology, High-frequency and millimeter wireless metrology, Impulse radar, Interconnect and packaging, Materials, Measurements and calibration in propagation, Microwave to submillimeter measurements/standards, Noise, Quantum metrology and fundamental concepts, Space plasma characterization, Techniques for remote sensing, Test facilities, THz metrology, Time and frequency, Time-domain metrology and other topics of interest.

Commission B – Fields and Waves
Antenna arrays, Antennas: recent advances and future outlook, Antenna theory, design and measurements, Cognitive radio, Complex media (bandgap structures, biological and geophysical media, metamaterials, and others), Educational methods and tools, Electromagnetic interaction and coupling, Guided waves and waveguiding structures, High-frequency techniques, Imaging, inverse scattering and remote sensing, Mathematical modeling of electromagnetic problems, Microstrip antennas and printed devices, Multiphysics electromagnetics, Nanoscale electromagnetics, Nonlinear electromagnetics , Numerical methods (differential- and integral-equation based, hybrid and other techniques), Optical phenomena, Optimization techniques in electromagnetics, Propagation phenomena and effects, Rough surfaces and random media, Scattering and diffraction, Theoretical electromagnetics, THz antennas and propagation, Transient fields, effects, and systems, Ultra-wideband electromagnetics , Wireless communications and other topics of interest.

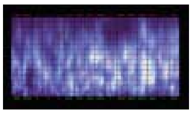


Commission C – Radiocommunication Systems and Signal Processing

Cognitive radio and software defined radio, Distributed sensor networks and sensors array processing, Energy-efficient ("green") communications, Information theory, coding, modulation and detection, MIMO and MISO systems, Novel radio communication systems, Physics-based signal processing, Radar target detection, localization, and tracking, Radio localization and positioning, Signal and image processing, Spectrum and medium utilization, Statistical signal processing of waves in random media, Synthetic aperture and space-time processing, Wireless networking and other topics of interest.

Commission D – Electronics and Photonics
Broadband ubiquitous network, Energy harvesting in wireless systems, Fiber lasers and solid state lasers, Graphene nanoelectronics applications, Multi-physics modeling in radio frequency nanoelectronics, Optical sensors and biosensors, Plasmonics, RF MEMS and NEMS, Signal processing antennas, 60 GHz electronics, Trends in RFID for identification and sensing, Trends in THz communications and other topics of interest.

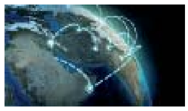
Commission E – Electromagnetic Environment and Interference



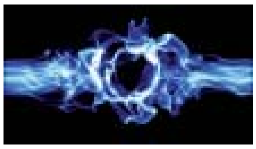
Communication in the presence of noise, Crosstalk, Electromagnetic compatibility education, Electromagnetic compatibility measurements and standards, Electromagnetic noise of natural origin, Electromagnetic radiation hazards, High-power effects of transients on electronic systems, Spectrum management and utilization and other topics of interest.

Commission F – Wave Propagation and Remote Sensing
Propagation measurements/models for fixed and mobile links, Measurements of fixed and mobile channels, Propagation models, Multipath/mitigation, Fixed terrestrial links: measurements and design strategies, Surface/atmosphere interaction, Dispersion/delay, Effects of natural/man-made structures, Outdoor to indoor propagation, Multi link MIMO channels, UWB channel characteristics, Small cell propagation, Remote sensing of the Earth/planets by radio waves, Passive sensing at millimeter wavelengths, Interferometry and SAR, Sensing of snow in open and forested environments, Remote sensing of precipitation, Atmospheric sensing, Sensing of soil moisture and biomass, Ocean and ice sensing, Urban environments, Radio Frequency Interference (RFI), Underground imaging, Propagation and remote sensing in complex and random media and other topics of interest.

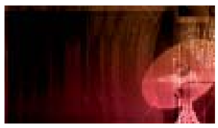
Commission G – Ionospheric Radio and Propagation
Ionospheric imaging, Ionospheric morphology, Ionospheric modeling and data assimilation , Radar and radio techniques for ionospheric diagnostics, Space weather – radio effects, Transionospheric radio propagation and systems effects and other topics of interest.



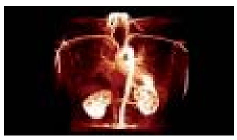
Commission H – Waves in Plasma
Chaos and turbulence in plasma, Plasma instabilities and wave propagation, Spacecraft-plasma interactions, Solar/planetary plasma interactions, Wave-wave and wave-particle interactions, Waves in laboratory plasmas and other topics of interest.



Commission J – Radio Astronomy
Detection of short-duration transients, Developments in array technology for radio astronomy, New telescopes, techniques, and observations, Radio frequency interference mitigation and spectrum usage, SKA, Timely technical tutorials and other topics of interest.



Commission K – Electromagnetics in Biology and Medicine
Biological effects, Dosimetry and exposure assessment, Electromagnetic imaging and sensing applications, Human body interactions with antennas and other electromagnetic devices, Therapeutic, rehabilitative, and other biomedical applications and other topics of interest.



AT-RASC 2015
Awards for Young Scientist
Conditions

Chair: Prof. Kazuya Kobayashi, Chuo University, Japan

40 Young Scientists will be selected and will be awarded a certificate, free registration to AT-RASC 2015 and free hotel accommodation at the IFA Buenaventura Hotel.

To qualify for an award the applicant:

1. must be less than 35 years old on September 1st of the year of the AT-RASC conference
2. should have a paper, of which he or she is the principal author, submitted and accepted for oral or poster presentation at a regular session at AT-RASC.

- Applicants should also be interested in promoting contacts between developed and developing countries. Applicants from all over the world are welcome, also from regions that do not (yet) belong to URSI. All successful applicants are expected to participate fully in the scientific activities of AT-RASC.
- The application needs to be done electronically by going to the same web site used for the submission of abstracts/papers via http://www.at-rasc.com/ The deadline for paper submission for AT-RASC 2015 is December 15th, 2014.
- A web-based form will appear when applicants check "Young Scientists Paper" at the time they submit their paper. All Young Scientists must submit their paper(s) and this application together with a CV and a list of publications in PDF format to the AT-RASC submission web site.
- Applications will be assessed by the URSI Young Scientists Committee taking account of the national ranking of the application and the technical evaluation of the abstract by the relevant URSI Commission. Awards will be announced on the AT-RASC web site and the URSI web site in March 2015.
- For more information about URSI, AT-RASC 2015 and the activities of URSI Commissions, please look at the URSI web site at: http://www.ursi.org or the AT-RASC 2015 website at http://www.at-rasc.com/
- If you need more information concerning the Young Scientists Program, please check the URSI web site at: http://www.ursi.org/en/home.asp?sub=youngscientists

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AT-RASC 2015
4th International Student Paper Prize Competition

Financially supported by the USA URSI National Committee (USNC-URSI)

Chair: Prof. Sembiam Rengarajan, California State University, Northridge, CA, USA

Student Paper Prize winners:
1st Place through 3rd Place, will be awarded a certificate and check in the amounts of $750, $500 and $250, respectively.

Rules and Guidelines

- First author and presenter must be a full-time university student.
- The topic of the paper must be related to the field of one of the ten URSI Commissions.
- An abstract must be submitted by December 15th, 2014 through AT-RASC 2015 on-line paper submission system and the appropriate box must be checked during the paper submission process.
- In addition to this standard paper submission, a full paper, not longer than 25 pages and in the single-column, double-spaced manuscript format of the journal Radio Science must be submitted by December 15th, 2014.
- A paper which is submitted to a journal before final submission to the student competition is ineligible. However, a student is encouraged to submit his/her paper to a journal after December 15th, 2014.
- A letter from the student's advisor on university letterhead must be appended to the paper. The letter must state that the author is enrolled as a full-time university student in a degree program. If co-authored, the letter must state that all co-authors played only an advisory role. No other students are permitted as co-authors.
- Ten finalists will be chosen based upon quality, originality and scientific merit. They will receive free access to the banquet, where all finalists will be recognized, and prizes will be presented to three.
- The URSI Panel of Judges will consist of the ten URSI Commission Chairs or their authorized representatives, in case of absence.
- In addition, the prizes will be awarded based on the clarity of their presentation, accessibility to the broad audience of the ten URSI Commissions and the ability to answer questions on their work.

Contact:
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Editor-in-Chief Needed for *Radio Science*

The AGU is looking for a dynamic, well-organized scientist with high editorial standards and strong leadership skills to serve a four-year term as the Editor-in-Chief for this exciting open access journal.

The Editor-in-Chief is the principal architect of the scientific content of the journal. The EIC is an active scientist, well-known, and well-regarded in his/her discipline. The EIC must be active in soliciting the best science from the best scientists to be published in the journal. Working with the other editors and AGU staff, the EIC is the arbiter of the content of the journal. Among other functions, the EIC is responsible for:

Acting as an ambassador to the author/editor/reviewer/scientist community

Setting the strategy for the journal

Leading the editor selection process

Assigning and balancing the reviewing workload

Decisions of ethics

Reviewing and contributing to periodic monitoring reports

Conducting and attending meetings

Journal Scope: *Radio Science* publishes original scientific contributions on radio-frequency electromagnetic propagation and its applications. Contributions covering measurement, modeling, prediction, and forecasting techniques pertinent to fields and waves – including antennas, signals, and systems, the terrestrial and space environment, and radio propagation problems in radio astronomy – are welcome. Contributions may address propagation through, interaction with, and remote sensing of structures, geophysical media, plasmas, and materials, as well as the application of radio-frequency electromagnetic techniques to remote sensing of the Earth and other bodies in the solar system.

A search committee appointed by the AGU President evaluates prospective candidates and conducts personal interviews with a small number of highly qualified individuals. The President makes the final selection and appointment. All AGU editors serve at the pleasure of the President.

If you would like to be considered for the position of Editor-in-Chief of *Radio Science*, send your curriculum vitae with a letter of interest via e-mail to **pubmatters@agu.org**. If you would like to nominate a highly qualified colleague, send a letter of recommendation to the same e-mail address. **Please make sure that you specify Radio Science in the subject line of the e-mail.**

Deadline for applications is October 31, 2014

Cognitive Radar Demystified

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Abstract

In this paper, cognitive radar and its potential benefits to the radar community are investigated. The definition of cognition is first explored to develop the necessary principal components for cognitive radar. The principal components for cognitive radar are based on decision-theoretic approaches and the feedback process. A generalized cognitive radar system is then introduced to provide a framework for advancing current traditional radar to cognitive radar. Each component of this system is explored in detail, where the principal components include: 1) informed decision making via the decision-theoretic approach; 2) passive environmental sensors and radar sensors; 3) learning algorithms to improve performance and adapt to unknown environmental scenarios; 4) a knowledge database that contains environmental, clutter, target, and other a priori information; 5) a waveform-solution space for known targets of interest; 6) receiver-to-transmitter feedback to mitigate clutter/interference and maximize target information.

1. Radar Challenges of Today

Perhaps the most precious commodity for the radio frequency (RF) community is the electromagnetic (EM) spectrum. The EM spectrum is regulated in the United States by governing entities such as the Federal Communication Commission (FCC) and the National Telecommunications and Information Administration (NTIA). The sole purpose of these entities is to ensure that people have access to rapid and efficient communication services such as radio, television, satellite, and the like [1]. A set of rules and standards are indeed necessary to ensure reliable communication services for consumers. A challenge to radar developers in both the private sector and the government is to design a radar system within these standards. This design restriction may inherently provide less flexibility of the intended radar product to adequately detect and locate frequency-dependent targets, thereby degrading performance. The loss of flexibility within the frequency spectrum thus reduces the radars' capability to detect and track targets in time-varying and cluttered environments.

Radars are further challenged by the potential new FCC regulations specified by the National Broadcast Plan, a plan to ensure "every American has access to broadband capability [2]." One aspect of these regulations is to free 500 MHz of federal and nonfederal spectrum for mobile and fixed wireless broadband usage [3]. It remains unclear as to how these regulations will be implemented, and what frequency bands will be affected. However, any radar currently operating in the affected frequency band will be rendered useless, unless the sensor has the capability to broadcast in another band. This FCC regulation challenge is likely to grow, as new unforeseen rules and regulations are enacted in order to satiate the ever-growing wireless communication industry. International regulations must also be adhered to if the radar is designed to operate outside the United States.

An additional challenge for radar is RF interference (RFI), caused by communication and other RF systems. RFI is documented by a variety of radar investigations. For example, consider the out-of-band (OOB) emissions generated by base-station transmitters operating between 2496 MHz and 2690 MHz. The NTIA, Institute for Telecommunication Sciences (ITS), conducted investigations of how these out-of-band emissions can potentially cause interference in next-generation weather radars (NEXRADs), operating between 2700 MHz and 2900 MHz [4]. Investigations by the United Kingdom (UK) Office of Communications (Ofcom) indicated similar findings with out-of-band emissions from communication systems (operating in the 2500 MHz to 2690 MHz band) potentially interfering with air traffic control radars operating in the 2700 MHz to 2900 MHz band [5]. Future radars must be capable of detecting and mitigating RFI in order to maximize radar performance.

It is also possible that the radar is the source of the RFI. Consider the notional example of military radar operating in the vicinity of "friendly" communication systems. If no cooperative policy is in place, then radar transmissions may directly (by operating in the same band) or indirectly (by out-of-band emissions) interfere with the communication systems. As such, future radars must be capable of automatically identifying and cooperating with other RF systems.

Figure 1a. The ASCC was a massive (51 ft × 8 ft) electromechanical calculator developed by Howard Aiken (Professor of Applied Mathematics at Harvard), his staff, and IBM engineers between the years 1939-1944. The Mark I was capable of addition, subtraction, multiplication, division, computing transcendental functions, and storing results for later computations via a set of 24 electromechanical storage wheels. The ASCC processed information sequentially as opposed to the parallel approach commonly used in that time period, a trend that continued for future generations of computers (photo taken from the "IEEE Global History Network" Web page).

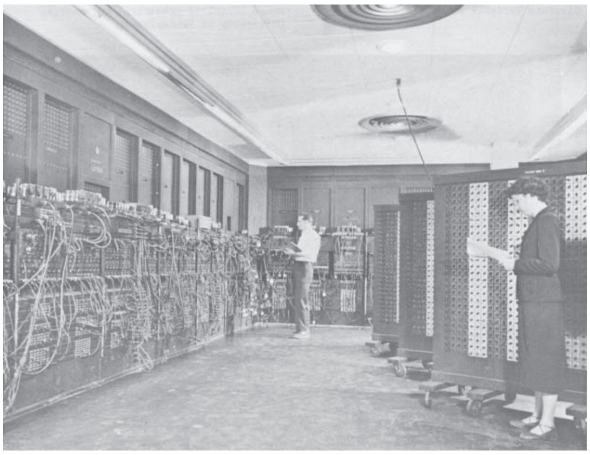

Figure 1b. The ENIAC was developed between the years 1943-1946 for the computation of firing and ballistic tables for the US Army. The ENIAC consisted of 18,000 vacuum tubes, and could multiply two decimal numbers in 2.8 ms (the ASCC multiplied two decimal numbers in approximately 6 s). The ENIAC computer caught the attention of John von Neumann, who suggested an improved wired programming system that stored functions rather than values. The improved programming system and other design concepts proposed by von Neumann transformed computer architecture designs for decades (photo taken from the "US Army Research Laboratory History" Web page).

Clearly, radars need a way to coexist in the EM environment by: 1) operating outside their licensed band while compiling with domestic and international regulations, 2) detecting and mitigating interference from RF sources, and 3) identifying and/or cooperating with RF systems in order to avoid causing interference. The radio community has explored coexistence via cognitive radio [6]. Cognitive radio was originally perceived by Mitola as a programmable and adaptable communications device that could passively learn user preferences and adjust to its operating environment [7]. The FCC then identified cognitive radio as a means for an unlicensed – or secondary – user to access the underutilized spectrum reserved for the licensed – or primary – user [8]. As such, cognitive radio then became a fast-growing research area, and was viewed by the RF community as a way to improve utilization of the EM spectrum for highly reliable communication [9]. Research topics within cognitive radio can be leveraged for radar co-existence; one such topic explored in this paper is spectrum sensing.

In addition to coexisting in the EM environment, the radar must continue to detect and locate targets with the goal to improve upon performance specifications. To address these radar challenges, engineers have looked to the research area of cognitive radar as a means to bridge the gap between coexistence and improved radar performance. Cognitive radar techniques have been shown to increase radar functionality and to improve radar performance.

In this paper, cognitive radar and its potential benefits to the radar community are investigated. The definition of cognition is first explored in Section 2, to develop the necessary principal components for cognitive radar. The principal components for cognitive radar are based on decision-theoretic approaches and the feedback process. A generalized cognitive radar system is then introduced in Section 3. This proposed system provides a framework for advancing current traditional radar to that of cognitive radar. Each component of this system is explored in detail, where the components include: 1) informed decision making via the decision-theoretic approach; 2) passive environmental sensors and radar sensors; 3) learning algorithms to improve performance and adapt to unknown environmental scenarios; 4) a knowledge database that contains environmental, clutter, target, and other a priori information; 5) a waveform solution space for known targets of interest; 6) receiver-to-transmitter feedback to mitigate clutter/interference and maximize target information.

2. Principal Components of Cognitive Radar

It is beyond the scope of this paper to speculate whether radars can think, or if radars are truly cognitive. Instead, the principal components of cognitive radar are identified and investigated using the existing literature. This literature is well founded in the research areas of cybernetics, decision-theoretic approaches, machine learning, knowledge-based (KB) radar systems, and

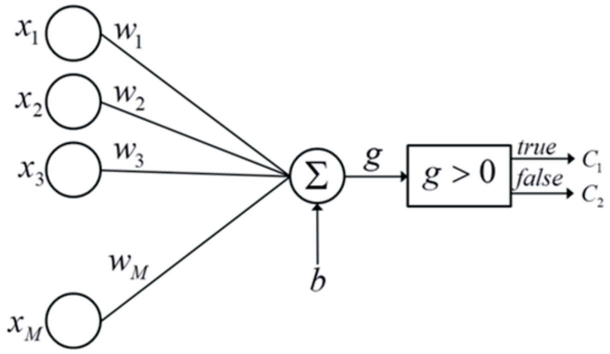

Figure 2. A simplified illustration of the perceptron brain model for the two-category case. This model discriminates between two linearly separable patterns based on the input stimulus. Define $\{x_1,...,x_M\}$ as the input stimulus, $\{w_1,...,w_M\}$ as the weights, and *b* as the bias (threshold weight). The two categories are defined as $\{C_1,C_2\}$. Each input is appropriately scaled using the weights, where the weights are trained through a supervised learning process. This model served as the basis for artificial neural networks.

matched illumination. Aspects of these research areas are then used for the proposed cognitive radar framework discussed in the next section.

Cognitive radar has a history well founded on machine learning. Learning machines and algorithms arose in the 1940s, during the time of computers like the IBM Automatic Sequence Controlled Calculator (ASCC) and the Electronic Numerical Integrator and Computer (ENIAC). Details of the ASCC and ENIAC are highlighted in Figure 1 [10-12]. Scientists and laymen alike were fascinated by comparing these computers to biological systems: calculators were “Giant Brains” [13]; the ENIAC was the “Great Brain” [14]; neurons were compared to the circuitry in computers [15]; and several questions arose as to whether machines could think [16].

Despite the hype of the analogies, investigations into the relationships between biological systems and computers established several founding principles in machine learning. These investigations are mainly attributed to research conducted in the area of cybernetics. Primarily founded by Wiener, the research area of cybernetics emerged in the 1940s. Cybernetics is an interdisciplinary study of communication and control consisting of two main features [17]: 1) existence of similarities between organic and inorganic systems, 2) and automatic controls that utilize a feedback process. Both of these features are essential for cognitive radar.

2.1 Decision-Theoretic Approach

The first feature of cybernetics indicates the existence of similarities between organic and inorganic systems, a founding concept for artificial intelligence. In 1943, McCulloch and Pitts investigated these similarities to formulate models of the nervous system. These models were used to study how the brain organizes complex patterns and behaviors. Their work led to the McCulloch-Pitts neuron, the first simplified model of a neuron [18]. The McCulloch-Pitts neuron was expanded upon in 1958 by Rosenblatt. Rosenblatt proposed the perceptron brain model, a neuron model that discriminates between linearly separable patterns based on supervised learning [19]. This model is described by the simplified illustration in Figure 2, which uses the following linear discriminate function for the two-category case [20]:

$$g = \sum_{i=1}^{M} w_i x_i + b \, , \qquad (1)$$

where $\{x_i,...,x_M\}$ are input stimuli, $\{w_1,...,w_M\}$ are the stimuli weights, and b is the bias (threshold weight). Each input is appropriately weighted, and the weights are trained through a supervised learning process. The discriminate function in Equation (1) is used to decide between two categories, $\{C_1,C_2\}$, using the following criterion: 1) decide C_1 if $g > 0$; 2) decide C_2 if $g < 0$ Artificial neural network concepts developed in later decades were based on Rosenblatt’s framework.

In the same time period, evolutionary computational methods were investigated by Friedberg to improve learning procedures [21], and the Pandemonium model was investigated by Selfridge to recognize unspecified patterns [22]. The research by Rosenblatt, Friedberg, and Selfridge laid the foundation for decision-theoretic approaches used today. These decision-theoretic approaches include artificial neural networks, metaheuristic algorithms (i.e., solution-space search algorithms), hidden Markov models, rule-based systems (i.e., If/Then rules), and case-based systems (i.e., applying known experiences/cases to guide decision making) [23]. *Decision-theoretic approaches allow cognitive radar to make informed decisions on observations in the environment, and are considered a principal component for cognitive radar.*

Early evidence of using decision-theory algorithms for radar was summarized by Vannicola in 1988, where multiple knowledge-based (KB) systems were explored for radar surveillance [24]. The applications included knowledge-based trackers, a knowledge-based target-identification system, and a knowledge-based expert system for operation and control. The knowledge-based system used a priori information (“domain knowledge”) and a posteriori information (“learned knowledge”) [24]. It is noted that such a system is “capable of rendering conclusions not only within the domain over which problem solving is taking place, but within the very algorithms being used

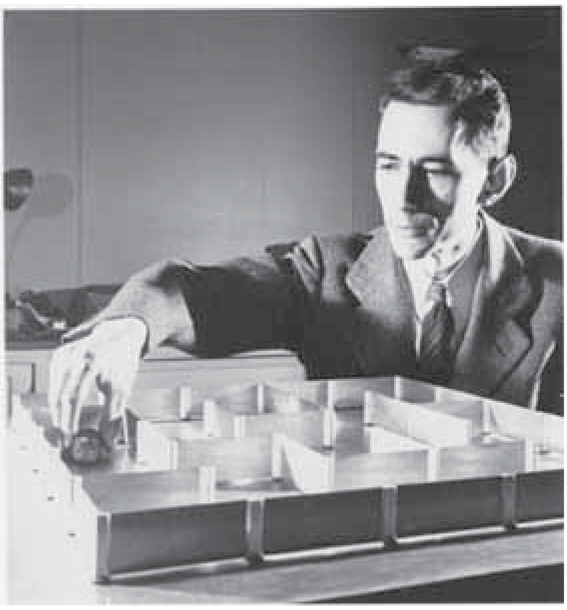

Figure 3. Claude Shannon demonstrating machine learning with his maze-solving device. Shannon described his maze-solving device, consisting of five-by-five squares and a magnetized mouse. Partitions were placed at desired locations within the maze, and the mouse was moved by an electromagnet. The mouse was placed in the maze, and wandered about until it located a food box. The mouse learned the path to the food box by trial and error, using a theorem in the mathematical field of topography. When the mouse was placed in the maze a second time at the same starting location, it proceeded to the food box without error. When the mouse was placed in the maze at an unknown starting location, it wandered about until it recognized a previous location, and it then proceeded to the food box without error. The mouse added information about the unexplored areas of the maze to its memory (photo taken from the "MIT Museum Collections – People" Web page).

[24]." In the applications described, the knowledge-based system uses a knowledge database of a priori information (e.g., target, environmental, etc.) in conjunction with decision criteria to improve radar system performance. *The knowledge database is necessary for cognitive radar, and is considered a principal component.*

Advancements of computer technology in the early 1990s supported the knowledge-based system approach. For example, Baldygo proposed a system to "intelligently select" (via decision-theoretic methods) an appropriate CFAR algorithm based on external sensors in the environment to reduce false alarms for a surveillance radar [25]. The external sensors were atmospheric, and included temperature, wind, and moisture sensors. The external sensors provided environmental awareness to the cognitive radar via supplementary information: *passive environmental sensing is another principal component of cognitive radar.* Results indicated performance improvement compared to traditional CFAR approaches.

KB-STAP was proposed by Melvin in 1998. It used various information sources to improve STAP performance [26]. A knowledge database was used for "pre-adaptive filtering" that resulted in an SINR improvement of 13.2 dB. In other work, Guerci established the DARPA knowledge-aided sensor signal processing and expert reasoning (KASSPER) project. The KASSPER project considered a system that integrated a priori environmental information into an adaptive space-time beamformer, a computationally demanding task [27]. The solution to manage the computational load used real-time look-ahead scheduling and prior information (terrain and road maps) to reduce the processing complexity.

To summarize, the above examples illustrate how the decision-theoretic approach improves a measure of success, e.g., SINR. The decision-theoretic approach uses advanced processing algorithms to assist in the decision-making process. The knowledge database provides the cognitive radar with necessary target, clutter, environment, and other a priori information. Processing the database information in real time requires the appropriate digital hardware. Finally, passive environmental sensing aides the decision-theoretic approach and requires appropriate sensing hardware and processing algorithms.

2.2 Radar Learning Via Feedback

The second feature of cybernetics indicates the need for a feedback process, a founding concept for learning. Learning algorithms for digital machines were first investigated in the late 1940s and early 1950s. Scientists and engineers of this time period formulated solutions to speed up and remove processing limitations of digital computers [14]. These learning programs were best summarized by Wilkes [16]: "the action of the machine upon receiving any signal depends on previous signals it has received and on the actions it has taken in response to them." Wilkes finalized his discussion on extending the concept of a learning program to a "generalized leaning program," a program that "modifies and extends itself as the learning process went on [16]."

An excellent review of early learning machines was written by Shannon in 1953 [28]. Shannon described several game-playing machines, in addition to his "maze-solving device," as illustrated in Figure 3 [29]. Shannon described the learning process as follows [28]:

> Suppose that an organism or a machine can be placed in, or connected to, a class of environments, and that there is a measure of "success" or "adaptation" to the environment. Suppose further that this measure is comparatively local in time, that is, that one can measure the success over periods of time short compared to the life of the organism. If this local measure of

> success tends to improve with the passage of time, for the class of environments in question, we may say that the organism or machine is learning to adapt to these environments relative to the measure of success chosen. Learning achieves a quantitative significance in terms of the broadness and complexity of the class of environments to which the machine can adapt.

Shannon's definition of learning is comprehensive and applicable to cognitive radar: *learning is indeed a principal component for cognitive radar.* For cognitive radar, learning is achieved by utilizing past information, i.e., a time history of the information, to improve the local measure of success. Utilization of past information is realized by implementing the feedback process. Learning provides the cognitive radar extended capabilities that include (but are not limited to): 1) increased target detection [30] and SINR [31] using the time history of radar data; 2) increased statistical understanding of clutter and target models [32]; 3) increased adaptability to unknown environmental scenarios [33]. The process of learning is also a topic of interest to the cognitive radio community. Bostian identified learning as the key ingredient for cognition as compared with adaptive solutions [33]. Bostian went on to state that through learning, a true cognitive radio is capable of "surprising its designers by arriving at unexpected solutions to problems and remembering these for future applications [33]."

Early research on improving radar target detection over time using feedback is best highlighted by Haykin's radar vision, the forerunner to cognitive radar [30]. Radar vision, an "intelligent remote sensing device," used a two-dimensional fast Fourier transform (FFT), a neural network, a knowledge processor, a knowledge database, and a feedback network. The feedback network was used to improve detection of weak targets. In this paper, Haykin commented that "time is the essential dimension for learning," and went on to discuss how the time history of radar data was the key to improving target-detection performance [30]. The feedback network of radar vision was also used to adapt radar illumination of the surrounding environment. Specifically, for radar vision, the frequencies and polarization of the transmitted waveform were adapted to minimize the clutter response. *Receiver-to-transmitter feedback is another principal component for cognitive radar: this feedback is used to mitigate clutter/interference and maximize target information.* The radar vision example also demonstrates that awareness of the environment is achieved by the radar sensors and by processing the radar returns. *The passive environmental sensing principal component (established in the previous section) is therefore extended to include the radar sensor.*

The term "cognitive radar" was introduced by Haykin in 2006. Haykin proposed a target-tracking system that [32]: 1) continuously learned about the environment, 2) intelligently adjusted the transmitter, and 3) incorporated receiver-to-transmitter feedback. The system processed radar returns using a knowledge database, a radar scene analyzer, and a target tracker to intelligently modify the transmitted waveform. This cognitive system was viewed as a dynamic closed-loop feedback system. Haykin went on to define learning as an offline and an online process. In the offline process, real-life data was collected at a time prior to radar operation. This data was then used to increase the statistical understanding of clutter and target models. In the online form, learning was achieved in real time to improve decision-making capability and improve actions chosen by the radar. In later work, Haykin extended his definition of cognitive radar using Fuster's Paradigm [34]. Haykin described Fuster's Paradigm in the context of a cognitive dynamic system consisting of four main elements [35, 36]: 1) perception-action cycle; 2) memory; 3) attention; 4) intelligence. Simulations were provided by Haykin to demonstrate increased radar-tracking accuracy using this cognitive radar approach (as compared with its traditional counterpart) [36].

The idea of radar-waveform adaptation has been investigated by the research area of matched illumination. Matched illumination is the process of matching a waveform to a known target, thereby creating an optimal detection system. Haykin proposed using the matched-illumination approach for cognitive radar. His method was to synthesize the illuminated waveform to provide a tradeoff among various performance objectives for a known target [37]. The waveform design performance objectives considered by Haykin in [37] were originally formulated by Bell in 1988 [38]. Bell investigated radar waveforms to maximize SNR and mutual information for optimal target detection and characterization [39]. Bell's research established design principles that were later used for matched illumination [40, 41]. Other work in optimal waveform matching included optimum pulse shaping for pulse communication [42]; optimum waveform design for detecting a known target in signal-dependent clutter [43]; and optimum transmitter-receiver design in additive color noise [44].

An example of learning for cognitive radar using matched illumination was best illustrated by the "knowledge-aided, fully adaptable approach" investigated by Guerci [31]. This approach successfully combined optimal/adaptive transmitted and received waveforms with knowledge-based processing for a cognitive radar architecture; receiver-to-transmitter feedback was included in the design. The most interesting result Guerci demonstrated was that SINR was significantly increased (5 dB to 7 dB) over time by incorporating prior radar scans.

To summarize, a set of specially designed waveforms matched to a known target of interest should be utilized by cognitive radar. For many targets of interest and sensing scenarios, it is challenging to realize the "optimal" waveform. In this paper, we generalize the matched-illumination concept to that of identifying the set of all possible waveform parameters (amplitudes, frequencies, phase quantities, and the like) of the transmitted waveform that are used to generate a response from a target of interest. These waveform parameters are defined as

$$\Phi = \{a, f, \phi, \chi\},\qquad (2)$$

where a is a vector of amplitudes that produce a target response, f is a vector of frequencies used to produce a target response, ϕ is a vector of phase quantities used to produce a target response, and χ is a vector containing other waveform parameters (e.g., chirp rate). The waveform parameters in Equation (2) constitute the waveform solution space that characterizes a known target of interest. *The waveform solution space is a principal component for cognitive radar.*

The above examples of cognitive radar highlight the need for learning, receiver-to-transmitter feedback, and the waveform solution space. It has been highlighted that learning gives the cognitive radar extended capabilities that include: 1) increased target detection and SINR using the time history of radar data; 2) increased statistical understanding of clutter and target models; 3) increased tracking performance; 4) and increased adaptability for unknown environmental scenarios. The supporting technology for learning is memory: as noted by Haykin, "the learning process of [cognitive radar] is largely carried out in the memory [36]." The supporting technology for receiver-to-transmitter feedback and the waveform solution space is reconfigurable analog hardware. Reconfigurable analog hardware, i.e., from the antenna to the analog-to-digital converter (ADC), is needed to support transmission and reception of a limitless number of synthesized waveforms that vary in frequency, power, phase, modulation, duty cycle, etc.

3. Generalized Cognitive Radar Framework

As discussed in the previous section, the principal components for cognitive radar are: 1) informed decision making via the decision-theoretic approach; 2) passive environmental sensors and radar sensors; 3) learning algorithms to improve performance and adapt to unknown environmental scenarios; 4) the knowledge database that contains environmental, clutter, target, and other a priori information; 5) the waveform solution space, Φ, for known targets of interest; and 6) receiver-to-transmitter feedback to mitigate clutter/interference and maximize target information. The technologies needed to support these six principal components include: 1) signal-processing algorithms to process target, clutter, environmental information (e.g., STAP); 2) digital hardware, including memory; and 3) reconfigurable analog hardware for the radar receiver and transmitter.

In this paper, the cognitive radar framework that incorporates the necessary principal and supporting components is illustrated in Figure 4. The proposed framework is presented at a generalized level, and is intended for advancing current traditional radar to that of cognitive radar. Awareness of the environment is enabled through the use of radar transmitters, radar receivers, and environmental sensors. The environmental sensors provide the cognitive radar with supplemental information to enhance radar performance; the environmental sensors are not used for target detection. The radar receivers

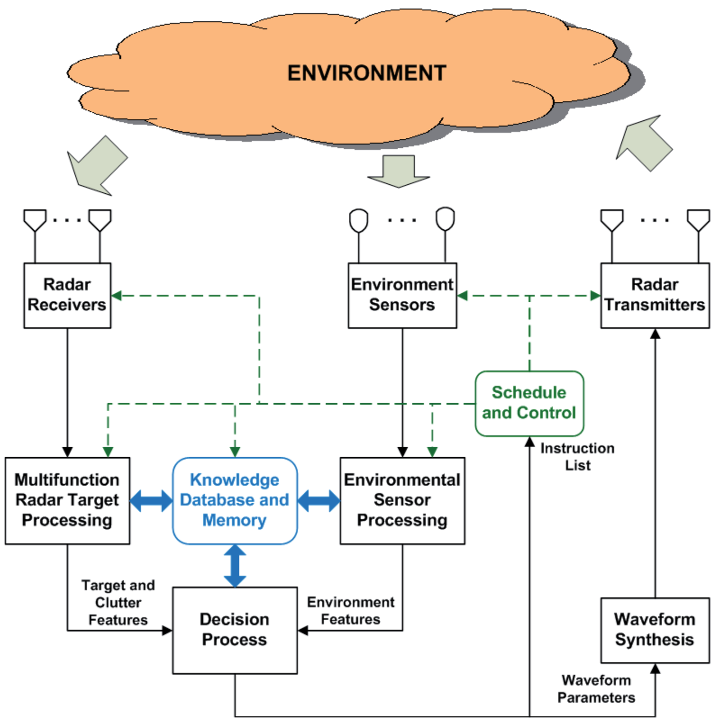

Figure 4. A generalized cognitive radar framework. This framework is intended for advancing current traditional radar to that of cognitive radar. Awareness of the environment is enabled through the use of radar transmitters, radar receivers, and environmental sensors. The multifunction radar target information processing incorporates multiple radar functions to achieve a better understanding of the target and the environment. The decision process uses decision-theoretic algorithms and past/present target information from multiple radar functions. The schedule and control function provides the necessary feedback to the other cognitive radar processes. The optimal waveform is then synthesized and transmitted into the environment, and the entire process reiterates. The iterative process adapts the cognitive radar to the environment over time to achieve learning.

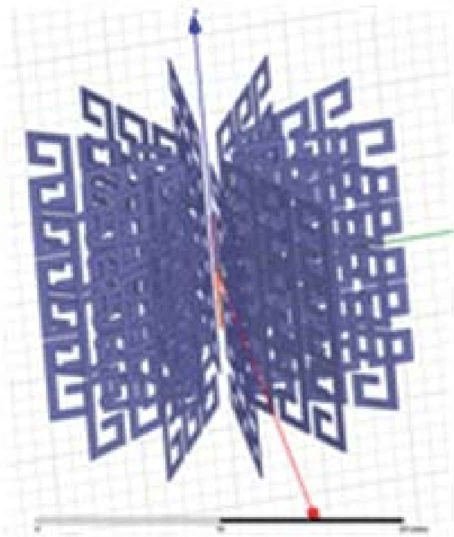

Figure 5a. A metamaterial structure of 12 radial fins surrounding a dipole antenna. This structure configures the radiation pattern of the omnidirectional dipole antenna to an antenna with directivity and high realized gain. The metamaterial approach offers significant gain improvement compared to the standard half-wave planar dipole antenna design.

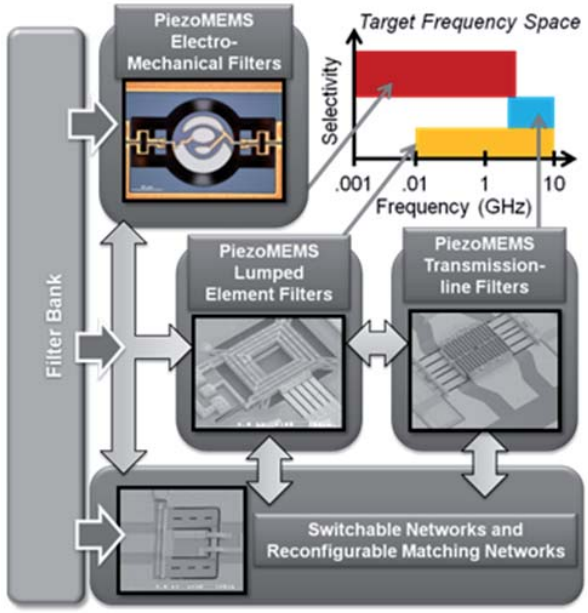

Figure 5b. An RF MEMS filter bank and matching network capable of configuring the cognitive radar transmitter and receiver to support waveform adaptation, while rejecting (or notching out) high-powered interference. The electromechanical filters offer very high rejection and narrow bandwidths. The lumped-element filters offer wide bandwidths and high power handling. The tunable transmission-line filters offer high tunability, high power handling, and high *Q*. Figures 5a and 5b show metamaterials and RF MEMS technology for reconfigurable hardware. The hardware architecture design for the proposed cognitive radar requires the use of reconfigurable components for advanced performance and waveform adaptability.

and transmitters are used for target detection, and use reconfigurable hardware. The reconfigurable hardware supports the transmission and reception of adaptable waveforms, and the architecture needed for a multifunction radar approach.

The multifunction radar target information processing incorporates multiple radar functions to achieve a better understanding of the target and the environment. Radar functions include (but are not limited to) moving target indication (MTI), synthetic aperture radar (SAR), and nonlinear radar[1] [45, 46]. The multifunction radar approach used by the proposed cognitive radar employs only one function at a given time. Each radar function in the proposed framework uses specialized processing algorithms to extract target and clutter information, e.g., a moving target's position and velocity. The target information is then sent to the decision process.

The decision process has a variety of functions, and requires digital hardware and memory sufficient for real-time processing. It uses decision-theoretic algorithms, learning algorithms that process past and present target information from multiple radar functions, the knowledge database, and memory. The specific functions of the decision process are the target decision process (TDP), the environmental decision process (EDP), the systems decision process (SDP), and the waveform decision process (WDP). Each decision process is explained in detail in Section 3.4.

[1] Nonlinear radars are designed to detect nonlinear responses from targets with inherent nonlinearities (such as semiconductors in radios). Nonlinear radar has the advantage over traditional linear radar of separating natural clutter from the induced nonlinear response.

After the decision process, the schedule and control function provides the necessary feedback indicated by the decision process to the other cognitive radar functions. As indicated in Figure 4 by the green lines, the schedule and control function reconfigures all sensors (i.e., the transmitter, receiver, environmental sensors), changes the radar function (if required), updates the target-detection algorithms for future processing, and updates the database with any newly learned information. The optimal waveform is then synthesized and transmitted into the environment, and the entire process reiterates. The iterative process adapts the proposed cognitive radar to the environment over time to achieve learning.

3.1 Reconfigurable Hardware

Reconfigurable hardware is used to enhance the baseline analog hardware architecture needed for the proposed multifunction cognitive radar. There exists a wealth of information on analog hardware architecture design for RF and radar systems. The general components for the analog architecture include antennas, filters, amplifiers, mixers, ADCs, and digital-to-analog converters (DACs). The analog hardware architecture is typically fixed (or permanent) for the traditional radar system: this restricts functionality, and limits the adaptability of the waveform. The hardware architecture design for the proposed cognitive radar requires the use of reconfigurable components, e.g., replacing a single filter with a filter bank that is reconfigurable to match a known sensing scenario.

The reconfigurable components considered in this paper can use the technologies of metamaterials and RF micro-electromechanical systems (MEMS). Metamaterials are artificially engineered materials that have unique properties compared to those found in nature. When used for antenna applications, metamaterials offer a means to control the reflectivity of a surface as a function of phase variation [47]; this naturally lends itself to applications involving covert operations. Metamaterials are also used for tunable impedance surfaces for advanced beam-steering [47]. As an example of reconfiguration applications, metamaterials are used to transform an omnidirectional dipole antenna to an antenna with directivity and high realized gain [48]. This reconfiguration is achieved by surrounding the dipole antenna with capacitively loaded loop (CLL) metamaterial elements, as shown in Figure 5a. "Interactions between the antenna and metamaterial elements result in enhancement of the maximum radiated field amplitude and front-to-back ratio [48]." The metamaterial approach offers significant gain improvement compared to the standard half-wave dipole antenna design.

RF MEMS offer high-performance solutions for tunable filters, tunable antennas, amplifiers, and reconfigurable matching networks [49]. For cognitive radar, RF MEMS offers a means to realize a high-performance filter bank that is capable of configuring the transmitter and receiver to support waveform adaptation (for both narrowband and wideband applications) while rejecting (or notching out) high-powered interference. Such a filter bank utilizing RF MEMS technology is shown in Figure 5b. The electromechanical filters offer very high rejection (>80 dB) and narrow bandwidths (bandwidths of 0.01% to 10%). The lumped-element filters offer wide bandwidths (bandwidths of 10% to 100% with "tunability" of $>100\%$) and high power handling capabilities with a frequency range of 100 MHz to 100 GHz. The tunable transmission-line filters offer high tunability ($>10\%$), high power handling, and high Q for frequency ranges of the low GHz to >100 GHz. A tunable RF MEMS matching network is used to maintain high RF performance and to compensate for impedance mismatches between filters. The matching network is realized with varactor and inductor integration, and offers a high Q and high linearity. This filter bank with matching network solution provides the reconfiguration and high performance necessary to transmit and receive an endless number of synthesized waveforms.

3.2 Multifunction Radar Target Information

The multifunction radar target information processing expands upon the receiver-to-transmitter radar concept discussed in Section 2.2 by increasing the types of interactions the cognitive radar has with the environment. Each radar function uses specialized processing algorithms for target and clutter feature extraction, where the features constitute distinct target/clutter information. The target and clutter features are defined as

$$\Omega_i = \left\{\omega_{i,1}, \ldots, \omega_{i,N_1}\right\}, \tag{3}$$

where $\omega_{i,N}$ is the nth feature of data collected at iteration $i \in \{1, \ldots, I\}$, I is the total number of iterations of the cognitive radar, and N_1 is the total number of features. In the remainder of this paper, the term N is used to denote the total number of symbols in a set. The processing algorithms used to determine the features are known a priori and stored in the knowledge database. The target and clutter feature types are dependent on the radar function employed. For example, position and velocity features are used for the moving target indication radar function. The features are sent to the decision process for target assessment.

An example of the multifunction radar approach is detection of personnel inside building structures. The SAR function is used to generate a high-resolution image of the building. Features are extracted from this image that identify the position of the walls, points of entry (e.g., doors and windows), and other clutter inside the building. The SAR image is registered with blueprint images of the building to determine the exact layout of the building's structure and other building information (such as wall material types). Change detection is then applied to the SAR images to detect the position of the moving target [50, 51]. The position of the moving target is yet another feature provided by the SAR radar function. Doppler processing is next employed by the moving target indication radar function to detect and track any moving targets in the building. Doppler processing features are target position and velocity. The nonlinear radar function is next used to detect nonlinear circuit components in communication devices of the moving personnel [52]. Features for the nonlinear radar function include: 1) operational frequency of the communication device, and 2) the harmonic response (i.e., power level) from the communication device. All features are collected over time and used by the decision process for threat assessment.

3.3 Environmental Sensors and Spectrum Sensing

The environment sensors of the proposed cognitive radar framework in Figure 4 are used to characterize the environment to enhance radar performance. The example in Section 2.1 illustrates how atmospheric information aids CFAR processing to improve performance. Environmental sensors range from a variety of transducers that include passive RF sensors, thermo sensors, atmospheric sensors, and/or global positioning system (GPS) sensors. A widely used passive sensing technique to characterize the RF environment is spectrum sensing. Spectrum sensing is a technique employed by cognitive radio to monitor the RF spectrum for channel availability and the activity of the primary user, i.e., the licensed user, in order to communicate on an unused channel. Detection of the primary user is carried out by spectrum sensing processing. The detection is based on detection theory methods that include matched filtering, energy detection, CFAR, spectral correlation, radio identification based sensing, and waveform based sensing [53].

Spectrum sensing is the environmental sensor considered in this paper. However, the proposed cognitive radar framework is generalized to incorporate other environmental sensing modalities. Spectrum sensing processing is used to identify spectral features, where the spectral features constitute distinct information that characterizes the environment. The environmental features are defined as

$$\Theta_i = \left\{\theta_{i,1}, \ldots, \theta_{i,N_2}\right\}, \tag{4}$$

where $\theta_{i,n}$ is the nth feature, and N_2 is the total number of features. These features are used by the decision process to characterize the RF environment.

3.4 Decision Process

Figure 6 highlights the components of the decision process. The components share information via the database and memory. The target decision process uses current, Ω_i, and past, $\left\{\Omega_1, \ldots, \Omega_{i-1}\right\}$, features (retrieved from memory), for target threat assessment. This assessment is made based on detection, classification, and data fusion techniques known a priori and stored in the knowledge database. Each technique contributes a level of information, or inference level, used for the threat assessment. The inference-level hierarchy is categorized as follows (from low to high) [54]: existence of target (detection), position/velocity (tracking), identity of target (classification), behavior of target, situational assessment, and threat analysis. Following the sensing through-the-wall example, the moving target indication radar function establishes the existence of a moving target and provides position and trajectory. Partial target identity is provided by the nonlinear radar function by identifying the type of communications device carried by the moving target (military radio versus common cell phone). The behavior and situational assessment of the moving target is established over time (with memory) based on a predetermined set of criteria stored in the database. The criterion includes the rooms visited by the moving target or the pace of the moving target (running versus walking). Finally, the threat analysis tags the previous assessments with known conditions, e.g., a person walking with a cell phone is "normal."

A learning measure is used to monitor how the target threat assessment improves over time. The learning measure also monitors the quality of information provided by each radar function. If the quality level of learning is low or deteriorates, then decisions are made by the target decision process in an effort to improve the learning measure for future iterations. Two types of decisions are made by the target decision process: 1) modify the waveform solution space in Equation (2) using predetermined decision criteria (discussed in the paragraph that follows); 2) change the target assessment algorithms or the radar function. Changing the target assessment algorithms (e.g., switching from an energy detection algorithm to a CFAR algorithm) or the radar function (e.g., switching from moving target indication mode to SAR mode) constitutes a systems level event that requires software and hardware changes of the cognitive radar. For example, changing the radar function requires changing the reconfigurable hardware, radar waveforms, target detection algorithms, environmental sensing algorithms, etc. The specific software and hardware changes needed for the cognitive radar are ultimately determined by the systems decision process. One function of the target decision process is to provide the systems decision process with a list of the needed changes. This list is defined as

$$A_i = \left\{a_{i,1}, \ldots, a_{i,N_3}\right\}, \tag{5}$$

where $a_{i,n}$ is the nth systems level change, and N_3 is the total number of changes determined by the target decision process.

To modify the waveform solution space, the target decision process accesses Equation (2) via the knowledge database. The target decision process then changes the ranges of a, f, ϕ, and χ, based on the decision criteria used to improve the learning measure. For example, frequency-dependent clutter is mitigated if f is modified to exclude the frequencies that produce a large response from the clutter. Note that this action could negatively affect the target's response (the target responds at these frequencies, too), and the decision process would need to appropriately balance these tradeoffs. The modified input parameter ranges of the ith iteration are defined as

$$\Phi_i^T = \left\{a_i^T, f_i^T, \phi_i^T, \chi_i^T\right\}, \tag{6}$$

where $\left\{a_i^T, f_i^T, \phi_i^T, \chi_i^T\right\}$ are the modified waveform parameters from Equation (2) determined by the target decision process. Φ_i^T is uploaded to memory and used by the waveform decision process.

The environmental decision process uses current, Θ_i, and past, $\left\{\Theta_1, \ldots, \Theta_{i-1}\right\}$ (retrieved from memory), environmental features for characterization of the environment. The environmental decision process has two main functions: 1) modifying the waveform solution space in Equation (2) using predetermined decision criteria, and 2) identifying significant environment events. Similar to the target decision process, the environmental decision process modifies the waveform solution space in Equation (2) using decision criteria. The decision criteria use the environmental features extracted by spectrum sensing to identify available frequencies for radar transmission and reception. These frequencies are used to modify *f* in Equation (2). The decision criteria uses other environmental features (from different environmental sensors) to modify the other parameters (a, ϕ, and χ) in Equation (2). The modified input parameter ranges of the *i*th iteration are def

$$\Phi_i^E = \left\{ a_i^E, f_i^E, \phi_i^E, \chi_i^E \right\}, \tag{7}$$

where $\left\{ a_i^E, f_i^E, \phi_i^E, \chi_i^E \right\}$ are the modified waveform parameters from Equation (2) determined by the environmental decision process. Φ_i^E is uploaded to memory and used by the waveform decision process.

The environmental decision process is also used to identify significant environment events. An environmental event constitutes any activity that has significant consequences to the cognitive radar. Examples of these events include high-power interference that could saturate the ADC (or other analog components), significant noise-floor elevation in a band used for target detection (a secondary band must then be identified), other RF systems operating in the environment, etc. The environmental decision process creates a list of the environmental events that is defined as

$$B_i = \left\{ \beta_{i,1}, \ldots, \beta_{i,N_4} \right\}, \tag{8}$$

where $\beta_{i,n}$ is the *n*th environmental event and N_4 is the total number of events. The resulting environmental events are uploaded to memory and used by the systems decision process.

The systems decision process formulates the appropriate actions from A_i and B_i. These actions include (but are not limited to) 1) reconfiguration of the analog hardware components to notch out high-power interference; 2) establishment of communication protocols to properly coordinate activities between the cognitive radar and other RF systems operating in the environment; and 3) switching the radar function or target detection algorithm when cued by the target decision process. The systems decision process creates a prioritized list of instructions based on these actions that is then sent to the schedule and control function (Figure 4). This instruction list is defined as

$$\Lambda_i = \left\{ \lambda_{i,1}, \ldots, \lambda_{i,N_5} \right\}, \tag{9}$$

where $\lambda_{i,n}$ is the *n*th instruction and N_5 is the total number of instructions. The resulting instruction list is also uploaded to memory and used by the waveform decision process.

The waveform decision process requires input from all decision processes, memory, and the knowledge database. The decision processes provide the modified waveform solution spaces, $\left\{ \Phi_i^T, \Phi_i^E \right\}$, and the instruction list, Λ_i. The database provides the permissible waveform parameters (transmit power levels, frequencies, etc.) derived based on

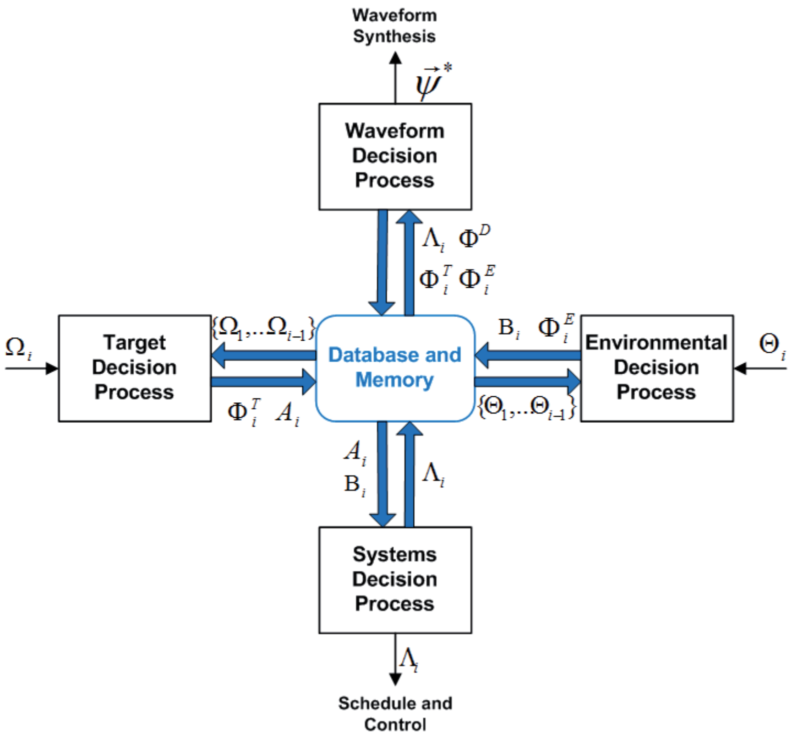

Figure 6. The decision process used by the generalized cognitive radar system in Figure 4.

regulations set by governing authorities:

$$\Phi^D = \left\{ a^D, f^D, \phi^D, \chi^D \right\}, \qquad (10)$$

where $\left\{ a^D, f^D, \phi^D, \chi^D \right\}$ are the permissible set of waveform parameters that can be used for transmission. The waveform decision process must then find the optimal set of waveform parameters using the input information from $\left\{ \Phi_i^T, \Phi_i^E, \Phi^D \right\}$. A possible formulation of this problem is multi-objective optimization. Multi-objective optimization was explored by Rondeau, Rieser, and Bostian [55, 56] for software-defined radio (SDR), where a set of "knobs" and "meters" were defined to control the functions of the radio. The knobs defined the input parameters used by the software-defined radio, and included the carrier frequency, transmitted power, modulations, symbol rate, and pulse shaping [56]. The knobs constituted the solution space for multi-objective optimization. The meters defined the objective functions used for the software-defined radio that included bit error rate, spectral efficiency, occupied bandwidth, SINR, data rate, and power consumption [56]. The multi-objective optimization problem was to select the "best" solution (knobs) that optimized all objective functions (meters).

The waveform decision process first selects the proper objective functions using the actions in the instruction list, Λ_i: different actions correspond to different objective functions used for the optimization process. For example, objective functions used for the SAR radar function (e.g., maximize bandwidth) are different than those used by the nonlinear radar function (e.g., maximize spectral resolution). Objective functions for the proposed cognitive radar include (but are not limited to) maximum target SNR; minimum environment interference and noise power; minimum system power consumption; minimum transmission power; maximum/minimum bandwidth; maximum/minimum step or chirp rate; maximum/minimum spectral resolution. For this development, K objective functions are utilized and defined as $\left\{ z_1(\bullet), \ldots, z_K(\bullet) \right\}$.

Once the objective functions are identified, the solution space, $\Psi = \left\{ \psi_a, \psi_f, \psi_\phi, \psi_\chi \right\}$, used for multi-objective optimization, is formulated using the mapping functions $\left\{ \Gamma_a, \Gamma_f, \Gamma_\phi, \Gamma_\chi \right\}$, where $\psi_a = \Gamma_a\left(a_i^T, a_i^E, a^D \right)$ $\psi_f = \Gamma_f\left(f_i^T, f_i^E, f^D \right)$, $\psi_\phi = \Gamma_\phi\left(\phi_i^T, \phi_i^E, \phi^D \right)$, $\psi_\chi = \Gamma_\chi\left(\chi_i^T, \chi_i^E, \chi^D \right)$. Each term in $\left\{ \psi_a, \psi_f, \psi_\phi, \psi_\chi \right\}$ is a knob with a range of values. The mapping functions combine the appropriate waveform parameters using a set of predetermined conditions. One possible formulation for the mapping functions is the intersection operation. For example, $\psi_f = \Gamma_f\left(f_i^T, f_i^E, f^D \right) = f_i^T \cap f_i^E \cap f^D$ indicates the common frequencies between the vectors f_i^T, f_i^E, and f^D.

The multi-objective optimization problem is formulated as follows [57]. First, define the decision-variable vector, $\vec{\psi} = \left\{ \vec{\psi}_a, \vec{\psi}_f, \vec{\psi}_\phi, \vec{\psi}_\chi \right\}$ in the solution space Ψ. Note that the terms $\vec{\psi}_a \in \psi_a$, $\vec{\psi}_f \in \psi_f$, $\vec{\psi}_\phi \in \psi_\phi$, $\vec{\psi}_\chi \in \psi_\chi$ are single elements (not vectors). The optimizer must find a vector $\vec{\psi}^* \in \vec{\psi}$ that minimizes/maximizes the set of K objective functions $z\left(\vec{\psi}^* \right) = \left\{ z_1\left(\vec{\psi}^* \right), \ldots, z_K\left(\vec{\psi}^* \right) \right\}$. The vector $\vec{\psi}^*$ consists of the optimized waveform parameters, and is sent to the waveform synthesis process (Figure 4).

Solutions to multi-objective optimization problems consist of finding the Pareto optimal set [58], a surface of non-dominated solutions. Non-dominated solutions are determined based on their superiority to all other solutions in the solution space. The set of non-dominated solutions are optimal because the solutions are neither superior nor inferior to one another. Genetic algorithms can then be used to solve the multi-objective optimization problem. Note that genetic algorithms should only be implemented for a large solution space. Genetic algorithms search difference regions of the solution space in parallel allowing for complex solutions with non-convex, discontinuous, and multimodal solution spaces [57]. The search method used by genetic algorithms is randomized, and therefore permits a rapid global solution and avoids losing potential non-optimal solutions [55, 56].

4. Conclusion

Although it remains unclear if radars are truly cognitive, the literature indicates that cognitive radar is well founded in the research areas of cybernetics, decision-theoretic approaches, machine learning, knowledge-based radar systems, and matched illumination. These research areas were investigated to highlight the six principal components of cognitive radar: 1) informed decision making via the decision-theoretic approach; 2) passive environmental sensors and radar sensors; 3) learning algorithms to improve performance and adapt to unknown environmental scenarios; 4) the knowledge database that contains environmental, clutter, target, and other a priori information; 5) the waveform solution space Φ for known targets of interest; and 6) receiver-to-transmitter feedback to mitigate clutter/interference and maximize target information. The technologies needed to support these six principal components include 1) signal processing algorithms to process target, clutter, environmental information; 2) digital hardware, including memory; and 3) reconfigurable analog hardware for the radar receiver and transmitter. The six principal components were used in the generalized cognitive radar framework that is intended for advancing current traditional radar to that of cognitive radar.

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Human-Body-Perturbed Antenna Integration in Indoor Propagation Simulator

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Abstract

This paper presents first results of simulation of a radio link between two antennas mounted on a body. The body mobility is handled at two levels: the trajectory level and the body-mobility level. A perturbed antenna model is used to acknowledge the effect of the body directly in the radiation pattern. The aggregated channel impulse response simulated in an indoor environment is presented. The presented results validate the interest of the proposed approach for further integration with higher-layer simulation.

1. Introduction

In the context of the conception and design of communication systems, the knowledge of the channel is always of importance. This is especially true for body-area network (BAN) channels, since the transmission channel is strongly affected by the body and its effect on body-mounted antennas. This work is a part of the CORMORAN project. One of the project requirements is studying location-related scenarios: large-scale individual motion capture (LSIMC) and coordinated group navigation (CGN) [1]. The tool used has thus been designed to handle body-area networks (BANs) for multi-agent and multi-link situations. However, in this work, for ease of exposition, we focus on a simple single-agent, single-link case.

The body-area network channel is manifold, as it may consist of different kinds of links: on-body and off-body links, the later including body-to-infrastructure and body-to-body links. The simulator used implements classical ray-tracing techniques [2]. It handles the agents' mobility in a specific layout, and also the body mobility using realistic body abstraction obtained from motion-capture files. The antennas are fully described in a compact form using spherical-harmonic expansions, as described in [3].

The chosen approach has two levels. A first level acknowledges the motion of the center of gravity of the body along realistic indoor trajectories, using a discrete event simulator (DES). A second level superimposes the body mobility on the trajectory. All the links of interest for the scenario can be calculated and stored for further post processing. To this end, a perturbed antenna model, assessing the pattern behavior when the antenna is placed around the human body, is presented. This approach assumes that the effect of the body's presence is being taken into account in the antenna's radiation pattern, avoiding having to manage a complex body description in the ray tracing.

The paper is organized as follows. Section 2 describes the human-body mobility model, based on motion-capture files, and the dedicated antenna model. Section 3 presents first integration simulation results, and a comparison between situations using a body-perturbed and a non-body-perturbed antenna.

2. Human Mobility and Antenna Model Integration

In this section, the body-area network channel simulation is presented, including a description of how the human-body mobility and the antenna model are handled.

2.1 Modeling of Human-Body Mobility

Two main approaches can be used to model the human-body mobility. Traditionally, biomechanical models are used to represent the human mobility in a walking situation [4]. An alternative is to make use of data coming from motion capture. Among the different existing motion-capture data file formats, the C3D (Coordinates 3D) format

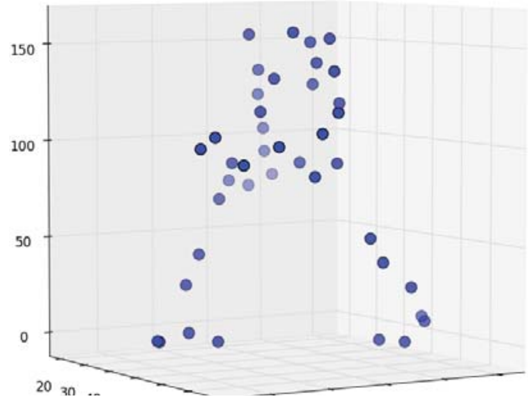

Figure 1a. A C3D frame.

Figure 1b. A cylindrical body model.

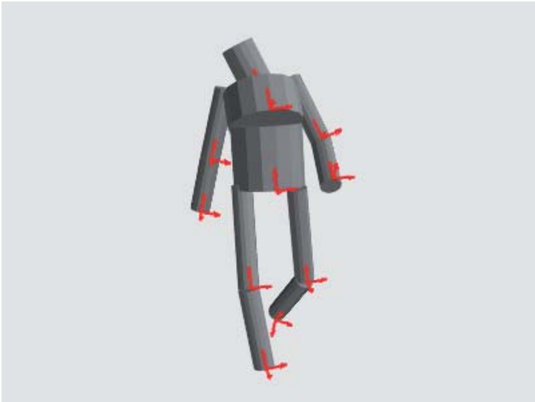

Figure 1c. A cylindrical body model with 11 *CCS*.

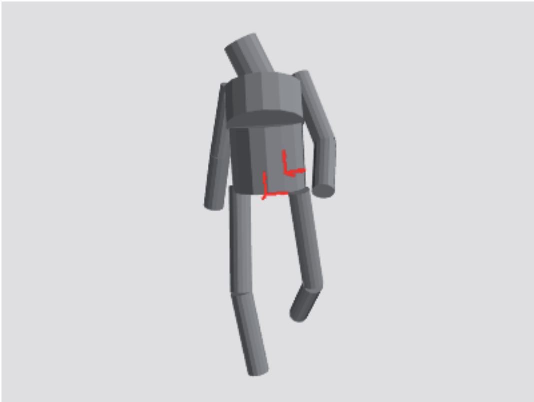

Figure 1d. A cylindrical body model with two *DCS*.

is used here, due to its compliance with most motion-capture systems. Among the data stored in C3D files are the whole three-dimensional coordinates of a fixed number of points, representing human-body sensors at very specific conventional locations on the body at each time stamp. A "3D frame" consists of a set of those three-dimensional points. For example, Figure 1 represents a 41-point frame. The main advantage of using motion-capture data is that it enables investigating a large variety of motion situations, not only limited to a walking scenario.

The data extracted from C3D files are then used to build a human-body cylindrical model. The C3D original full-marker data are filtered out from 41 to 16 points, creating a simplified cylindrical model. This model is a good tradeoff between fidelity of the representation and simplicity of the implementation. Similar approaches were proposed in [5]. Sometimes, we may have at our disposal a full captured trajectory of the body. In this case, there is no need for any further processing. In practice, an arbitrary trajectory is generated, and in this case, it is necessary to merge the synthesized trajectory with a body-walking sequence. In this work, the body trajectory is obtained from a discrete event simulator force-based multi-agent simulator, which can produce an arbitrary number of realistic human trajectories into the layout. Once the trajectory has been calculated, the body is inserted at a good location in time and space. Once properly positioned, it remains to handle the positioning and orientation of the body-mounted radiating element in the global scene. This is done through the introduction of a chain of time-dependent (except for the global one) coordinate systems, relating one to another via specific linear transformations (translation or rotation). The important aspect is to properly ponder the rays with the appropriate complex gain from the antenna pattern. The defined chain of coordinate systems is as follows:

$$GCS \rightarrow CCS(t) \rightarrow DCS(t) \rightarrow ACS(t). \qquad (1)$$

- *GCS* refers to the global coordinate system. The layout and the rays from the ray tracing are expressed in this *GCS*.
- *CCS* refers to the cylinder coordinate system: each cylinder of the body model is associated with a dedicated *CCS*. A *CCS* is obtained from the large-scale trajectory and the body frame corresponding to a given time on the body trajectory.
- *DCS* refers to the device coordinate system: this coordinate system is a rotated and/or translated version of the *CCS*. The origin of this coordinate system is the

device's position. A device is unambiguously placed on a body cylinder via three parameters: $(l, h, cylId)$. $0 < l < 1$ is a parameterization of the length of the cylinder, h is the height of the device with respect to the cylinder of ID $CylId$.

- *ACS* refers to the antenna coordinate system: it is an arbitrarily rotated version of the *DCS* that defines the antenna's local coordinate system. The radiation pattern of the antenna is known in this *ACS*. One device could theoretically have several different *ACS*. This possible feature is not exploited in the following.

Figure 1 shows the C3D frame in Figure 1a, the body cylinder model built using C3D data in Figure 1b, the body and all the *CCS* in Figure 1c, and the body with the two selected *DCS* in Figure 1d.

2.2 Antenna Model

In the context of body-area-network radio-channel simulation and modeling, knowledge of the antenna's radiation pattern is fundamental. The human body disturbs the antenna pattern in a considerable way. One rigorous way to introduce the body effect in the physical simulator would be to apply an electromagnetic solver. However, for the purpose of the higher-level simulation we are addressing, this approach is too computationally intensive. As a compromise alternative, we proposed to account for the body effect in the antenna pattern itself by using an equivalent antenna, obtained from the unperturbed free-space antenna and parameters depending mostly on the distance of the antenna from the body.

To study the effect of a human phantom on a UWB antenna, a measurement campaign was carried out to study the effect of the human presence on the antenna. The antenna was measured in free space and placed around a cylindrical human phantom at different distances [6].

It is well known that a natural and compact representation of the antenna pattern is based on a spherical-harmonic (SH) basis expansion. According to [3, 7], the far-field radiation pattern $\mathbf{F}$ can be expanded in terms of scalar spherical harmonics with vector coefficients:

$$\mathbf{F}(\theta,\phi,f) = \sum_{l=0}^{L} \sum_{m=-l}^{l} \mathbf{c}_{lm}(f) Y_l^m(\theta,\phi), \qquad (2)$$

where $Y_l^m(\theta,\phi)$ are the spherical-harmonic functions at the level l and the mode m, $\mathbf{c}_{lm}$ are spherical-harmonic coefficients, and θ and ϕ are respectively the co-elevation and azimuth angle of the spherical coordinate system. Using the spherical-harmonic (SH) expansion, the antenna data is reduced to a few spherical-harmonic coefficients. Exploiting the above spherical-harmonic decomposition, we have proposed a model that predicts in the spherical-harmonic coefficient domain the perturbation of the complex pattern caused by the human presence. It is obtained from experimental data, and consists of a simple linear model relating the spherical-harmonic coefficients of a disrupted antenna to the free-space coefficients and antenna-phantom distance:

$$\tilde{\mathbf{C}}(d) = \mathbf{A}(d) \odot \mathbf{C}^{\mathbf{fs}}, \qquad (3)$$

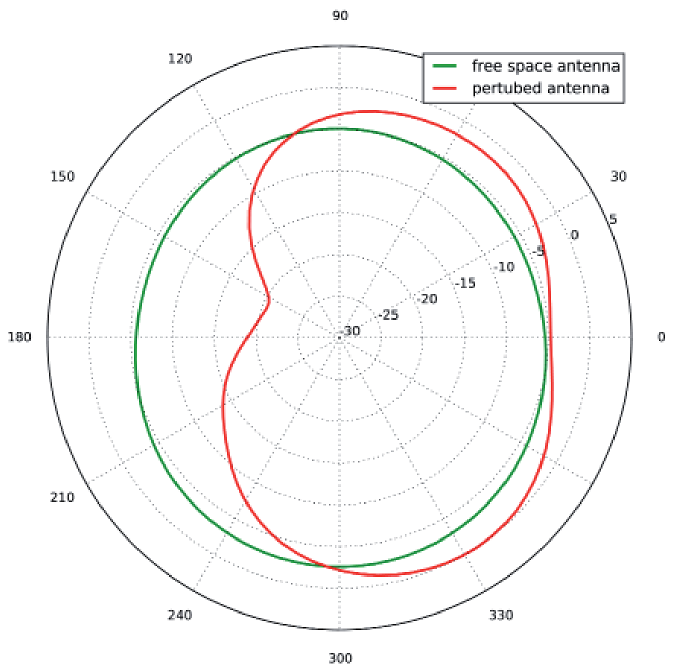

Figure 2. The perturbed (red) and free-space (green) antenna patterns at $f = 4$ GHz in the plane (x, y).

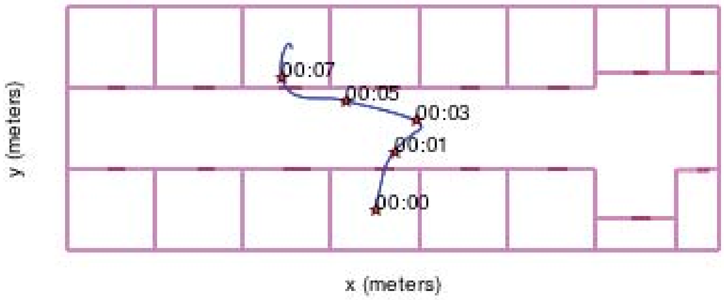

Figure 3. The simulation layout and agent 10 s trajectory from one room to another.

where d is the antenna-phantom distance, $\mathbf{C}^{\mathbf{fs}}$ are the spherical-harmonic coefficients of the antenna in free space, $\tilde{\mathbf{C}}(d)$ denotes the perturbed version of the spherical-harmonic coefficients, and $\mathbf{A}(d)$ is the linear model vector of parameters representing the perturbation. Figure 2 shows the "Thomson" antenna patterns in the plane (x, y) at $f = 4$ GHz in free space (green), and around the human phantom (red). We observed the perturbation brought out by the human phantom's presence, placed at the distance $d = 30$ mm from the antenna. The phantom was a cylinder with dimensions that were chosen to represent a human arm, and filled with a phantom liquid. This model was described with more detail in [8].

This model was integrated in the indoor propagation simulator to simulate and model a realistic body-area-network channel by taking into account the antenna perturbation.

3. Simulation and Results

In this section, we consider the link from hip to right wrist. Comparisons between using a perturbed antenna and a free-space antenna are presented. The simulation was made in a defined layout and for a specific trajectory in a walking scenario, shown in Figure 3. There were three different regimes in this trajectory. The agent started to move in a room, then went into a long corridor, and finally reached another room on the other side of the corridor. The overall trajectory time was 10 s, and the sampling period along the trajectory was 10 ms. At each instant, the rays between the transmitter and the receiver were identified and evaluated.

The antennas were applied with their proper orientation, and the transmission channel's impulse response, $h(t, \tau)$, was evaluated. The two patterns that were used are presented in Figure 2.

The pattern used for the perturbed antenna was obtained using a phantom modeling of the antenna in the vicinity of a human arm. This same pattern was also used for modeling of the antenna mounted on the hip, which, of course, was less justified. However, for the purpose of illustrating the approach, this was not an issue. Any more-realistic antenna pattern coming from a rigorous simulation or measurement could be used instead, if more realism was needed.

Figure 4 represents the body cylindrical model with the antenna placed on the body. The chosen pattern radiated mostly toward the half space opposite to the body's members (arms, in this case). In fact, by using these antennas, the human body's presence was taken into account without having to actually represent the body in the global scene. Notice that this was an approximation that did not capture everything from the propagation phenomena appearing on the body.

The channel impulse response was evaluated over a bandwidth from 3 GHz to 6 GHz, allowing UWB waveform simulation. The time-varying channel impulse response is expressed as

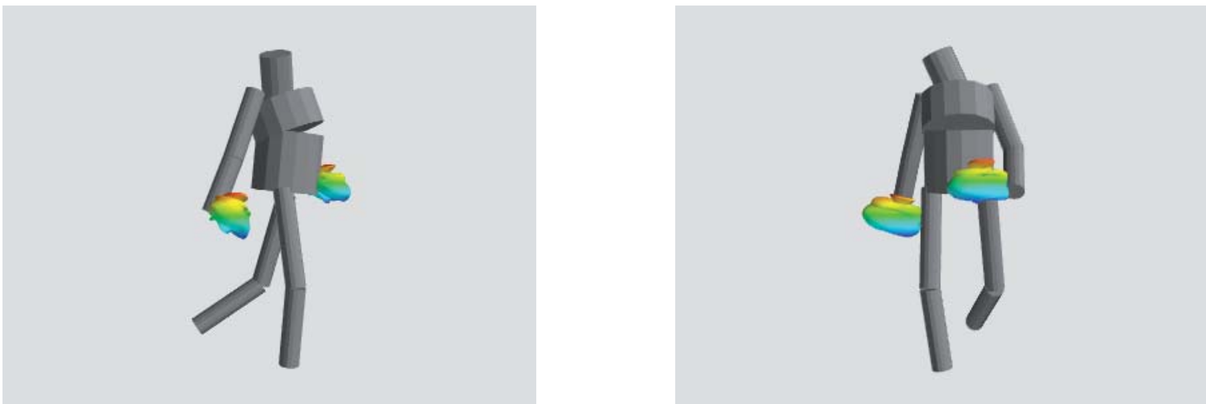

Figure 4. Two views of the cylindrical body model with the perturbed antenna.

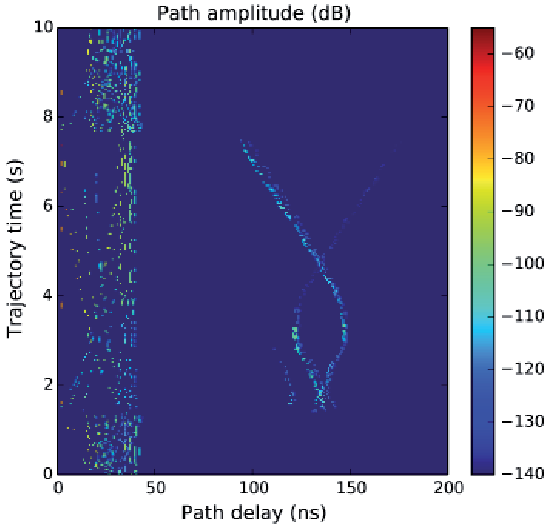

Figure 5a. The amplitude of the paths during the trajectory time using the perturbed antenna.

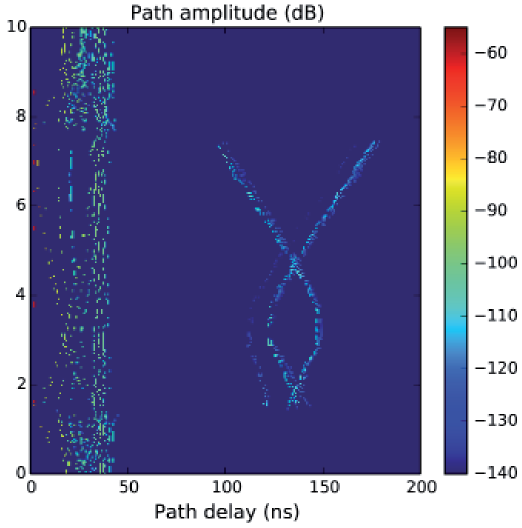

Figure 5b. The amplitude of the paths during the trajectory time using the free-space antenna.

$$h(t,\tau) = \sum_{k=0}^{K(t)} \alpha_k(t)\delta\left[\tau - \tau_k(t)\right], \qquad (4)$$

where $K(t)$ is the number of paths, and $\alpha_k(t)$ and τ_k are the amplitude and the arrival time of the kth path.

The situation we are studying is an on-body channel, in the sense that the transmitter and receiver are placed on the body. However, the part of the channel we are considering is obtained via off-body interactions. In this example, the pure on-body contribution was not fully taken into account, especially in the delay domain. There exists a delay gap in the delay domain between the direct path and the first path coming to the off-body contribution (reflection on the environment). In this section, the preliminary results obtained for the human-body mobility and antenna model obtained with the WBAN physical simulator are presented, as well as a comparison between aggregated infinite bandwidth CIR obtained using a perturbed antenna and a free-space antenna.

Figure 5 shows the amplitudes and delays of the different paths while the agent was traveling during the trajectory using the free-space antenna (Figure 5b) and using a perturbed antenna (Figure 5a). It shows the different regimes in the trajectory, and how the channel structure varied with the environment. We noticed that the global channel structure was nearly the same. However, we observed a dissimilarity in terms of the amplitudes of the paths, since they were weighted differently according to the antenna used. At the beginning of the trajectory during the first two seconds, the agent was walking in a small room, and the channel structure did not exceed 50 ns, which corresponded to the vertical band on the left. The agent the went out from the room, almost in the middle of the corridor, and the two reflections at both ends of the corridor were almost superimposed. The agent then went on the right until time 3 s, when the delay from the reflection from right corridor wall was decreasing while the delay from the left wall was increasing. Finally, the agent reached another room, and the multipath structure observed during the first second was reestablished. The major effects of the body-perturbed antenna were observed in two specific regions. The first region was the corridor region, where the ray weight differences were clear, and illustrated well the body shadowing of one reflected path coming from the back. This simple approach is thus in fact able to correctly capture what would be observed in practice.

The second region, and the most important difference, was when zooming and observing the first paths affected by the body's presence during 3 s, which corresponded to approximately three human steps in Figure 6. This showed that the amplitudes of the first paths did not vary in a considerable manner when using the free-space antenna. The observed variation was due to distance variations between the receiver and the transmitter, relative to the arm movement in a walking scenario. The variations were not due to the human-body shadowing, which was quite well reproduced with the perturbed antenna case where the line-of-sight, non-line-of-sight, and even the transition region were observed.

These results might be well observed when representing the total received power, P_r, at each instant, given by

$$P_r(t) = \sum_{k=0}^{K(t)} \left|\alpha_k(t)\right|^2, \qquad (5)$$

where $K(t)$ is the number of paths at t, and $\alpha_k(t)$ is the kth path's amplitude.

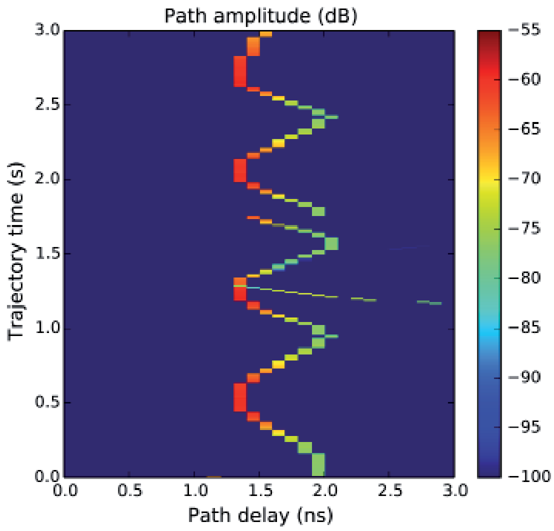

Figure 6a. The first path amplitude during the trajectory time using the perturbed antenna.

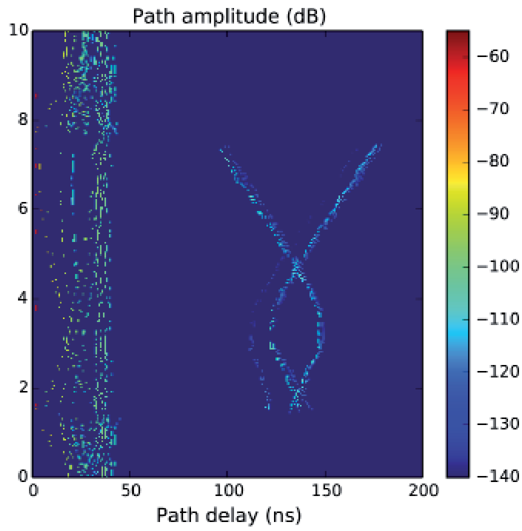

Figure 6b. The first path amplitude during the trajectory time using the free-space antenna.

Figure 7 explicitly showed the human trunk shadowing in the hip-to-right-wrist link in a walking scenario, and confirmed the paths' amplitude results. It showed that the total received power variation when using the free-space antenna was around 5 dB, which did not consider the presence of the human body: it was only a distance-variation effect. However, with the perturbed antenna, the variation in P_r was around 15 dB, which is more realistic in body-area-network channels. These variations in received power are coherent with measurement results in [9], which confirms that the shadowing variation in almost the same condition (hip-to-right-wrist link, walking scenario) but in an anechoic chamber is around 10 dB.

4. Conclusion and Perspectives

This paper presented a full simulation of a radio link between two antennas mounted on the body, integrating realistic large-scale mobility and body mobility. An original technical choice for the integration of a perturbed antenna model by a human phantom in the physical simulator PyLayers has been presented. The results showed that the proposed approach provides a realistic range in terms of received power, and provides a realistic radio observable variation. These observables can always be produced with ground-truth values of the position and orientation of the radiating element on the devices.

A further step would be to produce an improved antenna description, better describing the trunk perturbation, and to introduce the statistical model described in [9] for the on-body channel because the currently implemented approach cannot give access to the correct CIR delays. Another immediate perspective is to study the body-to-body channel in realistic indoor human motion and exploitation of produced traces for evaluating various MAC layer schemes suited for body-area-network localization scenarios of the CORMORAN project.

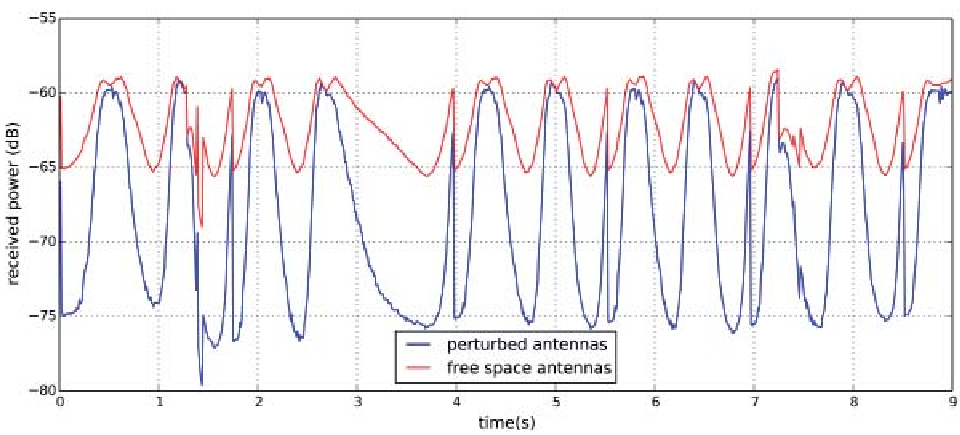

Figure 7. Shadowing for the link from hip to right wrist for a walking sequence.

5. Acknowledgment

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Introduction to Three Papers on Radio-Propagation Studies Related to Public-Safety Communications

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The National Institute of Standards and Technology (NIST) is involved in a several-year effort to understand and address the wireless communication problems that first responders (e.g., firefighters, police, and emergency medical services, EMS) are confronted with day-to-day and in large-scale emergencies and disaster situations.

Regardless of the type of emergency event, the ability to maintain voice and voice communications remains one of the most important elements for a successful response. The success or failure of a radio transmission can make a life or death difference for a police officer in need of assistance, a firefighter trapped in a burning building, or an EMS professional needing patient information before being able to administer potentially lifesaving treatment. For over a decade, NIST, in partnership with the National Telecommunications and Information Administration (NTIA), and with sponsorship from the Department of Homeland Security (DHS), has dedicated significant resources towards addressing the most pressing wireless communications issues facing the public-safety community. The Public Safety Communications Research (PSCR) program work addresses issues such as developing test processes and programs to ensure that public-safety radios from different manufacturers are interoperable with one another, developing measurement methods to determine audio intelligibility in high-noise environments (such as a burning building), and creating new techniques for grading video quality based on the public-safety-related tasks to be performed. As public safety begins the move to broadband communications, efforts are now underway to ensure the standards are in place so that public safety has access to next-generation communications equipment that meets their mission-critical needs.

One major part in this overall effort is to understand the radio-propagation environments confronted by first responders. In what follows, we present three papers that summarize experiments performed and data collected and processed for various radio-propagation environments over the past ten years. The first paper, entitled "Propagation Measurements Before, During, and After the Collapse of Three Large Public Buildings," reports on experiments performed before, during, and after the implosion of three large building structures. This consisted of measurements of the attenuation of radio signals caused by the building materials and structures during the implosion process of the various structures. Measurements were performed at frequencies of interest to emergency responders, including public-safety and cell-phone bands (approximately 50 MHz, 150 MHz, 225 MHz, 450 MHz, 900 MHz, and 1.8 GHz). The second paper [which will appear in the December issue of the *Radio Science Bulletin*], entitled "Radiowave Propagation in Urban Environments with Application to Public-Safety Communications,'' characterizes key elements that pose challenges to public-safety radio communications into and out of large buildings. This includes the strong attenuation of radio signals caused by losses and scattering in the building materials and structure, and the large signal variability that occurs throughout these large structures. We provide the parameters for representative log-normal distributions for six frequency bands ranging from 430 MHz to 4.9 GHz. Finally, the third paper [to appear in the March 2015 issue], entitled "Peer-to-Peer Urban Channel Characteristics for Two Public Safety Frequency Bands," reports on experiments performed in the streets in downtown Denver, CO, for frequencies between 700 MHz and 4.9 GHz. The channel models discussed in this paper should be useful for public-safety communication system designers.

The experimental data discussed here represent a large public-domain dataset. The experimental dataset presented here and in the various references will aid in improving channel descriptions for large public buildings, and will be useful for assessing current and future wireless technology in emergency scenarios. These data may also be used for standards development, and for qualifying wireless equipment in environments such as those studied here.

Propagation Measurements Before, During, and After the Collapse of Three Large Public Buildings

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Abstract

NIST is investigating radio communications problems faced by emergency responders (e.g., firefighters and police) in disaster situations such as collapsed buildings. A fundamental challenge to communication into and out of large buildings is the strong attenuation of radio signals caused by losses and scattering in the building materials and structures, and the problem is amplified in a collapsed building. We are investigating various schemes for detecting emergency responders and civilians with portable radios or cell phones who may be trapped in voids in a collapsed or partially collapsed building. The first part of this effort is to understand radio propagation in collapsed structures. Buildings scheduled for implosion provide the ideal research environment for investigating radiowave propagation issues in fully or partially collapsed structures. The experiments reported here were performed before, during, and after the implosion of three large building structures. They consisted of measurements of the attenuation of radio signals caused by the building materials and structural components. Measurements were performed at various frequencies of interest to emergency responders, namely frequencies near the public-safety and cell-phone bands (approximately 50 MHz, 150 MHz, 225 MHz, 450 MHz, 900 MHz, and 1.8 GHz).

1. Introduction

Understanding the shielding and/or attenuation properties of large buildings and structures is becoming an important issue for two particular applications. First of all, when first responders (emergency workers) enter large structures (such as apartment and office buildings, sports stadiums, stores, malls, warehouses, convention centers, etc.), communication using portable radios to individuals on the outside of these large structures can be problematic [1]. This is especially true in large-scale disaster situations (e.g., collapsed buildings). Unreliable communications may occur due to decreased signal strength and large variability in the signals brought about by losses through structural materials, and the problem is amplified in a collapsed building. Reports published on the rescue efforts at the World Trade Center Towers [2, 3] highlighted this difficulty. The second application involves protecting sensitive electronic equipment from harm due to intentional directed electromagnetic energy (e.g., directed electromagnetic weapons). In this application, the shielding properties of large buildings can contribute to the protection of electronic devices. Understanding the behavior of these large structures therefore gives guidance for the protection of electronic devices.

In this paper, we concentrate on first-responder communication problems. However, the results presented here can be used to address the issue of protecting sensitive electronics, as well. The National Institute of Standards and Technology (NIST) has investigated communication problems faced by emergency responders (firefighters, police, and emergency medical staff) in disaster situations such as collapsed buildings. As part of this effort, we investigated the propagation and coupling of radio waves into large structures. We are also investigating various schemes for detecting emergency responders and civilians with portable radios or cell phones who are trapped in voids in a collapsed or partially collapsed building. In order to investigate the propagation issues associated with fully or partially collapsed structures, buildings scheduled for implosion were used in this study, and as such, various data sets were collected during the collapse of three different building structures.

The experiments reported here were performed on three different types of large building structures that were scheduled for demolition by implosion: a 13-story apartment complex in New Orleans, the old Veterans

Figure 1a. A 13-story apartment building in New Orleans, Louisiana.

Figure 1b. A close-up of the exterior of the 13-story apartment building in New Orleans, Louisiana.

Figure 1c. An interior view of the 13-story apartment building in New Orleans, Louisiana.

Figure 1d. An interior view of the 13-story apartment building in New Orleans, Louisiana.

Figure 1e. An interior view of the 13-story apartment building in New Orleans, Louisiana.

Stadium in Philadelphia, and the old Convention Center in Washington, DC. Measurements were performed at frequencies of interest to emergency responders, including public-safety and cell-phone bands (approximately 50 MHz, 150 MHz, 225 MHz, 450 MHz, 900 MHz, and 1.8 GHz).

Three types of data were collected during these experiments. The first set of data, which we refer to as a "radio mapping," was collected a few days before the structures were imploded. This involved carrying transmitters (or radios) tuned to various frequencies throughout the structures while recording the received signal at sites located outside the structures. The purpose of the radio-mapping measurements was to investigate how the signals at the different frequencies coupled into the structures, and to determine the variability in field strength throughout the structures.

The second set of data was gathered from radios placed at fixed sites throughout the structures. Received signals were collected before, during, and after the implosion. The receiving systems in this case were at both fixed and mobile sites. The mobile receiving system consisted of measurement instruments and antennas mounted on a modified garden cart (approximately 1 m^3 in size). The cart was pulled around the perimeter of the structures both before and after the implosion, enabling direct comparison of signal strength as a function of azimuth angle (a) through the standing structure, and (b) through the resulting pile of rubble after the collapse.

The third set of data was obtained by monitoring signals coupled to metallic debris located in the proximity of transmitters buried in the collapsed building. These metallic "debris radiators" (a set of cables laid to investigate the concept) ran through the rubble, and were exposed at the perimeter of the collapsed building. The idea is that when a large structure collapses, metal objects (electrical wires, metal piping, rebar, venting pipe, etc.) protrude from the rubble.

The purpose of this paper is to provide an overview of the data obtained in these three implosion experiments. We briefly summarize the data collected, including propagation statistics, and discuss some of the interesting propagation and attenuation effects we observed (including the "effective" antenna patterns of buildings). More detailed data are given in NIST Technical Notes [4-6]. We anticipate that improved channel descriptions provided by these measurements presented here will be useful for assessing current and future wireless technology in emergency scenarios, for standards development, and for qualifying wireless equipment in environments such as those studied here.

The measured results presented here provide key parameters that describe the wireless propagation environment in representative responder environments. The variability in received signal level throughout the structures we studied was on the order of tens of decibels, while the expected combined systematic and random errors introduced by our measurement equipment were expected to be on the order of tenths of decibels. As a result, the uncertainties were dominated by the variability in the received signal level, and were not explicitly reported.

Figure 2a. The sports stadium in Philadelphia, PA.

2. Building Descriptions

Three different types of large buildings were studied in the NIST tests. The first building was a 13-story apartment complex, located in a suburb of New Orleans, Louisiana (Figure 1). The thirteen stories included a ground-level common area and parking, and 12 floors, with 14 efficiency apartments on each floor. The individual apartments on each level opened to a common outside hallway on the west side of the building. There was an elevator control

Figure 2b. The infield of the sports stadium in Philadelphia, PA.

Figure 2d. A view of the interior of the sports stadium in Philadelphia, PA.

Figure 2c. Another view of the sports stadium in Philadelphia, PA.

Figure 2e. Another view of the interior of the sports stadium in Philadelphia, PA.

and maintenance room in a penthouse on the roof of the building. This space was accessed by a metal spiral staircase on the top floor. There were two internal passenger elevators and one external freight elevator near the center of the building. Two external stairwells near each end of the building accessed all floors. There was no basement in this building. The building was constructed of reinforced concrete, steel, and standard interior finishing materials. Significant demolition was already completed when we arrived: all plumbing fixtures, most glass windows and doors, and the contents of the apartments had been removed. The reinforced-concrete walls on the lower two levels had been cut away, with only support columns remaining. The ground-level common-area structure was demolished and the debris in the area removed. Material had been judiciously removed from certain structural parts of the lower levels, including stairwells and elevator shafts, to facilitate a proper collapse during the implosion. Figure 1 shows the details of the original building, and some of the preparations and partial demolition of the lower levels.

The second structure was Veterans' Stadium, a large sports arena in Philadelphia, PA. The nearly circular stadium was constructed of reinforced concrete, steel, and standard interior finishing materials. Figure 2 shows details of the original stadium, and some of the preparations and partial demolition of the different sections of the stadium. As shown in these figures, the stadium had multiple levels, with large open areas. The exterior perimeter of the stadium was approximately 805 m (1/2 mile). Significant demolition was already completed when we arrived two weeks before the implosion: all plumbing fixtures, most glass windows and doors, and other contents had been removed.

The third structure was the old Washington DC Convention Center. The two-level structure was constructed of reinforced concrete, steel, and standard interior finishing materials. Figure 3 shows details of the original convention center, and some of the preparations and partial demolition of the different sections of the convention center. As shown in Figure 3, the convention center had two large levels with

Figure 3a. The Convention Center in Washington, DC.

Figure 3b. Another view of the Convention Center in Washington, DC.

Figure 3c. Another view of the Convention Center in Washington, DC.

Figure 3d. A view of the interior of the Convention Center in Washington, DC.

Figure 3e. Another view of the interior of the Convention Center in Washington, DC.

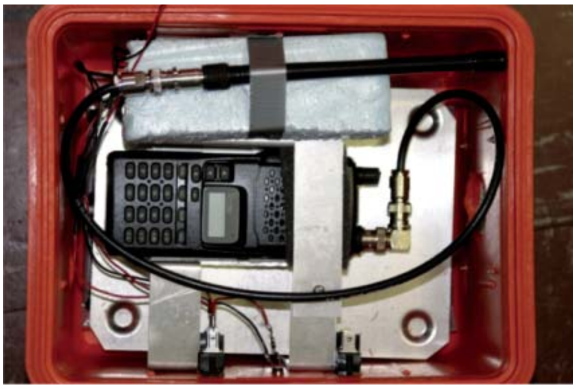

Figure 4a. A close up of a typical transmitter for the lower frequency band.

Figure 4b. A typical transmitter for the lower frequency band.

Figure 4c. A typical transmitter for the higher frequency band.

three levels of offices. As with the other two buildings, significant demolition was already completed when we arrived two weeks before the implosion: all plumbing fixtures, most glass windows and doors, and other contents had been removed.

3. Experimental Setup

We used portable radios similar to those used by emergency responders, hardened against falling debris and modified to transmit over long time periods (see Figure 4). These radios were either carried through the building structures, for the radio-mapping experiments, or were placed at fixed locations in the structures before implosion. The measurement system consisted of a portable spectrum analyzer, a GPS receiver, and a laptop computer. The data-collection process was automated by use of software designed to control the analyzer, and to collect, process, and save data at the maximum throughput of the equipment. GPS information was recorded in order to track the position of the mobile cart during perimeter measurements around the buildings. We assembled four antennas on a 4 m mast. The radio-frequency output from each antenna was fed through a 4:1 broadband power combiner, giving us a single input to the spectrum analyzer, which could then scan over all the frequencies of interest without switching antennas. The four antennas were chosen to be optimal (or at least practical) for each of the measured frequency bands. The selected antennas consisted of an end-fed vertical omnidirectional antenna for 50 MHz; a log-periodic dipole array (LPDA) used for the 160 MHz, 225 MHz, and 450 MHz bands; and Yagi-Uda arrays for 900 MHz and 1830 MHz. This assembly could then be mounted on a fixed tripod at one of the receiving sites, or it could be inserted into a modified garden cart for portable measurements: see [4-7] for photos and more details on the measurement system.

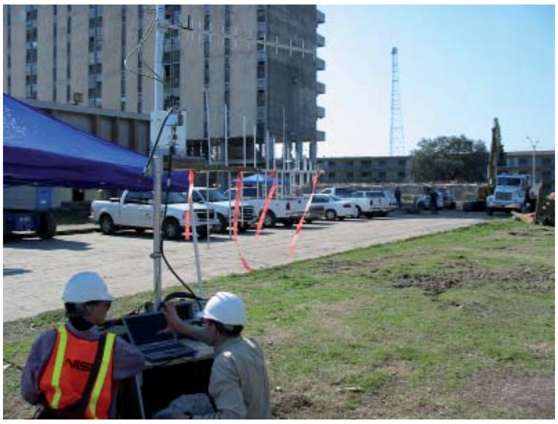

Figure 5a. The receiver site for the radio-mapping experiment for the apartment building.

Figure 5b. A different view of the receiver site for the radio-mapping experiment for the apartment building.

Figure 6a. The receiver site for the radio-mapping experiment for the sports stadium.

Figure 6b. A different view of the receiver site for the radio-mapping experiment for the sports stadium.

4. Experiments Before the Collapse

One receiver site was used for the radio-mapping experiments for the 13-story apartment building and for the sports stadium, as shown in Figures 5 and 6, respectively. Three different receiver locations were used for the convention center (see Figure 7), which provided additional data. We could use only one receiver location for the apartment building and the sports stadium because of limited access to the buildings' perimeters (due to pre-implosion preparation by the demolition company). More details on the location of the receiver sites used in these three experiments were given in [4-6].

Figures 8-10 show typical sets of data collected during the radio-mapping experiments (moving transmitters in the building with a fixed receiver outside of the building) for the apartment building, the sports stadium, and the convention center, respectively. As each transmitter was carried throughout the building structures during these experiments, the transmitter location was noted in the data file. This location is indicated on the *x* axis of Figures 8-10, where this location was used to determine a specific location of the transmitter. A detailed description of the actual place in the buildings to which these locations corresponded may be found in [4-7]. The peaks at the beginning of the data traces indicated when the transmitters were turned on and then carried throughout the buildings. We saw that propagation through the buildings could reduce the radio signal by as much as 60 dB for the apartment building and for the stadium, and by as much as 70 dB for the convention center, depending on the location of the transmitter in the buildings' structures.

More data sets for these experiments are found in references [4-7], in which were discussed different interesting propagation and coupling effects in these

Figure 7b. The receiver site RX2 (northeast site) for the radio-mapping experiment for the convention center.

Figure 7a. The receiver site RX1 (northwest site) for the radio-mapping experiment for the convention center.

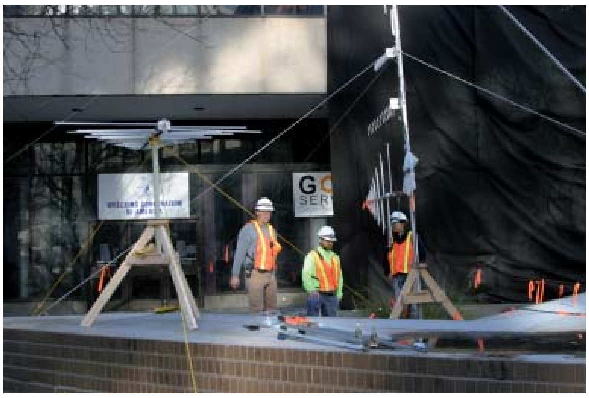

Figure 7c. The receiver site RX3 (southeast site) for the radio-mapping experiment for the convention center.

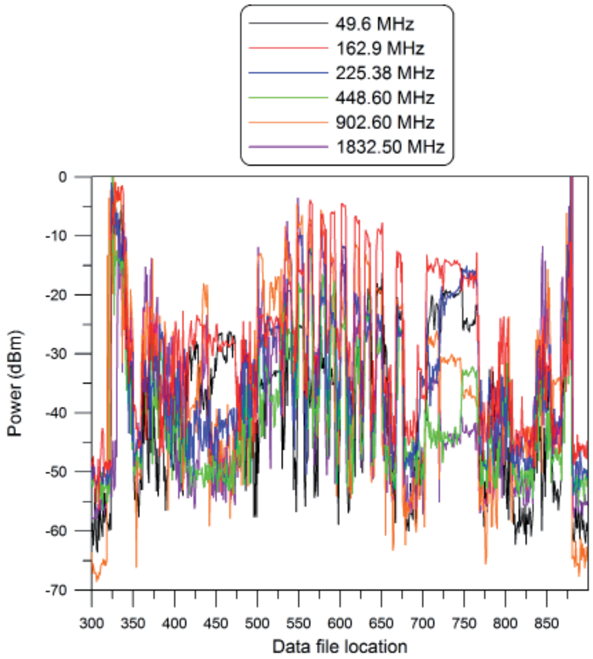

Figure 8. The received power for the radio-mapping experiment for the apartment building.

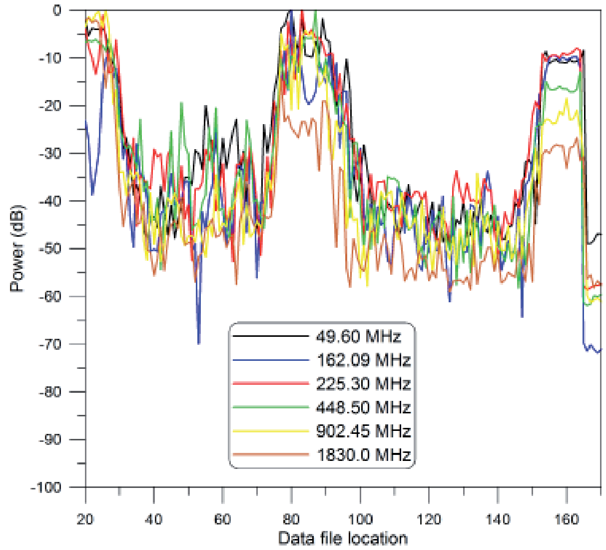

Figure 9a. The received power for the radio-mapping experiment for the sports stadium with horizontally polarized receiving antennas.

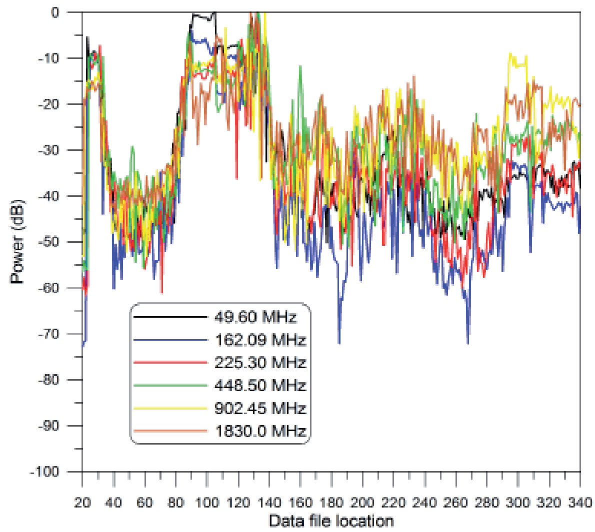

Figure 9b. The received power for the radio-mapping experiment for the sports stadium with vertically polarized receiving antennas.

three buildings. For example, in Figure 8 we saw that the signal strength oscillated between a high and low value for the data-file locations between 500 and 675. This range of data corresponded to carrying the transmitters up the stairs and, at each floor, the transmitters were placed outside a window (which was within line-of-sight of the receiver). These data illustrated the change in the amount of shielding that the building exerted on the radio signals. They showed that the building offered about 40 dB to 50 dB of shielding of the signals by simply moving the transmitter from outside to inside the building. Note that for the sports stadium (see Figure 9) we collected data for both horizontally and vertically polarized receiving antennas (for both data sets, the transmitting antenna was held in the horizontal polarization). The peak values (around 800-100 in Figure 9a and 80-140 in Figure 9b) occurred at places in the stadium where the line-of-sight (or minimal building materials) were present between the transmitter and the reference location. The results in Figure 9 illustrated the de-polarizing property of the sport stadium. In other words, the propagation of the signal throughout the building de-polarized the signal such that the received signal levels were similar and almost independent of the polarization of the receiving antenna's orientation. Finally, in Figure 10, the low signal strengths observed between data-file locations

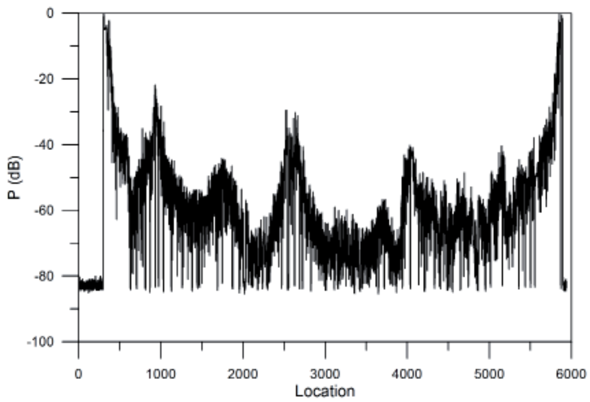

Figure 10. The received power for the radio-mapping experiment for the convention center at 226.40 MHz.

Frequency (MHz)	Mean (dB)	Standard Deviation (dB)
49.60	–38.6	12.1
162.00	–28.4	11.2
225.38	–33.9	10.4
448.60	–40.7	9.2
902.60	–35.2	13.1
1832.50	–38.4	12.5

Table 1. The normalized received signal strength for the apartment building.

Frequency (MHz)	Mean (dB)	Standard Deviation (dB)
49.60	–30.6	15.0
162.00	–34.4	15.2
225.38	–30.0	13.9
448.60	–33.5	14.4
902.60	–37.2	13.8
1832.50	–43.6	12.5

Table 2. The normalized received signal strength for the sports stadium.

Frequency (MHz)	Mean (dB)	Standard Deviation (dB)
49.60	–51.8	14.5
162.00	–63.2	14.0
225.38	–59.3	14.8
448.60	–58.6	13.8
902.60	–56.5	14.4
1832.50	–56.6	15.0

Table 3. The normalized received signal strength for the convention center.

2500 and 3500 corresponded to the transmitter being in the basement of the convention center, and hence experiencing high attenuation.

The results in Figures 8-10 also illustrate that the received power varied by as much as 60 dB to 70 dB. In communication-system design, the variability of the received signal level is often as important as the field strength, itself. Knowing the variability allows the system designer to develop for first responders devices that are capable of operating in an environment over a large dynamic range. Some statistics of the signal-level variability inside and outside the structures were investigated. Tables 1 to 3 summarize the mean-normalized received signal strengths and the standard deviations for each building's structure.

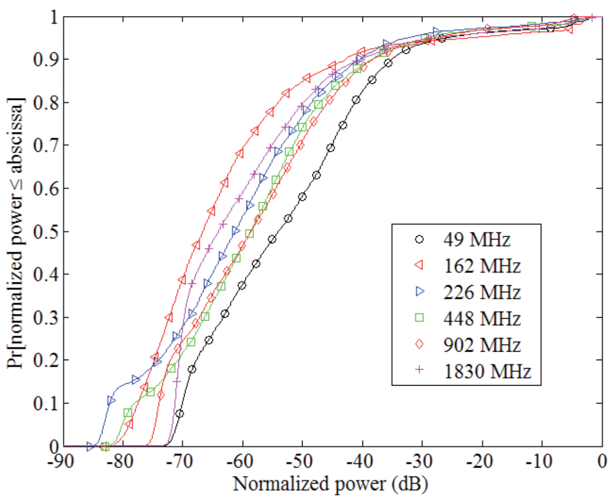

Figure 13. The cumulative distribution functions for the radio-mapping experiment for the convention center.

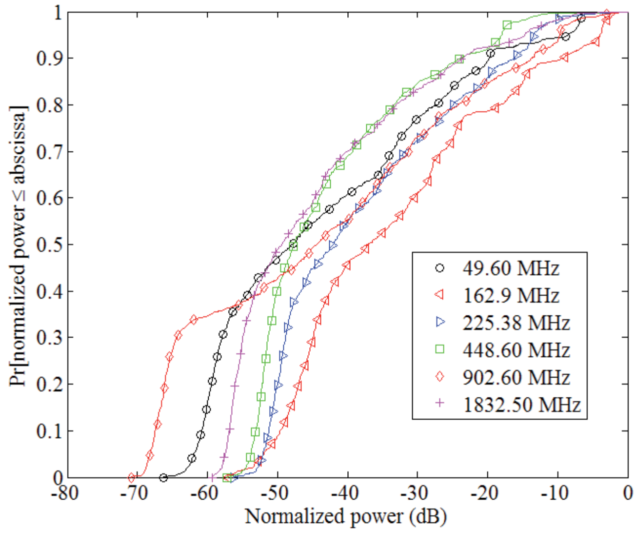

Figure 11. The cumulative distribution functions for the radio-mapping experiment for the apartment building.

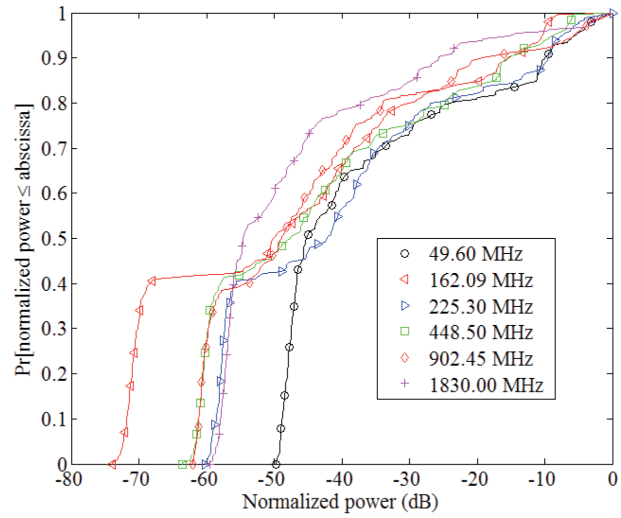

Figure 12a. The cumulative distribution functions for the radio-mapping experiment for the sports stadium with horizontally polarized receiving antennas.

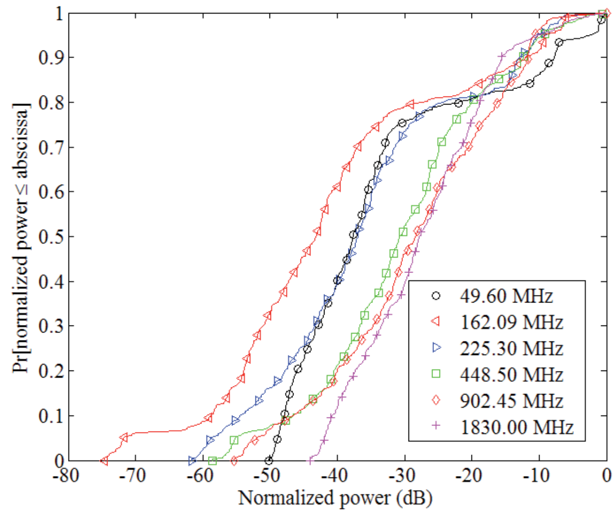

Figure 12b. The cumulative distribution functions for the radio-mapping experiment for the sports stadium with vertically polarized receiving antennas.

Figure 14a. A photo of the apartment building before the implosion.

Figure 14b. A photo of the apartment building after the implosion.

These attenuation numbers were obtained by normalizing the signal to outside line-of-sight values. Histograms (with a 2 dB bin size) for received signal strengths for all three buildings were given in [4-6]. Alternatively, the cumulative distribution function (CDF) of the received power is a way of indicating the percentage of locations in the building where the power levels exceeded or were below a given value. Figures 11-13 show the cumulative distribution functions for the data given in Figures 8-10. More data for these three buildings were given in [4-7]. These cumulative distribution functions may be used to estimate how reliable a particular communication system would be in this environment. For instance, based on the results in Figure 11, to be 50% reliable, the communications link would have to overcome the median attenuation of approximately 50 dB if operating at 1832.5 MHz. A robust 100% reliable system would have to overcome all the attenuation present, which exceeded 70 dB at 1832.5 MHz in the case of the apartment (Figure 11).

The measurement-system noise floor was a function of many parameters, such as the spectrum analyzer's sensitivity and the separation between the transmitter and the location of the maximum received signal. Some of the collected data thus include signals that were at or below the noise floor of the measurement system. However, the cumulative distribution functions still provide useful information. For example, in Figure 12, the step-like

Figure 15a. A photo of the sports stadium before the implosion.

Figure 15b. A photo of the sports stadium after the implosion.

Figure 16a. A photo of the convention center before the implosion.

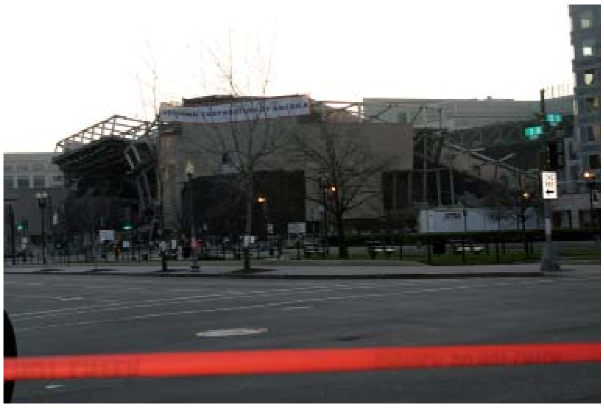

Figure 16b. A photo of the convention center after the implosion.

behavior in the horizontal polarization in normalized power levels below –50 dB were the result of reaching the dynamic range of the measurement setup. We could still conclude that approximately 40% of the received signals were 50 dB below the maximum for all frequencies in the horizontal case. By comparison, in the vertical-polarization case, for all frequencies except 225 MHz, the received signal was 50 dB below the maximum less than 20% of the time. (The received signal for 225 MHz was 50 dB below the maximum less than 30% of the time.)

5. Experiments During the Collapse

We next consider the impact on communication if the radio source was buried in the implosion debris. Before the implosion of the three buildings, transmitters were placed in various locations throughout the buildings. A detailed description of where they were placed was given in [4-6]. Figures 14-16 show the three buildings before and after the implosion. From these figures, we saw that the apartment building and the sports stadium represented totally collapsed structures, while the convention center represented a partial collapse.

Figures 17-19 showed typical pre- and post-implosion data for a receiver located at one of the fixed receiving sites for two different structures. The dramatic change in the received signal level indicated the time of the implosion. In some of the data sets, no received signals were detected after the collapse, due to the high attenuation caused by the building's rubble after the collapse. This finding was verified by the fact that the transmitters were later recovered and were still functioning. When the transmitters were connected to new batteries after the recovery, they still transmitted. More discussion on these implosion data was given in [4-6].

From Figures 17-19, we also saw that the signal strength increased at certain frequencies and locations after the implosion. This was explained by the fact that once

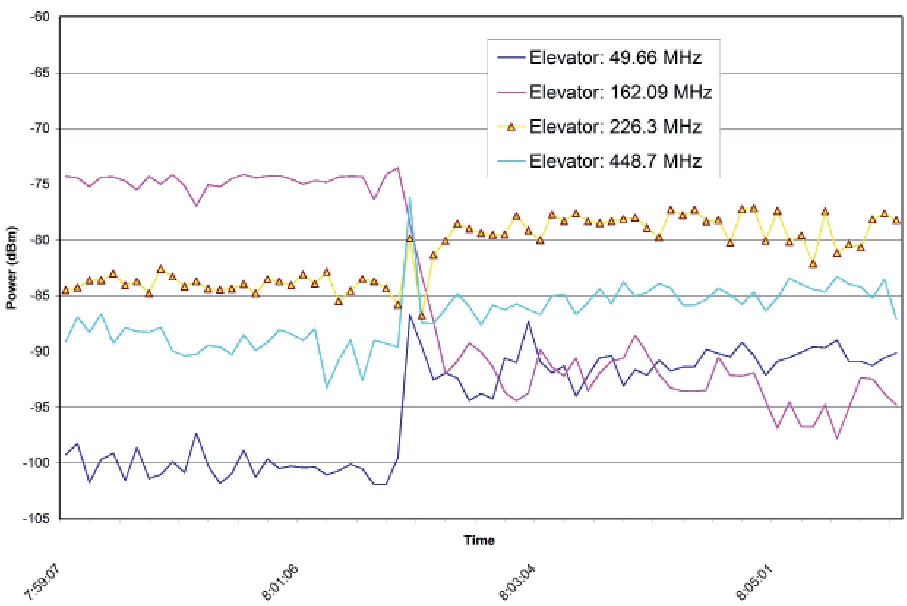

Figure 17a. The received power as a function of time during the collapse of the apartment building from a transmitter at the "elevator" position.

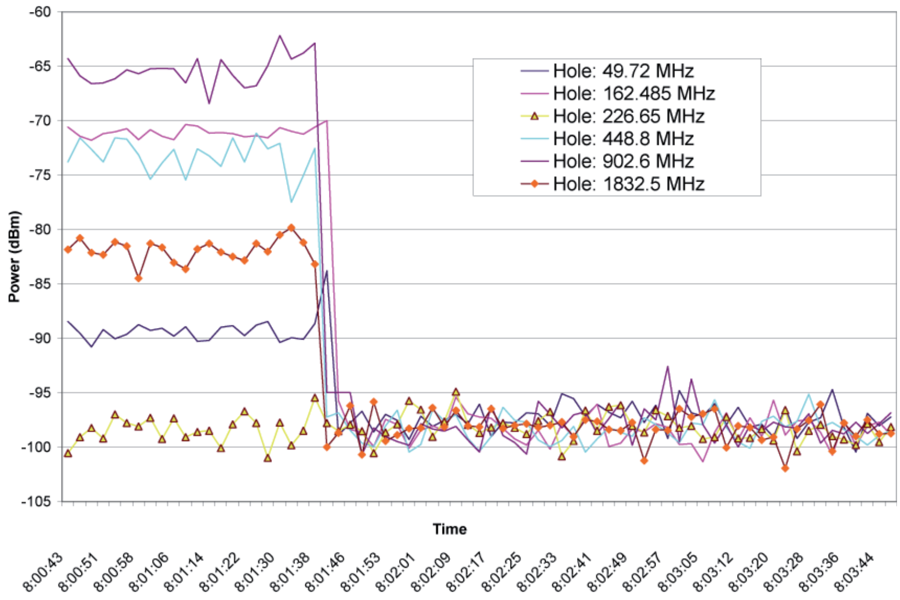

Figure 17b. The received power as a function of time during the collapse of the apartment building from a transmitter at the "hole" position.

the building collapsed, portions of the building opened up, reducing the amount of building material, and hence allowing for better reception. This behavior was observed for transmitters placed in various other locations in the three buildings. For more details, see [4-6].

Depending on the construction of the building and the frequency of operation, radio signals were able to couple into and out of the building's structure and to freely propagate outside the building after the collapse, such that the signal levels could even be higher than before the collapse. This was observed in Figure 18. In fact, in some of the data sets presented in [4-6], it was observed that sometimes higher frequencies propagated to the outside better than the lower-frequency signals. This might appear counterintuitive, but depending on the piping and/or air ducts in the building, such structures can allow high-frequency propagation (wave guiding) to receivers outside of the building.

6. Experiments After the Collapse

After the implosion, the mobile cart was used to move a receiving system around the perimeter of the building to record the received signals. The path used was generally the same path as that used in the cart measurements before the implosion. By comparing these pre- and post-implosion mobile-cart data, the effect of the building collapse on the signal strength was investigated. In order to better compare the pre- and post-implosion measurements, the two data sets were overlaid with respect to the compass bearings derived from GPS measurements of the cart's location. Figures 20 and 21 show the comparisons of these data sets for a few frequencies for the sports stadium and the convention center, respectively. Note that the azimuth angles on the axis corresponded to the compass bearings with respect to the geometric center of the building, where zero degrees

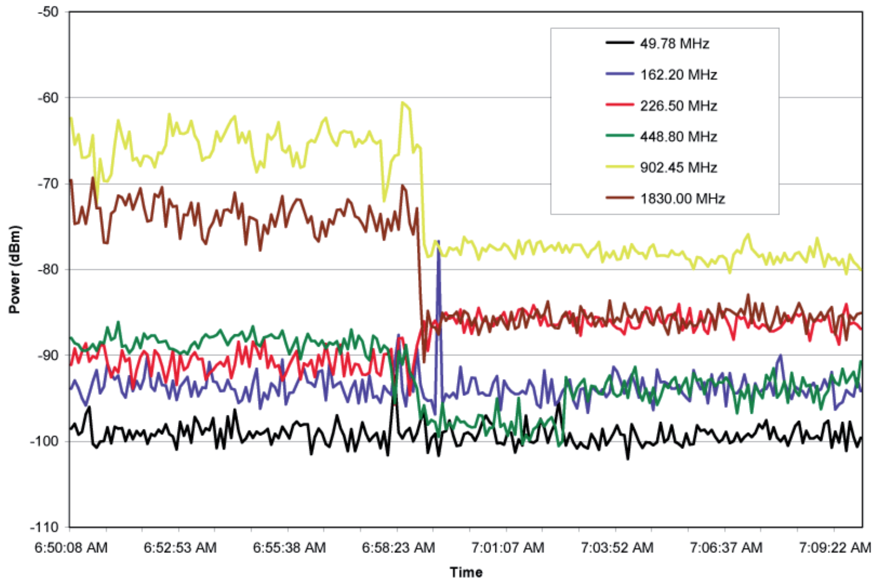

Figure 18a. The received power as a function of time during the collapse of the sports stadium for a transmitter at one position.

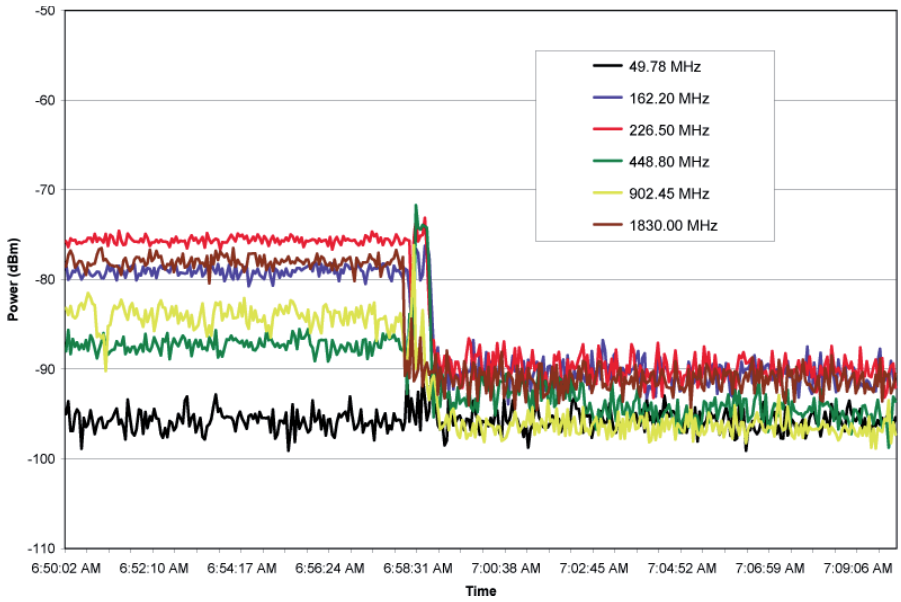

Figure 18b. The received power as a function of time during the collapse of the sports stadium for a transmitter at another position.

was defined as north. The radial scale corresponded to the received signal levels in dBm.

The data in these plots can be thought of as the effective antenna pattern of the buildings. In these comparisons, we saw a wide range of effects from the collapse. The data showed increased signal strength, little change in signal strength, or, in many cases, an additional 30 dB to 50 dB of attenuation after the collapse, depending on location and frequency. Trying to communicate to someone trapped under a similar rubble pile would thus require the radio to overcome an additional signal attenuation of 30 dB to 50 dB. Other interesting effects could be observed. For example, all the plots in Figure 20 are on the same scale, and as such, we could compare the relative change pre- and post-blast for various frequencies. Very little signal was detected for the 225 MHz and 1800 MHz transmitters after the implosion, while for the 49 MHz and 450 MHz cases, we saw that the post-blast signals were still detectable. In fact, for 450 MHz, we saw that besides an overall attenuation of the signal, the pre- and post-blast data had a very similar pattern. For the convention center, Figure 21, we saw that post-blast signals were detected for all four frequencies. In fact, we saw that at 160 MHz, the post-blast signal was higher, indicating better propagation to the receiver after the implosion (either a better propagation path, or material had been removed by the implosion), similar to results discussed in the previous section.

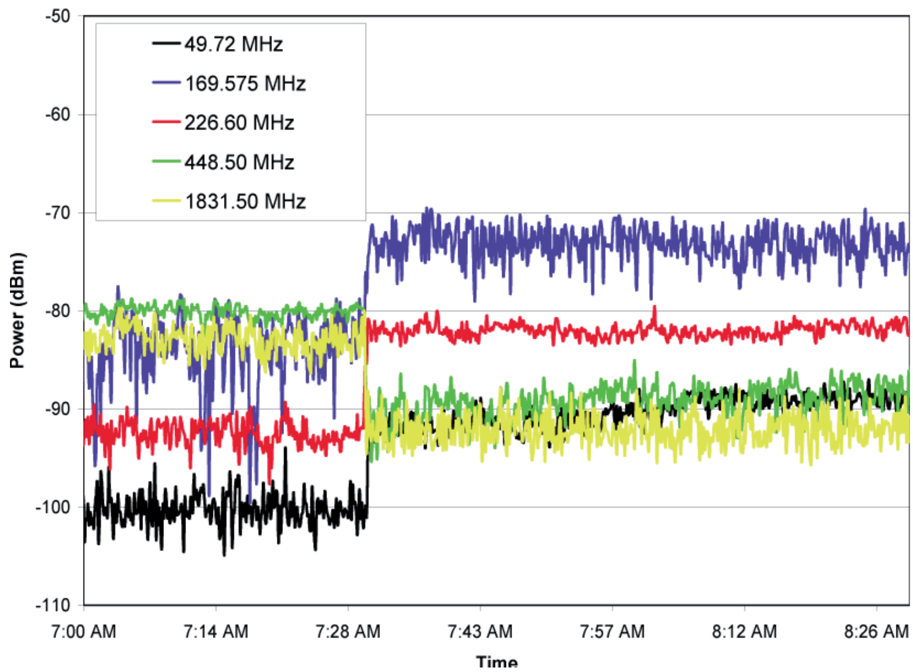

Figure 19a. The received power as a function of time during the collapse of the convention center for a transmitter at one position.

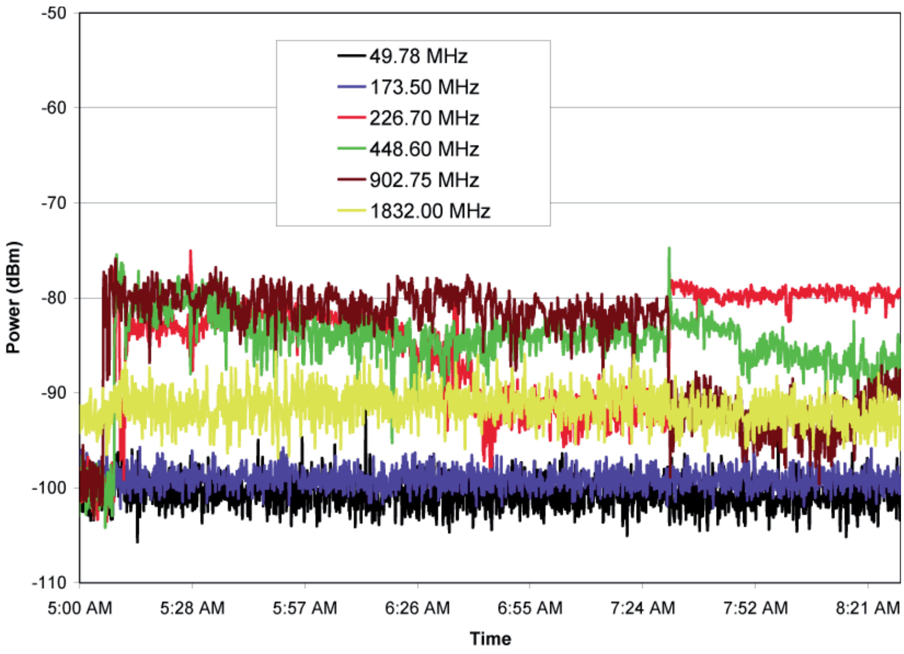

Figure 19b. The received power as a function of time during the collapse of the convention center for a transmitter at another position.

7. Experiments on the Debris Radiator Concept

We collected an additional set of data that consisted of monitoring signals coupled to metallic debris located in the proximity of transmitters buried in the collapsed buildings. These metallic "debris radiators" (e.g., a set of cables laid to investigate the concept) ran through the rubble, and were exposed at the perimeter of the collapsed structures. The idea was that when a large structure collapses, metal objects (electrical wires, metal piping, reinforcing bars, venting pipes, etc.) protrude from the rubble. These objects may improve radio reception by coupling radio signals to searchers on the outside. When first responders approach a collapsed structure, one of their first priorities is to determine whether survivors are present in the debris. Reception of signals from handheld radios or cell phones may let searchers know of survivors' presence and their condition. We measured the signals from the buried transmitters using instruments physically connected to the metallic debris through impedance tuners. Antennas were also used to investigate signal detection from these metallic-debris radiators.

Our studies utilized pre-laid steel cables to emulate metallic debris in the collapsed building. Use of pre-laid cable helped to ensure that we could test the debris-radiator concept even if we were not able to make measurements in close proximity to the debris pile for safety reasons. In these experiments, we investigated whether improved signal reception could be obtained by replacing a radio's transmitting antenna with metallic debris connected through an impedance-matching network. The purpose of the matching network was to increase efficiency in coupling a signal to the metallic debris. We compared measurements from transmitters that had standard omnidirectional antennas, and those that used the debris radiator. On the receiver side, we performed similar comparative experiments. We measured the signals from the buried transmitters using instruments physically connected to the metallic debris through impedance tuners, using standard receiving antennas, and using directional antennas. These various experiments showed that the improvement in received signal level could range from zero to several orders of magnitude when debris radiators were used: see [4-6] for details.

8. Summary and Discussion

In this paper, we reported on a series of measurements performed before, during, and after the collapse of three large building structures. These results illustrated the large attenuation or high shielding that could occur in these types of public structures. The results also indicated that a large variability in attenuation or shielding does occur, depending on the location of the transmitter in the structure. We measured an additional 20 dB to 70 dB of attenuation after the collapse, depending on the building type and the location of the transmitter. If someone is trapped under such a rubble pile of a collapsed building and is trying to communicate with an emergency responder, their communication link may thus have to overcome 20 dB to 70 dB of additional attenuation caused by the building's collapse. More detailed data based on the experiments reported here were given in [4-6].

Three different types of experiments were performed during this effort. The first set of data, radio mapping, was collected a few days before the structures were imploded. The results showed that the received signal levels varied significantly throughout the different structures. In designing communication systems, the variability of the signal is as important as the signal level itself. The results showed large variability, sometimes with small changes in

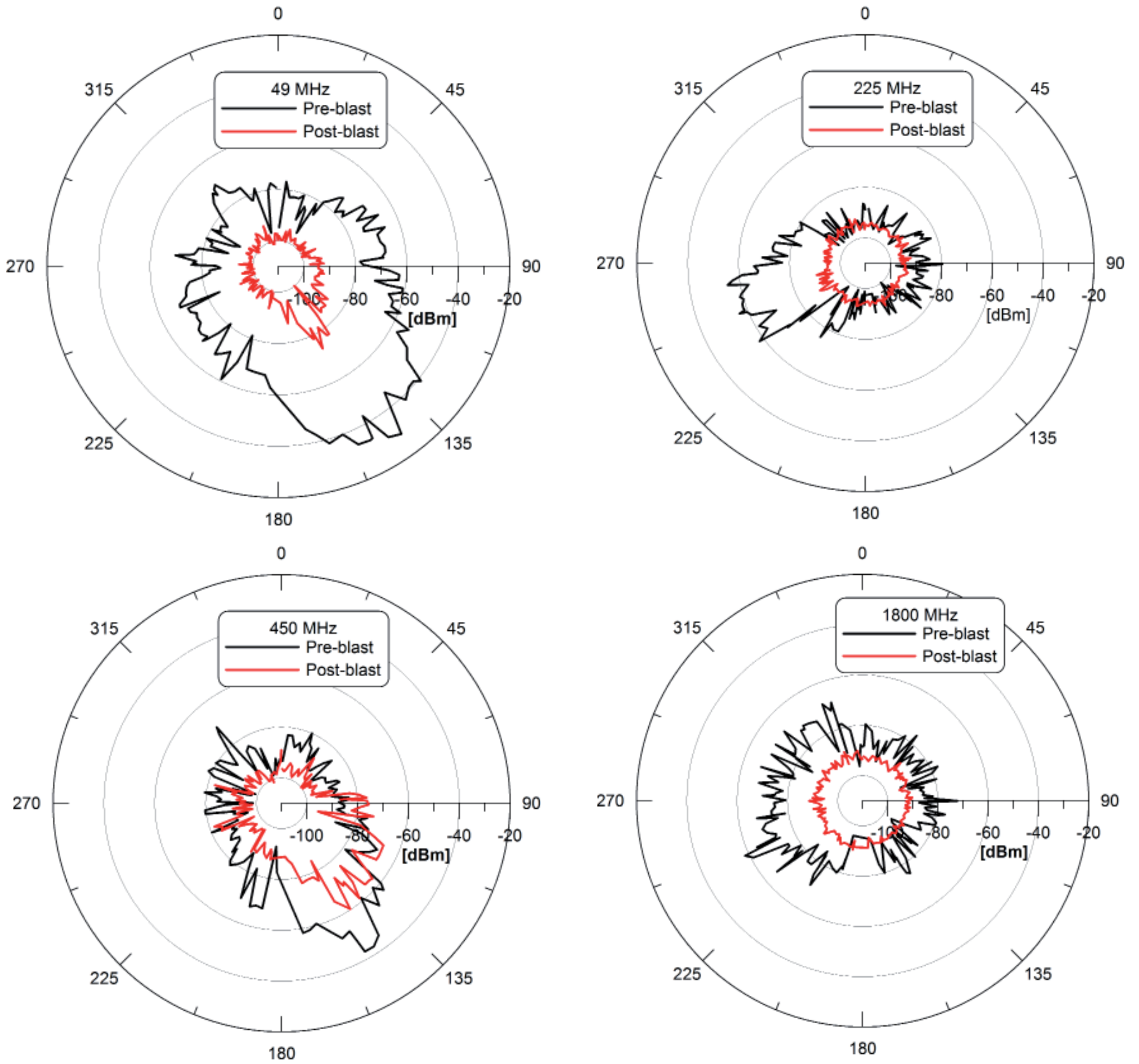

Figure 20. A comparison of the pre- and post-implosion received signal levels as measured with the mobile cart for the sports stadium.

physical position. Cumulative distribution functions may be used to estimate how reliable a particular communication system would be in these high-attenuation, high-variability environments. For instance, to be 50% reliable, the communications link would have to overcome the median attenuation (for example, 60 dB) at that frequency. On the other hand, a robust, 100% reliable system would of course have to overcome all the attenuation present, and this easily ranged up to 70 dB or more. The results in these studies were also used to show how the mean, median, and standard deviation of the signals varied with both frequency and location of transmitters and receiver [4-6]. These data therefore indicated the additional design margins that may be required in a link-budget analysis of a communication system in order to achieve reliable communication into a large structure of this type.

There are a number of other interesting studies and measurements published in the literature related to the attenuation of radio-frequency signals into buildings and through building materials [8-17]. Many, if not most, of these studies concentrated on frequencies allocated to cellular and personal communications systems near 850 MHz and 1900 MHz and the higher gigahertz bands, by use of measurement scenarios that modeled some part of the commercial cellular network, including building interiors. On the other hand, our dataset covered several other frequencies. As such, it gives us a set of data for comparing how different frequencies propagated throughout the buildings. In general, there was a huge variability in the experimental setup and objectives, the definition of the reference measurement, the building properties, and the surrounding environment in the various studies of building-penetration loss. However, there is a consistent message in the data, namely, that there is always some attenuating effect on the radio-frequency energy caused

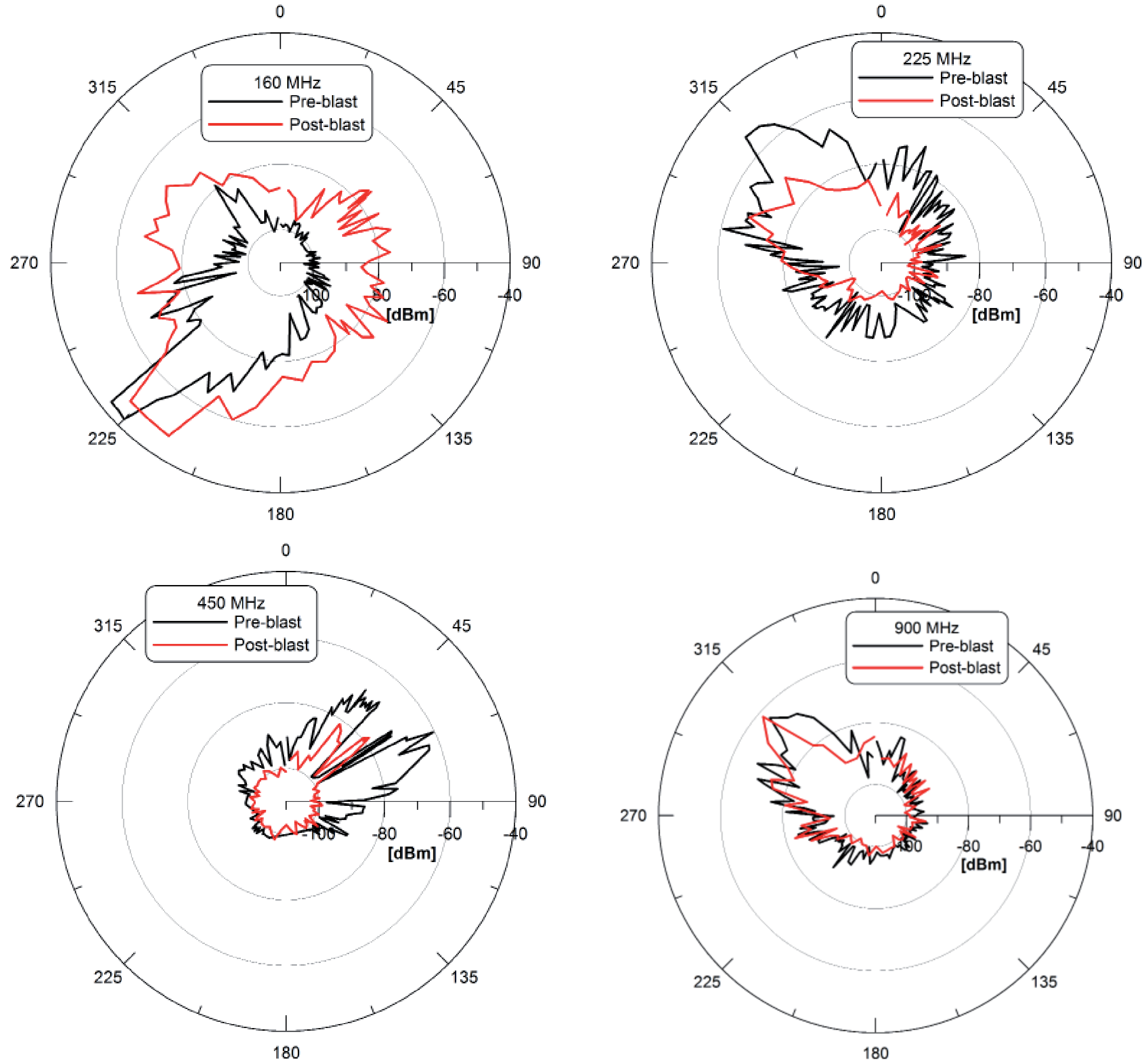

Figure 21. A comparison of the pre- and post-implosion received signal levels as measured with the mobile cart for the convention center.

by the building. This attenuation is usually on the order of 10 dB to 30 dB, but in certain situations it can climb as high as 70 dB or more.

In the second type of data collection, radio transmitters were placed in fixed sites throughout the building interiors. Signals received at listening stations exterior to the buildings were collected before, during, and after the implosion. The implosion was indicated by the dramatic change in the signal levels. These results showed that some signals experienced large amounts of additional attenuation, while other signals actually increased (less attenuation) after the implosion. This was an indication of how the mass of the structure moved during the implosion, with some regions being compacted and other regions becoming more open, and also how the signals at various frequencies interacted with the debris.

Our receiving sites for these measurements were both fixed and mobile. As discussed above, a receiving system mounted on a modified garden cart was pulled around the perimeter of the convention center both before and after the implosion. Measurements for the transmitters in the different sites were made before the implosion such that a pre- and post-signal strength comparison could be made. In these comparisons, we saw a wide range of effects from the collapse. The data showed increased signal strength, or little change in signal strength, but in many cases, we saw an additional 20 dB to 70 dB of attenuation after the collapse, depending on location. A communication link may thus have to overcome 20 dB to 70 dB of additional attenuation caused by the building's collapse. With that said, interesting wave-guiding effects (due to signals propagating in the piping and/or air ducts in the building) can occur after a building collapses, such that received signal strengths on the outside of a building can be larger than those before a building's collapse.

It is interesting to note that the increases in signal attenuation after the collapse of the convention center were not as large as observed during the apartment-building implosion. This can be explained by the fact that the convention center had such massive amounts of concrete and steel throughout that the signal propagating through the interior of the convention center prior to the implosion behaved similarly to the signal propagating through the partially collapsed rubble piles. On the other hand, the apartment building was very open (or essentially gutted) prior to the implosion, and extremely compact afterwards. The overall attenuation in the convention center was also about 10 dB less than we measured at the Veterans' Stadium [5].

The effective antenna pattern of the building as presented here can be very useful, in practice. For example, when first responders arrive at an emergency at a large building, they may set up a communication vehicle with antennas pointing at the building. In this situation, it is important to know where the best coupling into the building may be achieved around the perimeter of the building. Data similar to that presented in Figures 20 and 21 give such information.

The third set of data, referred to as "debris radiators," was collected by connecting instruments to the convention-center rubble, and by using a directional antenna connected to our instruments placed in the proximity of metallic debris. The purpose of this experiment was to investigate the probability of detecting radio signals from transmitter(s) under the rubble that might couple onto these metal objects and radiate signals to the edges of the rubble pile. Use of debris radiators may improve the reception of signals emitted from deep within a convention center in collapsed-building or other weak-signal scenarios. When the transmitting antenna from a buried transmitter was replaced by a metallic cable attached through an impedance-tuning network, the received signal strength increased significantly in some cases, but remained unchanged in other cases. Signals could be received from all buried transmitters by either a direct connection to the metallic debris through a matching network or a directional receiving antenna placed in close proximity to the debris radiator. A directional receiving antenna in close proximity to a debris radiator generally had higher received signal levels than did signals acquired from direct connection to the metallic debris.

We also performed radio-mapping experiments in various other large structures, including apartment and office buildings, stadiums, stores, shopping malls, hotels, a convention center, an oil refinery, and warehouses. The results of the signal-strength measurements and statistical distribution for these radio-mapping experiments were given in [7, 18-23]. The data presented in [7, 18-22] also included results for the 2.4 GHz and 4.9 GHz frequency bands. References [7, 18-22] also presented data on excess path loss, RMS delay spread, and the effects of channel fading on wideband digitally modulated signals for an apartment building, office corridor, oil refinery, and a subterranean tunnel, while the data presented in [23] discussed the urban-canyon environment. The propagation properties for a 750 MHz signal for various building were given in [21]. The data discussed here as well as those given in [4-7, 18-23] represent a large database of propagation data that can aid in the design and implementation of communication systems for large public buildings. Various interesting propagation and/or building-coupling effects were presented and discussed in these references. This is a public-domain database available for anyone who can use it. The experimental data presented here and in the various references will aid in improving channel descriptions for large public buildings. It will be useful for assessing current and future wireless technology in emergency scenarios, for standards development, and for qualifying wireless equipment in environments such as those studied here.

9. Acknowledgements

These RF propagation-channel studies were funded by the Public Safety Communications Research (PSCR) program, a joint program of the National Institute of Standards and Technology (NIST) Office of Law Enforcement Standards (OLES) and the National Telecommunications and Information Administration (NTIA) Institute for Telecommunication Sciences (ITS). Dereck Orr was the Program Manager, and Jeff Bratcher was the Technical Manager.

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2012 - 2014
Commission Triennial Reports

COMMISSION C

1. Scope of Activities

Commission C promoted research and development in: information theory, coding, modulation and detection; spectrum and medium utilization, including cognitive and cooperative techniques; wireless networking; radar, radio localization and navigation systems; green, energy-efficient radio communications. The design of effective radio-communication and signal processing systems also included scientific, engineering, and economic considerations. This Commission emphasized the scientific aspects of radio communications, but also provided enabling technologies to other areas of radio science.

2. International Events Sponsored or Cosponsored by Commission C

2.1 9th Edition of the International Symposium on Signal System and Electronics ISSSE 2012

Sponsors: Commissions C and D
Venue: Potsdam, Germany
Date: October 3-5, 2012
General Chair: Prof. Rolf Kraemer, BTU Cottbus and IHP, Germany; General Co-Chair: Dr. Thomas Haustein, Fraunhofer HHI/Heinrich-Hertz Institut, Germany

The ISSSE (International Symposium on Signals, Systems, and Electronics) is held every three years, exceptionally in 2012 after two years. It is organized under the guidance and with the sponsorship of the international steering committee of URSI Commissions C (Radiocommunication Systems and Signal Processing) and D (Electronics and Photonics). Moreover, each radio system depends on its antenna, which couples the electromagnetic waves into the medium. We thus included aspects of URSI Commission B (Fields and Waves) in the technical scope of the symposium. The ninth edition of the ISSSE was held in Potsdam, Germany, October 3-5, 2012. The reason why ISSSE was shifted from 2013 to 2012 is the following. In so doing, Commission C will sponsor one main URSI event every year in the three-year cycle of each chair, namely ISSSE in 2012 (2015, -18, etc.), AP-RASC (see below) in 2013 (-16, -19, etc.), and the GASS in 2014 (-17, -20, etc.).

2.2 Asia-Pacific Radio Science Conference AP-RASC 2013

Sponsors: URSI (main sponsor), in cooperation with National Taiwan University, National Central University, Chunghwa Telecom Co., Institute for Information Industry, Academia Sinica Institute of Astronomy and Astrophysics

Venue: Howard International House, Taipei, Taiwan
Date: September 03-07, 2013
Honorary Chair: Phil Wilkinson, President of URSI; General Chair: L.-C. Lee President, China (SRS) National Committee of URSI; General Co-Chairs: S.-C. Lu ex-Chair & CEO, Chunghwa Telecom Co. Ltd., R.-B. Wu President, Institute for Information Industry; Professor, National Taiwan University.

AP-RASC is the Asia-Pacific regional URSI conference held between the URSI General Assemblies and Scientific Symposia. The objective of the AP-RASC is to review current research trends, present new discoveries, and make plans for future research and special projects in all areas of radio science, especially where international cooperation is desirable. A particular emphasis is placed on promoting various research activities in the Asia-Pacific area. Scientific sessions composed of oral and poster papers were organized at this conference in order to cover all scientific activities by URSI Commissions A-K. Commission C organized six specific sessions on different aspects of radio communications, plus five more joint sessions with other URSI Commissions.

2.3 URSI XXXI General Assembly and Scientific Symposium URSI GASS 2014

Sponsor: Union of Radio Science International
Venue: Beijing Conference Center, Beijing, China
Date: August 16-23, 2014
Honorary Chair: Han Qide, the Chair of China Association for Science and Technology; Chair: Lou Qinjian, the Chair of the Chinese Institute of Electronics

The XXXI General Assembly of the International Union of Radio Science was held at the Beijing Conference Center (BCC) in downtown Beijing, China, on August 16-23, 2014. The General Assemblies of URSI are held at intervals of three years to review current research trends, present new discoveries and make plans for future research and special projects in all areas of radio science, especially where international cooperation is desirable. The first Assembly was held in Brussels, Belgium, in 1922. This is the first time the Assembly was held in Beijing, China. The XXXI edition of the GASS had a scientific program consisting of plenary lectures, public lectures, tutorials, posters, invited and contributed papers organized around the ten Commissions of URSI. In addition, there were workshops, short courses, special programs for young scientists, a student paper competition, programs for accompanying persons, and industrial exhibits. Over 1,000 scientists from more than fifty countries participated in the Assembly. The activities of Commission C are summarized in Figure 1.

The GASS witnessed an unprecedented number of submissions fitting within the research themes of Commission C, which marked the relevance of such themes, as well as the success of the event.

3. Activity Reports from Member Nations

3.1 Brazil, by Marcelo S. Alencar

3.1.1 Introduction

The Brazilian telecommunication market continues to grow strong. In 2010, 37,642 municipalities were served by basic telephone service, and 97.1% of the population had access to mobile telecommunication services, which represented 86.7% of the municipalities [1]. In 2012, 43.2 million were served by the basic telephone service, an increase of 2.8% over the previous year. 250.8 million used mobile cellular communication services, which represented an increase of 19.2%. There were 13.7 million users of cable television services, an increase of 31.2%. Wideband fixed-access Internet services comprised 17.3 million users, which indicated an increase of 20.7%. The trunking companies attended to 4.3 million users, an increment of 17.2%, considering the 2011 figure [2]. The total investment by the companies in 2013 was US$13.2 billion. The gross revenue was US$102.3 billion, representing an increase of 6.2% in relation to 2012 [3].

3.1.2 Telecommunication Market

Regarding the composition of the telecom market, in terms of gross operational revenue in 2010, four or five telecommunication operators served 78.6% of the population, three operators served 6.2%, two operators served 4.8%, and only one operator served 7.3% of the population. The gross operational revenue for the telecommunications sector in the first quarter of 2010 was US$26 billion [1]. The number with telecommunication access in the first quarter of 2011 was 277.4 million, which included fixed and mobile telephony, wired and wireless broadband, and cable television. This was an increase of 15.5% compared to the same period of 2010. Wireless broadband increased 77%, from 13.8 to 24.4 million Internet accesses. Telephony grew from 179.1 to 210.5 million devices: a 17.5% increase. Fixed broadband evolved 20.5% in the period, from 11.7 to 14 million. Overall, the number of wideband connections, wired and wireless, reached 40.9 million in April, 2011. The growth in television subscribers was 31.6% in 12 months. The total number of clients increased from 7.9 to 10.4 million [4].

According to the Brazilian census for 2010, 87.9% of the houses had access to telephone services, fixed or mobile. In 2012, 39,121 localities were served by the fixed telephone system, and 17,059 had individual access, an increase from the number of 38,452 localities in 2011. 100.0% of the population had access to cellular services, divided into 83.1% served by four or five companies, 2.8% served by three companies, 4.9% served by two companies, and 9.2% served by one company. In 2012, 100.0% of the municipalities counted on mobile communication services, 85.3% of the population had access to wideband mobile services, and 60,512 public schools were connected by the government's wideband program. The gross operational revenue for the telecommunication sector from January to March, 2012, was US$26.6 billion, which represented an increase of 10.8% as compared to the same period in 2011. This figure projected a gross operational revenue of US$106.4 billion for the whole year.

The composition of the revenue in 2012 was as follows: industry: US$3.3 billion (35.0% increase in relation to 2011); fixed operators: US$6.2 billion (a decrease of 8.1% in relation to 2011); fixed wideband providers: US$3.0 billion (6.0% increase); mobile personal communication service operators: US$11.6 billion (14.3% increase); cable television providers: US$2.3 billion (33.0% increase); trunking operators: US$1.1 billion (12.8% increase). The gross operational revenue for the telecommunication sector in 2011 was US$100.6 billion, the highest in the history of Brazil, and equivalent to 4.9% of the country's gross national product (GNP). The telecommunications service providers collected US$7.4 billion in government taxes in the period January to March of 2012, which was equivalent to 46.2% of their net operational revenue US$15.9 billion. There were 489.3 thousand employees in the telecom market in 2012, an increase of 5.1% from 2011, of which 25,800 worked in industry, 50,600 were in deployment services, 165,500 were in telecommunication services, and 244,700 worked for call centers. The number of access points increased in 2012 to a total of 344.5 million (+7%), of which fixed telephony, 44 million (+2%); mobile, 263 million (+8%); fixed wideband, 20.8 million (+14%); television subscribers, 16.7 (+25%). The fixed telephony in Brazil in 2012 accounted for 64.7 million deployed accesses; 44 million (+2,4%) in service; market share of incumbents, 32%; 22.3 access points per 100 in-habitants (teledensity); one million public telephones; 39,600 municipalities attended; more than 240,000 km of optical multi-fibers deployed.

The telecommunication companies had positive figures in most services in 2013. The gross revenue per sector was fixed telephony, US$20.6 billion, a decrease of 5%; wideband fixed transmission, US$12.3 billion, an increase of 9%; mobile telephony, US$43.3 billion, an increase of 7%; cable television, US$11.1 billion, an increase of 22%; trunking, US$3.1 billion, a decrease of 16%. The number of employees in the telecommunication sector in 2013 was 504,700, an increase of only 1% in relation to 2012. Most of the these were employed in call centers. The total number of accesses in 2013 was 362.8 million, a growth of 4% in relation to 2012. Fixed telephony accounted for 45.3 million accesses, an increase of 2%. Fixed wideband transmission accounted for 23.2 accesses, an increase of 9%, and cable television had 18.8 million accesses, a growth of 11%. Mobile telephony accounted for 275.5 million accesses, an increase of 4% in relation to 2012. The number of mobile accesses per 100 inhabitants (teledensity) was 135. The number of radio base stations deployed was 67,749, which represented an increase of 11% in relation to 2012 figures [3].

3.1.3 Activities of the Scientific Societies and Institutions

3.1.3.1 Events

The Brazilian Telecommunications Society (SBrT) sponsored the XXIX Brazilian Telecommunications Symposium (SBrT'11), which was held in Curitiba, between October 2-5, 2011, at the convention center of the Pestana Hotel. The General Chair was Alexandre Pohl. There were four short courses, and three invited talks given by Javier Garcia-Frias, Paulo S. R. Diniz, and Dan Sadot. A total of 177 technical articles and 18 scientific initiation communications were presented, selected from 316 submitted papers. The number of participants was 269.

The Brazilian Telecommunications Society (SBrT) sponsored the XXX Brazilian Telecommunications Symposium (SBrT'12), which was held in Brasılia between September 13-16, 2012, at Centro de Conven¸c˜oes Ulysses Guimar˜aes. The General Chair was Ricardo Queiroz (UnB). There were four invited talks given by Amin Shokrollahi, Gaurav Sharma, Joseph Kahn, and Max H. M. Costa. Six tutorials were presented at the symposium. The technical articles and scientific initiation communications were selected from 320 submitted papers.

The Brazilian Telecommunications Society (SBrT) sponsored the XXIX Brazilian Telecommunications Symposium (SBrT¿13). In its 31st edition, the symposium was held in Fortaleza, between September 1-4, 2013, at the Vila Gal´e Hotel. The General Chair was Charles Casimiro Cavalcante, the Honorary Chair was Jo˜ao Cesar Moura Mota, and the Technical Program Chairs were Marcello Luiz Rodrigues de Campos and Rubens Viana Ramos.

The 2011 SBMO/IEEE MTT-S International Microwave and Optoelectronics Conference (IMOC 2011) was an international forum of telecommunication technologies organized by the Brazilian Microwave and Optoelectronics Society (SBMO) and co-sponsored by IEEE Microwave Theory and Techniques Society of the Institute of Electrical and Electronic Engineers (IEEE MTT-S). In its fourteenth edition, this conference was held in the city of Natal, Brazil. The conference venue was the Imir´a Plaza Hotel, a beach hotel with 166 apartments, located at Via Costeira. IMOC 2011 provided a major international forum for exchanging information on research and development in the theoretical and experimental fields of microwaves and optoelectronics including millimeter and nanometer waves, antennas, propagation, wireless communication, fiber optics, and photonic networks. The General Chair was Adaildo G. D'Assun¸c˜ao (UFRN, Brazil), and the Technical Program Chairs were Gerv´asio P. S. Cavalcante (UFPA, Brazil) and Evandro Conforti (Unicamp, Brazil). The 15th Brazilian Symposium on Microwaves and Optoelectronics and the 10th Brazilian Congress on Electromagnetism (MOMAG 2012) occurred in Jo˜ao Pessoa, Para´ıba, in 2012. The event was organized by the Grupo de Telecomunica¸c˜oes e Eletromagnetismo Aplicado (GTEMA) of the Instituto Federal de Educa¸c˜ao, Ciˆencia e Tecnologia da Para´ıba (IFPB) andby the Departamento de Engenharia de Comunica¸c˜oes (DCO) of the Universidade Federal do Rio Grande do Norte (UFRN). The event was supported by the Brazilian Microwave and Optoelectronics Society (SBMO) and by the Brazilian Electromagnetics Society (SBMag). The General Chairs were Alfrˆedo Gomes Neto (GTEMA, IFPB) and Adaildo Gomes D'Assun¸c˜ao (DCO, UFRN). The venue was the Tamba´u Hotel, a five star beach hotel, and the conference presented six special sessions and nine tutorials.

The SBMO/IEEE MTT-S International Microwave and Optoelectronics Conference is a biennial forum on telecommunication science, technology and innovation, sponsored by the Brazilian Microwave and Optoelectronics Society (SBMO) and the IEEE Microwave Theory and Techniques Society (IEEE MTT-S). In its fifteenth edition, the conference was held in the city of Rio de Janeiro, Brazil, from August 4-7, 2013. The General Chair was Jos´e Ricardo Bergmann and the Technical Program Chairs were Maria Thereza Rocco Giraldi and Luiz da Silva Mello.

The third Annual Meeting of the Iecom on Communications, Networks and Cryptography (ENCOM 2013) was held in Recife, from October 4-5, 2013, under the sponsorship of the Institute for Advanced Studies in Communications (Iecom) IFPE, UPE, UFPE and UFCG. It received support from Datashop and Rohde & Schwarz. The General Chairs were Marcelo Sampaio de Alencar and Geraldo Andrade de Oliveira, and the Technical Program Chairs were Wamberto Jos´e Lira de Queiroz, Jos´e Ewerton Pombo de Farias, Carmelo Jos´e Albanez Bastos Filho and Evio da Rocha Ara´ujo [5].

3.1.3.2 Journals Published

The Journal of the Brazilian Telecommunications Society (JBTS) was created in 1986 by the SBrT as a way to document and disseminate the results produced by Brazilian researchers. Effective December 2005, the Board of the SBrT approved a new title for its publication, which became known as *Journal of Communication and Information Systems* (*JCIS*). The Editors-in-Chief for the first five years were Marcelo S. Alencar (UFCG), Celia Desmond (IEEE ComSoc), and Elvino S. Sousa (UofT). *The Journal of Communication and Information Systems* (*JCIS*) features high-quality, peer-reviewed technical papers in several areas of communications and information systems. The *JCIS* is jointly sponsored by the Brazilian Telecommunications Society (SBrT) and the IEEE Communications Society (ComSoc). The *JCIS* aims at a larger international audience. The Steering Committee includes renowned scholars from the international and the Brazilian communities. Distinguished researchers in several fields of communication and information science act as area editors. Since 2012, Jo˜ao Marcos Romano (Unicamp) and Merouane Debbah from (SUPELEC) are the new Editors-in-Chief [6]. The *Journal of Microwaves, Optoelectronics and Electromagnetic Applications* (*JMOe*) is published by the Brazilian Microwave and Optoelectronics Society (SBMO) and Brazilian Society of Electromagnetism (SBMag). It is a refereed publication devoted to disseminating technical information in the areas of microwaves, optoelectronics, photonics, and electromagnetic applications. The journal has been published in electronic format since 1997. The editors are Maria Thereza Miranda Rocco Giraldi (IME) and Renato Cardoso Mesquita (UFMG). [7]. The *JMOe* is indexed in the following bibliographic databases: SciELO, SCOPUS, SIMAGO, EMBASE, Engineering Village, Reaxys, Sumarios.org and Directory of Open Access Journals (DOAJ). It is also part of the Scientific Electronic Library Online-SciELO´s collection.

The *Journal of Information and Communications Technology* (*RTIC*) is published by the Institute for Advanced Studies in Communications (Iecom). The journal has been published in electronic and printed formats since 2011. The RTIC is registered by DOI and was awarded a Capes Qualis B5 classification. The Editor-in-Chief is Wamberto Jos´e Lira de Queiroz.

3.1.3 Concluding Remarks and Recommendation

According to a report from the International Telecommunication Union (ITU), the telephone services in Brazil present the highest cost in the world. The blocking probability is very high, which led the Brazilian National Telecommunication Agency (Anatel) to punish the several telecom operators by blocking the sales of new services. As a recommendation, it is important that the International Union of Radio Science (URSI) Commission C begin to sponsor the conferences organized by the Brazilian Telecommunications Society (SBrT) and by the Brazilian Microwave and Optoelectronics Society (SBMO).

3.1.4 References

1. Telebrasil, "O Desempenho do Setor de Telecomunica¸c˜oes no Brasil S´eries Temporais – 1T10," Technical report, Telebrasil, March 2010.

2. Telebrasil, "O Desempenho do Setor de Telecomunica¸c˜oes no Brasil S´eries Temporais – 1T12," Technical report, Telebrasil, March 2012.

3. Telebrasil, "O Desempenho do Setor de Telecomunica¸c˜oes no Brasil S´eries Temporais – 1T14," Technical report, Telebrasil, March 2014.

4. Telebrasil, "O Desempenho do Setor de Telecomunica¸c˜oes no Brasil S´eries Temporais – 1T11," Technical report, Telebrasil, March 2011.

5. Institute for Advanced Studies in Communications, "Report of the Institute for Advanced Studies in Communications (Iecom)," Technical Report, Iecom, July 2014.

6. Brazilian Telecommunications Society, "Portal of the Brazilian Telecommunications Society," Technical Report, SBrT, July 2014.

7. Brazilian Microwave and Optoelectronics Society, "Portal of the Brazilian Microwave and Optoelectronics Society," Technical Report, SBMO, July 2014.

3.2 Egypt, by Said E. El-Khamy

Egyptian scientists have published 101 papers in the area of wireless communications and signal processing in the past three years. These papers have been presented in four URSI conferences, as follows:

GA 2011 Istanbul, August 2011, six papers: C05.4 , AC.2, C13.2, C13.7, CP.1 and CP.11.

NRSC 2012, Cairo, Egypt, April 2012: 41 papers, distributed over seven sessions, as followSession C-1, "CDMA and Cellular Systems 0," 6 papers

- Session C-2, "Encryption and Watermarking," 5 papers
- Session C-3, "Image Processing I," 6 papers
- Session C-4, "Image Processing II," 6 papers

- Session C-5, "Modulation Classification, Coding and Speech," 6 papers
- Session C-6, "OFDM Systems," 6 papers
- Session C-7, "Control and Computer Applications," 6 papers

NRSC 2013, April 2013**:** 32 papers distributed over six sessions, as follows:
- Session C-1, "MC, OFDM, OFDMA and OWDMA," 5 papers
- Session C-2, ""Cognitive Radio and Compressive Sensing," 5 papers
- Session C-3, "Watermarking and Security," 5 papers
- Session C-4, "Image Processing," 6 papers
- Session C-5, "Satellite, Localization and Networks," 6 papers
- Session C-6," Signal Processing, Speech and Receivers," 5 papers

NRSC 2014, Cairo, Egypt, April 2014: 22 papers distributed over six sessions, as follows:
- Session C-1: "Encryption/Security," 3 papers
- Session C-2: "Cognitive Radio," 5 papers
- Session C-3: "Signal/Image/Video Processing," 3 papers
- Session C-4: "LTE/WiMAX Networks," 4 papers
- Session C-5: "OFDM/MIMO/STC," 4 papers
- Session C-6: "Wireless Sensor Networks," 4 papers

3.3 Russia, by Alexander B. Shmelev

Members of Russian Commission C took part in organization and execution of the XVIII, XIX, and XX annual scientific/technical conferences, "Radiolocation, Navigation, Communication" (RLNC-2012, RLNC-2013, RLNC-2014), held in Voronez (Russia), in April 2012-2014. Every conference gathered nearly 200-300 participants, mainly from the Community of Independent States (the former USSR). The proceedings of these conferences were published in Russian. The Honorary Chair of these conferences was Academician Yu. V. Gulyaev, Chair of the Russian Committee of URSI.

Russian Commission C representatives took part as a members of program committees and invited speakers in the First and Second International Conferences on Telecommunications and Remote Sensing (ICTRS 2012, ICTRS 2013), held in Sofia (Bulgaria), August 29-30, 2012, and in Noordwijkerhout (The Netherlands), July 11-12, 2013, as well as in the Third International Symposium on Radio Systems and Space Plasma (ISRSSP'13), held in Sofia (Bulgaria), August 28-29, 2013.

Commission C, together with Russian Committee URSI, took part in activities related to the XXXI General Assembly URSI in Beijing.

3.4 Switzerland, by Marcos Rubinstein

Commission E has been active in the analysis and processing of measured wideband lightning electromagnetic fields and currents. As part of the work, lightning data from the Säntis tower in northeastern Switzerland has been analyzed. The tower has been instrumented to measure lightning currents and its update to measure remote fields is being implemented. This work has been carried out in cooperation with Commission C (Prof. Farhad Rachidi of the EPFL)

Journal and conference articles prepared in collaboration with Commission C on processing of measured field waveforms, measurements on the Säntis Tower, and on the time-reversal technique:

1. M. Rubinstein, J.-L. Bermudez, V. Rakov, F. Rachidi and A. Hussein, "Compensation of the Instrumental Decay in Measured Lightning Electric Field Waveforms," *IEEE Transactions on Electromagnetic Compatibility*, **54**, 2012, p. 685-688.

2. C. Romero, F. Rachidi, M. Paolone and M. Rubinstein, "Statistical Distributions of Lightning Currents Associated With Upward Negative Flashes Based on the Data Collected at the Säntis Tower in 2010 and 2011," *IEEE Transactions on Power Delivery*, **28**, 3, 2013, p. 1804-1812.

3. R. Romero, C. Alberto, M. Paolone, M. Rubinstein and F. Rachidi-Haeri et al., "A System for the Measurements of Lightning Currents at the Säntis Tower," *Electric Power Systems Research*, **82**, 1, 2012, p. 34-43.

4. G. Lugrin, N. M. Parra, F. Rachidi, M. Rubinstein and G. Diendorfer, "On the Location of Lightning Discharges Using Time Reversal of Electromagnetic Fields," *IEEE Transactions on Electromagnetic Compatibility*, **56**, 1, 2014, p. 149-158.

5. M. Azadifar, M. Rubinstein, F. Rachidi, M. Paolone, D. Pavanello, "On the Influence of Measuring Instruments Bandwidth Limitations on the Inferred Statistical Parameters for Lightning Currents," presented at the GASS in Beijing in 2014.

6. C. Romero, F. Rachidi, M. Rubinstein, V. A. Rakov and M. Paolone et al., "Bursts of Fast Pulses in Positive Lightning Current Waveforms Recorded on the Säntis Tower," 12th International Symposium on Lightning Protection SIPDA, Belo Horizonte, Brazil, 2013.

3.5 USNC, by Amir I. Zaghloul

The officers of the United States National Committee of URSI (USNC-URSI) for the triennium 2012-2014 are:

Chair: Dr. Amir I. Zaghloul, Sensors and Electron Devices Directorate, US Army Research Laboratory and Electrical and Computer Engineering Department, Virginia Tech University, e-mail: amirz@vt.edu

Vice Chair: Dr. Gregory H. Huff, Electrical and Computer Engineering Department, Texas A & M University, e-mail: ghuff@ece.tamu.edu

Secretary: Dr. Eric L. Mokole, Radar Division, US Naval Research Laboratory, e-mail: eric.mokole@nrl.navy.mil

3.5.1 USNC-URSI Meetings

The US National Committee of URSI holds two regular meetings every year. One meeting is held in January in Boulder, Colorado, and includes all Commissions of URSI. The second meeting is held in conjunction with the IEEE International Symposium on Antennas and Propagation, which is held in the summer of every year. Its location is determined by the IEEE AP-S/USNC-URSI Joint Meetings Committee, and has been traditionally held in the North American countries of the US and Canada. Not all URSI Commissions are represented in the summer meeting. Occasionally, when the summer meeting is held in Canada, it is declared as a North American USNC/CNC meeting, in which years the January meeting in Boulder, CO, is skipped. Commission C of USNC-URSI participates in all winter and summer meetings.

Over the triennium of 2012-2014, Commission C of USNC-URSI participated in the following meetings:

- 2012 USNC-URSI National Radio Science Meeting, January 4-7, in Boulder, CO
- 2012 AP-S Symposium/USNC-URSI Meeting: July 8-14, in Chicago, IL
- 2013 USNC/URSI National Radio Science Meeting: January 9-12, in Boulder, CO
- 2013 AP-S Symposium/USNC-URSI Meeting: July 7-13, in Orlando, FL
- 2014 USNC-URSI National Radio Science Meeting: January 8-11, in Boulder, CO
- 2014 AP-S Symposium/USNC-URSI Meeting: July 6-11, in Memphis, TN

The next meeting will be an AP-S Symposium/ North American USNC-CNC URSI Meeting to be held in Vancouver, BC, Canada, July 19-25, 2015. No January meeting will be held in 2015.

3.5.2 Regular Sessions

The USNC-URSI call for papers for the meetings list the following topics for regular sessions for Commission C:

- Cognitive radio
- Computational imaging and inverse methods
- Distributed sensor networks
- Physics-based signal processing
- Radar target detection, localization, and tracking
- Sensor array processing and calibration
- Signal processing for radar remote sensing
- Statistical signal processing of waves in random media
- Synthetic aperture and space-time processing

Special sessions: In addition to the regular session, special sessions are organized, sometimes jointly with other Commissions. A list of special sessions organized over this triennium is given below.

- Antenna, system, and spectrum sharing issues in cognitive radio and cognitive Radar
- Computational modeling of stochastic uncertainty in electromagnetic components and systems: methods and applications
- Deformable, tunable, and other advanced material systems in communication and sensing platforms
- Recent advances in cognitive radio and signal processing techniques
- Innovative applications of smart phones, tablets, and other mobile platforms
- Wireless power transfer and energy harvesting systems
- Spectral management, engineering, and theory
- Spectrum-awareness for circuits and systems
- Spectrum challenges and changes

3.5.3 Keynote Speeches

One of the main features of the January USNC-URSI meeting is a presentation by a well-recognized keynote speaker on a subject related to the URSI Commissions. Two Commissions are selected at every meeting to host the keynote speakers. In 2013, Commissions C and F were selected as the host Commissions. The topic chosen for this event was "Remote Sensing and Communication Systems in Disaster Mitigation and Response." The contribution from Commission C was given by Prof. Charles W. Bostian from Virginia Tech University. The title of his presentation was "The Promise of Cognitive Radio for Communications and Remote Sensing for Critical Infrastructure, Disaster, Safety, and Risk Management."

3.5.4 Radio Science Bulletin

The *Radio Science Bulletin* is one of the primary publications of URSI. The contributions to the *Bulletin* come from all Commissions of URSI. Commission C of USNC-URSI contributed two papers in the present triennium, with a third paper in preparation. The three papers cover the topics of "Cognitive Radio," "Cognitive Radar," and "Quantum Communications and Networks."

3.5.5 Membership

The membership in Commission C of USNC-URSI reached numbers close to 200 in the early part of the new millennium, around 2002. This number contracted in years prior to the present triennium. A turnaround and renewed interest occurred during the triennium of 2012-2014. An increase by around four to five members per year has taken place during this time.

4. Contributions to the Radio Science Bulletin (RSB)

The *RSB* is the most widespread periodical publication by URSI, and collects contributions from all Commissions. Emphasis lies on non-specialized contributions that are oriented towards the radio scientist community. During the triennium covered by this report, Commission C contributed directly (through the proactive invitation by Commission officers) or indirectly (from national committees, or in URSI conferences) the following papers:

- Issue 340, "Spectrum Management Overview" by Tjelta-Struzak
- Issue 340, "Opportunistic Secondary Spectrum Access: Opportunities and Limitations" by Zander and Sung
- Issue 341: "Satellite Navigation. Present and Future" by Enge
- Issue 342: "Cognitive Radio: A Practical Review for the Radio Science Community" by Bostian and Young
- Issue 345: "Two-Tier Femto-Macro Wireless Networks: Technical Issues and Future Trends" by J. Zhang, Xiao, X. Zhang, Liu
- Issue 347: "Massive MIMO Systems: Signal Processing Challenges and Future Trends" by de Lamare
- Issue 347: "On the Road Towards Green Radio" by Palicot, Zhang, Moy
- Issue 349: "Collaborative Non-Cryptographic Physical-Layer Authentication Schemes in Wireless Networks" by Cheng, Ho, Yeh

Marco Luise, Commission Chair
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Sana Salous, Commission Vice Chair
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Figure 1. A chart of Commission C events at the URSI GASS 2014.

COMMISSION E

1. Terms of Reference

During the General Assembly in Chicago in 2008, the name of the Commission and its terms of reference were changed to better reflect current scientific and industrial practice. Commission E promotes research and development in:

a) Terrestrial and planetary noise of natural origin, including lightning and 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. Commission E Working Groups

A number of Working Groups have been established to provide a focus for a number of activities relevant to the theme of Commission E. These are outlined below, together with the contact person and, where appropriate, a brief summary of the group's activities during the three-year period.

2.1 E1. Terrestrial and Planetary Electromagnetic Noise Environment

Co-Chairs: C. Price (Israel), Y. Hobara (Japan), A. P. Nickolaenko (Ukraine), and K. Hattori (Japan)

This WG deals with the study of the characteristics of electromagnetic noise taking place not only in the terrestrial but also in the planetary environment. The most well-known noise is atmospheric radio noise from 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 Shumann resonance phenomena in the ELF band; and (2) ELF transients related to the optical emissions in the mesosphere, due to lightning. Higher-frequency lightning emission provides us with information on the fine structure of lightning's 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 plasma instabilities in space. Our recent topic is radio emission from the lithosphere, which again covers a wide frequency range, from dc to VHF (or even more). The characteristics and generation mechanisms of those effects, and also the seismic effect on the ionosphere, will be discussed. Finally, the radio noise environment on other planets (such as Jupiter) will be our topic, as well. The interaction of these natural noises with artificial noises due to human activity is another subject. Power-line harmonic radiation penetrates into the ionosphere/magnetosphere, and induces particle precipitation into the lower ionosphere (this is a kind of pollution of the natural environment by human activity). We also discuss the interaction of the natural environment with human activity.

During the years between 2011 and 2014, the following international symposiums/conferences related to the subjects of our working group were held:

- International Symposium on Monitoring and Prediction of Earth's Environment by Using Electromagnetic Methods was organized by Prof. Hobara in the University of Electro-Communications (UEC) Tokyo, Japan, in May 2012.

- JpGU (Japan Geoscience Union Meeting) (Japan): International Session of Atmospheric Electricity was chaired by WG member in 2012-2013.

- COSPAR 2012 (India): Session (Ionospheric Disturbances Observed Through Very Low Frequency Radio Waves) was chaired by WG member.

- EMSEV (Inter Association Working Group on Electromagnetic Studies of Earthquakes and Volcanoes) in 2012 and 2014: Sessions were chaired by WG members.

- WG members actively presented papers in various international scientific meetings, such as EGU, AGU, IAGA, and Isradynamics.

2.2 E2. Intentional Electromagnetic Interference

Co-Chairs: M. Bäckström (Sweden) and W. Radasky (USA)

This working group studies the area of intentional electromagnetic interference (IEMI), which is defined by the IEC as the "Intentional malicious generation of electromagnetic energy introducing noise or signals into electric and electronic systems, thus disrupting, confusing or damaging these systems for terrorist or criminal purposes." In particular, this working group focuses on electromagnetic threat weapons, coupling to electronic systems, vulnerability of systems to these types of transients, and protection of systems from the IEMI threat.

Over the 2011-2014 period, a large number of conferences dealt with IEMI, along with other aspects of HPEM:

- Joint IEEE AP-S and USNC-URSI Meeting in Spokane, Washington, July 3-8, 2011. Dr. Giri and Prof. Uslenghi organized an "In Memoriam" special session to remember Dr. Carl Baum (11 papers).

- URSI General Meeting in Istanbul, Turkey, August 15-19, 2011. There was a session organized by Dr. Sabath and Dr. Radasky entitled "High Power EM and IEMI" with 11 papers presented.

- A weeklong short course, HPE 201-2011, was presented in Schloss Noer, Germany, September 18-24, 2011. Dr. Dave Giri served as Lecturer and Course Director.

- IEC SC 77C (High Power Transient Phenomena) Project and Plenary Meetings in Seoul, South Korea, October 19-21, 2011. Work continued on IEMI and HEMP standards for protecting civil systems from these threats. Dr. Radasky chairs IEC SC 77C, and the Secretary is Dr. Hoad.

- USNC-URSI Conference in Boulder, Colorado, January 4-7, 2012. Several papers were presented dealing with IEMI.

- A weeklong short course HPE 201-2013 was presented in Lohas Park, South Korea, May 26-June 1, 2013. Dr. Dave Giri served as Lecturer and Course Director

- APEMC in Singapore, May 21-24, 2012. A special session on HEMP and IEMI was organized by Dr. Radasky. Another regular session on HPEM was also held. A total of eight papers were presented.

- EUROEM Symposium held in Toulouse, France from July 2-6, 2012. This symposium is dedicated entirely to HPEM topics, and had 218 papers and 312 participants. There were a significant number of papers dealing with IEMI.

- IEEE EMC Symposium held in Pittsburgh, Pennsylvania from August 4-10, 2012. A workshop was held dealing with Intentional EMI (IEMI), and 15 papers were submitted dealing with HPEM and also EM Information Leakage.

- Joint ICEAA 2012 – IEEE APWC 2012 – EEIS 2012 (URSI Commission E) Conference held in Cape Town, South Africa from September 2-7, 2012. Eleven papers were presented dealing with various aspects of HPEM, including IEMI.

- Conference on Environmental Electromagnetics (CEEM) held in Shanghai, China from November 6-9, 2012. Several sessions were organized with IEMI papers.

- Directed Energy Professional Society (DEPS) Symposium Conference held in Albuquerque, New Mexico from November 26-30, 2012. While this conference is aimed mainly at source development, there was a session that included papers covering HEMP and IEMI.

- National Radio Science Meeting sponsored by the USNC-URSI held in Boulder, Colorado from January 9-12, 2012. There were a few papers dealing with HPEM and IEMI at this meeting.

- An IET Seminar entitled "Extreme Electromagnetics – The Triple Threat to Infrastructure," held in London, England on January 14, 2013. Ten papers were presented dealing with impacts of HPEM (HEMP, IEMI, and severe geomagnetic storms) on the critical infrastructures.

- Asia-Pacific EMC (APEMC) Symposium held in Melbourne, Australia from May 18-23, 2013. There was a workshop on the protection of commercial facilities from HEMP and IEMI, and there was a special session on HPEM with eight papers presented.

- IEEE EMC Symposium held in Denver, Colorado from August 4-8, 2013. There was a workshop on EM Information Leakage, and a special session on IEMI with six papers presented.

- A session entitled "Intentional EMI (IEMI) and EMC" was organized at PIERS 2013, August 12-15, 2013 in Stockholm with eight papers.

- EMC Europe Symposium held in Brugge, Belgium from September 2-6, 2013. There was a workshop presented on the impact of IEMI on the critical infrastructures in Europe reviewing the work of three special EU-funded projects. A special session on EM Information Leakage was also held.

- 8th Future Security Research Conference in Berlin, September 17-19, 2013. One session, "Electromagnetic Threats and Countermeasures," consisting of seven papers, and also a panel session with the same title.

- IEC SC 77C (High Power Transient Phenomena) Project and Plenary Meetings held in Ottawa, Canada from September 23-27, 2013. Work continued on IEMI and HEMP standards for protecting civil systems from these threats.

2.3 E3. High-Power Electromagnetics

Co-Chairs: F. Sabath (Germany), and R. L. Gardner (USA)

The objective is to encourage research in high-power electromagnetics (HPE). The technical area of HPE consists of the physics and engineering associated with electromagnetic sources where nonlinear effects associated with high-field regions (and air breakdown) must be 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 because of local field enhancement.

2.4 E4. Lightning Discharges and Related Phenomena

Chair: V. A. Rakov (USA) and S. Yoshida (Japan)

The lightning discharge is one of the two natural sources of electromagnetic interference (EMI), the other one being the electrostatic discharge. Electric and magnetic fields generated by lightning represent a serious hazard to various systems, particularly those containing sensitive electronics. This WG focuses on the characterization of lightning and its interaction with engineering systems and with the environment, as well as on lightning detection and testing. It covers all aspects of lightning research, including observations, field and laboratory experiments, theoretical studies, and modeling.

Sessions on lightning discharges and related phenomena were organized at PIERS 2011 in Marrakesh, ICAE 2011 in Rio de Janeiro, ICLP 2012 in Vienna, GROUND/LPE 2012 in Bonito, SIPDA 2013 in Belo Horizonte, GROUND/LPE 2014 in Manaus, and ICAE 2014 in Norman, Oklahoma.

2.5 E5. Interaction with, and Protection of, Complex Electronic Systems

Co-Chairs: F. Gronwald (Germany), J-P. Parmentier (France) and H. Reader (South Africa)

This working group studies the various electronic and electromagnetic aspects related to the interaction with, and protection of, complex electronic systems. The focus is the analysis of the various coupling paths and their associated transfer functions into complex electronic systems, as formalized in the framework of electromagnetic topology. Analytical, numerical, and measurement techniques are used to characterize the electromagnetic fields and currents in a complex environment. In the analysis, special attention is placed on the emergence of new technologies, and the inclusion of advanced materials and communication systems.

Prof. Reader announced that he will no longer be able to contribute to this working group because of a new position. Commission E thanks Prof. Reader for his great contribution to URSI in general, and this working group in particular.

2.6 E6. Spectrum Management

Chair: T. Tjelta (Norway) and R. Struzak (Poland)

The E6 focus is on sound scientific spectrum management for improved utilization of the radio frequencies for protection of wireless communications service and radio sciences. The goal is to assure further development of radio sciences and communication services, unobstructed by potential radio interference due to unwanted energy in the form of out-of-band and in-band encroaching and deleterious in-band and out-of-band emissions. The electromagnetic spectrum is treated as a limited natural resource with a multitude of competing demands for access to it and use of it. Spectrum management seeks innovative means and technologies for adequate coexistence of all of them, taking into account the need for protection of new and incumbent wireless and wired communication services, systems, and equipment, with special focus on science services and those that use passive technologies.

Two of the papers presented at the previous GASS were revised and submitted to the *Radio Science Bulletin*, published in No. 340 on the topics:

- Spectrum management overview.
- Opportunistic secondary spectrum access: Opportunities and limitations.

The WG had planned a session at the first Commission E Electromagnetic Environment and Interference Symposium (EEIS 2012), in Cape Town, but there was very limited response, and in the end, no session on spectrum management. It was seen as a good opportunity to deal with the spectrum issues in between the General Assemblies.

A session on spectrum management topics had been planned together with Commission J for the GASS 2014. Some papers were received, and the session was held.

It appears difficult to engage the community in between General Assemblies to address spectrum management topics: either it is to improve spectrum utilization, or to ensure acceptable "interference free" environment for radio science services.

Dr. Tjelte and Prof. Struzak indicated that they would stop their activities for working group E6. Commission E thanks both for their contributions over the long period they held their positions. Dr. J. P. Borrego will take the position in the next triennium. The Commission actively looks for a second Chair/member of this working group.

2.7 E7. Geo-Electromagnetic Disturbances and their Effects on Technological Systems

Chair: A. Viljanen (Finland)

2.8 E8. Electromagnetic Compatibility in Wired and Wireless Systems

Co-Chairs: A. Zeddam (France), F. Rachidi (Switzerland) and F. Gronwald (Germany)

The intensive use of the electromagnetic spectrum for communications has resulted in issues of compatibility and interoperability between different users. In addition, the continual increase in operating frequency of products and higher-frequency sources of disturbances (such as ultra-wideband systems) has resulted in an increase of potential EMC problems in communication systems. The use of power lines for carrying data is adding to interference problems. This session will focus on theoretical and experimental EMC aspects in both wire and wireless communication systems. Potential remedies will be also addressed.

Prof. Gronwald will become the new Vice Chair for Commission E at the 2014 GA in Beijing, and is also a member of Working Group E5. He decided to no longer be an official Chair for this Working Group.

2.9 E9. Stochastic Techniques in EMC

Co-Chairs: L. Arnaut, S. Pignari, R. Serra

The EMC community is increasingly interested in the development of analysis and design techniques that take account of the inherent uncertainty of system parameters. In fact, the system response is affected by the statistics of such parameters, and varies widely within a distribution. Typical areas of interest include effects due to unknown wave parameters of interfering signals, statistical nature of fields inside metallic enclosures, uncertainty in the location of conductors inside multi-wire structures and routing of bundles in metallic enclosures, values of termination impedances, values of stray parameters and material parameters, etc.

This new working group was proposed at the Commission meeting during URSI GASS 2014.

3. Commission E: Joint Working Groups

3.1 Inter-Commission Working Group on Solar Power Satellites

Chair: H. Matsumoto (Japan)
Co-Chair for Commission E: J. Gavan (Israel)

3.2 EGH. Seismo Electromagnetics (Lithosphere-Atmosphere-Ionosphere Coupling)

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

Different kinds of electromagnetic precursors have been accumulated during the last few decades. Especially, geoelectric signals, ULF (ultra-low-frequency) and ELF (extremely-low-frequency) electromagnetic emissions, etc., are the direct signatures of seismic activity. There have also been observed perturbations in the atmosphere and ionosphere in possible association with earthquakes. The final goal is to understand different kinds of electromagnetic phenomena in the context of lithosphere-atmosphere-ionosphere coupling.

3.2.1 Activity During the Last Three Years (2012-2014)

A lot of evidence has been accumulated that electromagnetic phenomena do appear prior to an earthquake (EQ) on the basis of extensive ground- and satellite-based measurements. In particular, geo-electric signals are found to be associated with EQs, and ULF (ultra-low-frequency) electromagnetic emissions have been studied in numerous countries and have been found to be statistically correlated with EQs. Ionospheric perturbations, both in the bottom and the upper parts, have been extensively studied by means of sub-ionospheric VLF/LF signals and ionosonde data, respectively, and a statistical correlation of those ionospheric perturbations with EQs has been recently established. Furthermore, the satellite Demeter has contributed a lot to the study of seismo-electromagnetics. Finally, in order to understand such seismo-atmospheric and -ionospheric perturbations, a few hypotheses have been proposed regarding a lithosphere-atmosphere-ionosphere coupling mechanism. A few monographs on seismo electromagnetics and EQ prediction have been published, and there have also been several workshops and many sessions in international conferences.

4. Commission E Related National Activities

During the triennial period, a large number of events linked to Commission E took place, in many cases directly sponsored by URSI. Listed below is a selection of national activities to show the breadth of Commission E-based events.

4.1 China (CIE)

During last three years, the China national Commission E Chair (Dr. Yinghong Wen) organized the special session "EMC and ITS Technologies" for the 2012 International Conference on Electromagnetics in Advanced Applications, which was held in South Africa from September 2 to September 7, 2012. Dr. Wen also organized the special session "EMC and other Related Technologies for Rail Transportation" for the 2014 International Conference on Electromagnetics in Advanced Applications, held in Aruba from August 3 to August 9, 2014.

The researchers in the EMC laboratory of Beijing Jiaotong University have been studying the EM environment of China's railways, the characteristics of EM disturbance sources in China's high-speed railway system, and EM interference protection technologies for the high-speed EMUs and the train control system. They have solved many train driving faults induced by EM interference.

4.2 France

During the past triennium, the activities of the Commission E have been presented in 2012 and 2014 on the occasion of the 16th and 17th international symposiums on EMC, which took place in Rouen (April 25-27, 2012) and Clermont-Ferrand (June 30-July 3, 2014). For both symposiums, about 100 communications were presented during three sessions in parallel. In 2014, the organization committee of this symposium tried to increase the international participation in inviting Prof. Christos Christopoulus to give an invited conference on the "Challenges for Experimenters and Modelers in EMC Analysis and Design." The effort was also to stimulate the relationship with the activities of other domains of URSI, in inviting a professor in the optical domain, who gave a presentation entitled "Emission and Radiation: The View of the Physicist."

4.3 Israel

Israel's contributions to URSI Commission E's scientific activities are connected with Israel's IEEE EMC Chapter activities. We organize a Chapter on EMC in the yearly conferences organized by the Israel national electrical engineering society with the Israel IEEE society, where members of URSI Commission E and distinguished guest lecturers from abroad also participate. This year, we organized on January 30, 2014, a national conference in EMC, radio systems interference, and radiation effects in HIT Holon, with more than 120 participants. A scientific exhibition was included. The description of this conference and abstracts of the 14 presentations were included in an appendix.

In December 2014, two EMC-related conferences were organized in Israel:

1. An international conference in Tel Aviv, led by Bill Radasky, co-Chair of the URSI Committee E2 Intentional EMC Interference, and Elya Joffe ex- President of the worldwide IEEE EMC Society.

2. A Chapter on EMC at the joint national conference of the Israel association of electrical engineers and the Israel IEEE society, where lecturers from abroad will also participate. The chapter is led by Jacob Gavan. Jacob is co-Chair of the URSI Committee E8 EMC in wired and wireless communication systems, and the Inter-Commission WG on SPS, and Moshe Netzer, ex-Chair of the Israel IEEE EMC chapter.

4.4 Italy

During the past triennium, the Italian contribution to the URSI Commission E scientific activities included the technology of EM shields, power line communication, modeling tools and verification techniques for the electromagnetic compatibility of transportation systems, reverberation chambers, statistical EMC, and development of optimized measurement systems for EMC assessment of high-speed railway systems.

An URSI Italy meeting is held every other year in conjunction with the national symposium of the Electromagnetics Society. In this meeting, the activities of all Commissions are illustrated. Commission E presented an overview of the activities of various research groups, and in 2014, Profs. Valter Mariani Primiani and Franco Moglie of Università Politecnica delle Marche delivered an invited speech on "Applications and Optimization of Reverberation Chambers."

4.5 Netherlands

Commission E related activities included:

- Three annual joint conferences with NERG (Dutch Institute of Electronic and Radio Engineers)
- A yearly joint symposium with the Belgian national URSI committee
- EMC PhD research funded by Ministry of Economic affairs IOP-EMVT and EU FP7

- Lightning-related research funded by the Dutch Technology Foundation STW (www.stw.nl) with substantial contribution from industry
- Various activities sponsored by the Dutch EMC Foundation (www.emc-esd.nl) such as an EMC knowledge market and EMC on Tour.
- Organization of the EMC session in EUMW, November 2012.

4.6 Portugal

In the last triennium (2011-14), the Portuguese Commission E has collaborated with the National Committee organizing the URSI Annual Congress. During these events, significant scientific contributions on the topics addressed by Commission E have been received, such as invited talks, papers, and posters. The national congresses also intend to stimulate a close relationship among industry, academia, and society by promoting scientific exhibitions to show new projects, demonstrators, and industrial and commercial products, most of them related to Commission E activities.

- 2011: 5th Congress of Portuguese Committee of URSI, devoted to the theme, "Detection and Measurement of Radio Signals in the Future of Radio Communications," program: http:// www.anacom.pt/ render.jsp?contentId=1093180
- 2012: 6th Congress of Portuguese Committee of URSI, theme: "Electromagnetic Wave Applications: from Energy Efficiency to Bioengineering," program: http:// www.anacom.pt/ render.jsp?contentId=1130476
- 2013: 7th Congress of the Portuguese Committee of URSI, theme: "An Ocean Without Borders: Technological Challenges," program: http://www. anacom.pt/render.jsp?contentId=1168130

4.7 South Africa

In September 2012, the South African Commission E was actively involved in the International Conference on Electromagnetics in Advanced Applications (ICEAA-offshore, Cape Town, September 2012). This was in parallel with the first Electromagnetic Environment and Interference Symposium (EEIS) for Commission E. This URSI mid-term engagement was discussed at the last URSI GA in Turkey.

The local Commission E was also represented at the URSI BEJ meeting, which ran in parallel with IEEE Africon 2013 in Mauritius September 9-12. The URSI meeting was entitled: "Large Scale Science Projects: Europe-Africa Connects." A plenary paper was given on "New Robust Approaches to Designing Large Radio Research Instruments" by H. C. Reader. The paper explored the challenges to engineers, radio astronomers, and construction teams in their collaboration throughout the design process of large radio telescopes.

In other activities, Eskom, South Africa's national utility, is involved with the CIGRE national and international committee with regards to EMC. Eskom is involved with the following working groups addressing EMC in the power industry:

- CIGRE WG C4.30 – EMC of wind energy system
- CIGRE WG C4.31 – EMC between communication circuits and power systems
- CIGRE WG B4.61 – General guidelines for HVDC electrode design

EMSS South Africa, recently acquired by Altair, and its computational electromagnetics code, *FEKO*, is used extensively in EM and EMI simulations for research activities; a contemporary focus is allied to MeerKAT.

Various engineering departments were polled at main universities in South Africa to ask after 2014 activities in URSI E. The University of Witwatersrand has strong lightning research interests led by Prof. Ian Jandrell and Dr. John Van Coller. Prof. Ivan Hofsaier reported that their group has been involved with measurement and mitigation of conducted EMI from power electronics; offline switching ballasts for LED lighting applications; and modeling, measurement and mitigation of capacitively conducted EMI across transformer-isolated supplies. More recently, research has been active on multipath conductive structures consisting of multiple parallel paths of differing materials offering intrinsically EMI-immune conductors. The physics of these multipath conductors has been investigated, and results are already useful.

Geomagnetically induced currents (GIC) continue to be studied by the group led by Prof. Trevor Gaunt at Cape Town University, in collaboration with Dr. Pierre Cilliers at South Africa's National Space Agency in Hermanus. This work is linked to ESKOM.

The EMRIN Group at the Department of EE Engineering at Stellenbosch continues with its research on RFI mitigation and EMC for the SKA pre-cursor, MeerKAT. Signal propagation, shielding, reverberation chamber, common-mode current coupling, and time-domain impulse metrology form part of the research focus. As a final note from the Stellenbosch group, Dr. P. Gideon Wiid is taking over the South African Commission E Chair as Prof. Reader takes early retirement after years of involvement in the South African URSI committee.

4.8 Sweden

Commission E in Sweden holds two meetings per annum, a total of six over the triennium. Of these, three meetings are held jointly with the IEEE EMC Chapter. The attendance at these meetings ranges between 10 and 50. The Swedish Commission E has 29 members.

Topic areas for meetings in the period included "EMC and Railways," "Smart Grid: Future Electric Power Distribution and EMC," "EMC in Naval Applications," and "EMC in Space Applications."

Members of commission E have been active in the arrangement of national and international conferences, notably "EMC Europe 2014," which will be held in Sweden in September 2014.

Members have also been giving lectures, plenary talks, and papers at national and international meetings and conferences, published articles in scientific journals, and been acting as opponents or members of the evaluation committee of doctoral dissertations.

4.9 Switzerland

Recent activities of Commission E (in cooperation with Commission C) in Switzerland include the design, test, and installation of a lightning current measurement system at the Säntis telecommunication tower in the Appenzell region of Switzerland. The site has been operational since June 2010, and more than 400 flashes have been successfully measured. The data obtained constitute the largest dataset available to this date for upward negative flashes.

4.10 United Kingdom

The UK commission E started to join the scattered forces associated with the Institute of Physics and the Royal Meteorological Society, which are genuinely associated with the work of URSI commission E in the UK. A series of annual meetings was started in 2013, now known as the Wilson meetings, which are held on an annual basis at the University of Bath. These meetings bring together UK experts working in the general area of atmospheric electricity and its applications. For example, topics range from cosmic rays, cluster ions, charged aerosols, and current flow in fair weather conditions, to disturbed weather electrification, rain electricity, thunderstorm electrification, lightning, corona discharges, transient luminous events, and even to space weather. The meetings were attended by scientists and representatives of companies working in the areas of lightning detection and location, applications of static electric fields in production processes, and high-voltage power line surveying. The next meeting is planned for November 5, 2014, at the University of Bath. The long-term aim of the Wilson meetings is to establish a "CTR Wilson Centre" as a communication portal to respond to requests by the government, the general public, and to provide scientific expertise upon request.

4.10.1 UK Festival of Radio Science

Commission E participates in the IET-URSI UK Festivals of Radio Science, which will be held this year at the University of Manchester on December 16, 2014. These events are organized by the UK URSI panel and cover all URSI commissions. The meetings are specifically designed to promote radio science by giving an opportunity for research students and early career researchers to present their work to an audience consisting of senior radio scientists.

4.11 United States

During the 2011-2014 triennium, the US National Committee of URSI Commission E participated in four series of conferences. First, we participated in the USNC-URSI National Radio Science Meetings held in Boulder in January of 2013 and 2014. Particularly strong areas of interest included spectrum management, lightning, and wireless power transfer.

Second, we participated in the Antennas and Propagation/URSI conferences held in July of 2012 (Chicago), 2013 (Orlando), and 2014 (Memphis). Of particular note was a memorial session held in Chicago to celebrate the life of Dr. Carl Baum, who contributed so much to high-power electromagnetics and related areas. It was moving to see so many of his colleagues from around the world talk about how Carl had mentored their work, and helped them to build HPEM programs in far-off places.

Third, we participated in the EUROEM/AMEREM series of conferences in July of 2012 (Toulouse) and 2014 (Albuquerque). The focus of this conference is high-power electromagnetics. Finally, we participated in the 2014 URSI GASS in Beijing.

5. Meetings

A large number of meetings took place in the review period, as outlined above. In addition, Commission E sponsored a number of international meetings that are listed in a table, which also indicated expenditure, provided to the URSI Secretariat.

6. Reviews of Radio Science

The *Radio Science Bulletin* September 2012 was devoted to Commission E issues, with Dr. D.V. Giri as guest editor. The following papers were contributed:

D. V. Giri and F. M. Tesche, "Energy Patterns of Pulsed Antennas Illustrated with a Reflector Type of an Impulse-Radiating Antenna (IRA)," *Radio Science Bulletin*, **340**, September 2012, pp. 14-24.

Terje Tjelta and Ryszard Struzak, "Spectrum Management Overview," *Radio Science Bulletin*, **340**, September 2012, pp. 25-28.

Jens Zander and Ki Won Sung, "Opportunistic Secondary Spectrum Access: Opportunities and Limitations," *Radio Science Bulletin*, **340**, September 2012, pp. 29-33.

Etienne Sicard, Mohamed Ramdani, Samuel Akue Boulingui, "Recent Advances in Integrated Circuit Immunity to Radio-Frequency Interference," *Radio Science Bulletin*, **340**, September 2012, pp. 34-52.

James C. Lin, "Radio-Frequency Radiation Safety and Health: Are Radio-Frequency or Mobile-Phone Electromagnetic Fields Possibly Carcinogenic to Humans?," *Radio Science Bulletin*, **340**, September 2012, pp. 53-54.

7. Web Site

Further information about Commission E may be found in the Web links below:

http://www.ursi.org/en/commission.asp?com=E
http://ursi-test.intec.ugent.be/files/E/Homepage.htm

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COMMISSION G

1. In Memoriam

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

- Klaus Bibl (USA)
- Santimay Basu (USA)
- Robert D. Hunsucker (USA)

2. Chair's Comments

2.1 General

My considerable thanks to immediate past Chair Mike Rietveld and to past Chair Paul Cannon for their advice and help with Commission activities. I would also like to thank Vice Chair Iwona Stanislawska, as well as the GA conveners and WG leaders for their help and suggestions.

Commission G remains a very active Commission, as reflected in the reports below and in the active participation in URSI meetings. At this date, we have 281 abstracts, including joint sessions, for the Beijing General Assembly. This response leads all other Commissions.

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 EUR 9000 was made available. Approximately EUR 7500 was spent in supporting various meetings, typically with 500 or 1000 Euros. The remaining EUR 1500 is being used to support General Assembly attendance for two scientists: one a young scientist and the other from Africa. More detailed meeting sponsorship is summarized in Section 5.

2.3 Web Site

The Commission Web site is found via a link at URSI http://www.ursi.org/en/commission.asp?com=G. This link is http://www.ursi.org/files/G/Homepage.htm and also gives access to the Commission G mailing list.

2.4 Beijing GASS

Program: Including joint sessions, Commission G currently has ~280 papers at the GA. This is an excellent showing, matching that at the last two GAs, and the largest number of any Commission. The Commission G tutorial paper was given by Dr. Bodo Reinisch, on "Ionosphere and Plasmasphere Electron Density Profiles."

2.5 Working Groups

Commission G working groups are the primary focus for active collaborative research. During the triennium 2008-2011, URSI Commission G has been active through a number of WGs. Reports from these WGs are provided in Section 4.

3. Comments on the Radio Science Bulletin

The primary responsibility of the Commission Vice Chair is soliciting and editing papers for the *Radio Science Bulletin*. As usual, this task has proven difficult! PLEASE consider submitting a review-type paper to the *RSB*. These issues and the 50th anniversary of the Arecibo Observatory led me to become *RSB* Associate Editor for Historical Papers. This has led to two papers, listed below, that were published in the *RSB*. As always, my thanks go to Dr. Ross Stone, *RSB* Editor, who has enabled these activities. I also thank Kristian Schlegel, *RSB* Associate

Editor for Book Reviews and Editor of the journal *History of Geo- and Space Sciences* (*HGSS*), who got all of this started with an *HGSS* history series on the large geophysical radars. I especially encourage the more senior members of Commission G to submit histories or memoirs from a radio science perspective to *RSB* or to *HGSS*.

The history-related papers were published in *RSB* No. 346, September 2013, and were:

"My Time with Arecibo Observatory: An Exotic Experimental, Scientific, and Personal Challenge" by Jürgen Röttger.

"Fifty Years of Radio Science at Arecibo Observatory: A Brief Overview" by J. D. Mathews.

4. Working Group Reports

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

4.1 G1: Ionosonde Network Advisory Group

Chair: I. A. Galkin (USA), Vice Chair: J. B. Habarulema (RSA), INAG Bulletin Editor: P. Wilkinson (Australia)

Over the 45 years of INAG service, its primary advisory function has been to ensure the best quality of the ionogram-derived data provided by the ionosonde network for research and applications. Originally, the INAG was principally responsible for implementation of the uniform rules for the *manual* ionogram interpretation across the growing international network of ionosonde observatories. The *INAG Bulletin*, with its first issue in October 1969, became the reference and the communication means for the worldwide community of ionosonde data analysts. The INAG membership quickly reached triple-digit registration; its current roll remains fairly constant at about 300.

Over the years, the main focus of INAG recommendations has shifted from the consistent manual ionogram interpretation and standards for data exchange to the *automatic* ionogram scaling and quality of the autoscaled data. This transformation reflected the strengthening role of the ionosonde as a fully autonomous 24/7 instrument for prompt specification of the bottomside ionosphere, in which the ionogram's autoscaling plays a critically important part. The early efforts to build a space-weather forecast system driven by the autoscaled near-real-time (nRT) data were made in the 1980s. However, it was not until the advent of new concepts for ionosonde engineering, ionogram autoscaling, and assimilative nRT modeling in the 2005-2014 period that the original call became an operational reality.

Two key enabling technologies developed for the nRT ionospheric monitoring task in recent years were (1) the Global Ionosphere Radio Observatory (GIRO), http://giro.uml.edu/, first announced in December 2008 to comprise over 80 ionosondes under a uniform operating framework, and (2) the IRI Real-Time Assimilative Mapping (IRTAM) project, http://giro.uml.edu/RTAM, first announced in January 2013, that uses the nRT data feeds from GIRO stations to produce 15-minute global maps of the ionospheric peak density and height, as well as their deviations from the quiet-time climatology. With improved quality of ionosonde instrumentation, higher reliability of autoscaling, faster networking solutions, and greater robustness of the assimilation techniques to the real-life artifacts of unattended operations, a new quality of ionospheric specification has emerged under the guidance of INAG. In March 2012, the GIRO data-acquisition software was expanded to accept data from a variety of ionosonde observatories, as long as they comply with the URSI "SAOXML" format convention for the ionogram-derived data. The *AUTOSCALA* software for ionogram scaling, developed at INGV, Italy, was enhanced to comply with the SAOXML standard, thus expanding the list of potential contributors of nRT data. The GIRO is thus getting ready to accept and unify the individual observations from the ionosondes of the world to assimilate them in IRTAM, and produce both near-real-time maps and retrospective timelines of the ionospheric conditions. With a word of appreciation, INAG welcomes new nRT GIRO participants from USA, China, Italy, Poland, Guam, Australia, and Brazil, as well as acknowledges long-time participants throughout the world. The INAG will continue to be the communication point for contributing observatories.

Academic research using ionosonde data has always been in the center of INAG attention. Regretfully, with the passing of Prof. Henry Rishbeth in 2010, the INAG had lost one of its avid members of the ionosonde-related science advisory panel, responsible for the "Rishbeth List" of proposed investigations. Sustaining the list's legacy and filling the void on the science panel will be important aspects of the INAG operation in the upcoming triennial period.

4.2 G2: Studies of the Ionosphere Using Beacon Satellites

Vice-Chairs: P. Doherty (USA); P. V. S. Rama Rao (India) and Honorary Chair: R. Leitinger (Austria)

The Beacon Satellite Group (BSG) is interdisciplinary, servicing science, research, applications, and engineering interests. The prime objective is to study the ionosphere using beacon satellite signals.

This workshop group continued to be active in its traditional fields, namely compilation, exchange and dissemination of information, communication and exchange of experience of various organizations of relevance (augmentation systems for GPS-based satellite navigation, international and national advisory bodies, the United Nations Office for Outer Space Affairs (UNOOSA), the Institute of Navigation, the NASA International Space Weather Initiative (ISWI) and others), providing advice and collaboration on request. These activities were carried out by correspondence and through attendance at conferences and other meetings.

The most important activities of the BSG are the Beacon Satellite Symposia. After a forerunner organized at the Max-Planck Institut fur Aeronomie at Lindau, 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. To date, there have been 18 symposiums held in different countries including Russia, USA, Italy, India, Finland, China, Argentina, the United Kingdom, Hungary, and Spain. All of these events were organized by the Chairs of the BSG, together with a local chair and organizing committee consisting of URSI Commission G members.

The most recent symposium was held in 2013 in Bath, UK. This event was hosted by the University of Bath, with Dr. Cathryn Mitchell of the University of Bath as the local organizing Chair. This symposium was a great success. It was attended by nearly 150 scientists from 28 countries including Belgium, Brazil, Canada, Croatia, China, Finland, France, Germany, Greece, India, Indonesia, Italy, Japan, the Netherlands, Nigeria, Norway, Peru, Poland, the Russian Federation, Slovenia, South Africa, Spain, Taiwan, Turkey, the United Kingdom, and the United States of America. There were eight major sessions centering on scintillations, TEC measurements and analysis, ionospheric modeling, multi-instrument techniques, space weather studies and initiatives with Beacon satellites, ionospheric effects on navigation and new techniques and advances in ionospheric measurements.

The presentations and poster session were of excellent quality, and they included many papers by young scientists. To showcase the best papers of this symposium, a special issue of *Radio Science* is in progress, with Patricia Doherty serving as an Associate Editor of *Radio Science* for this issue.

The Beacon Satellite Group is grateful for the generous support from our sponsors, including URSI, the University of Bath, Boston College, the Office of Naval Research, the Institute of Navigation, Spirent, and Septentrio. These supporting funds made it possible to waive registration fees for students, and to provide some travel support for a number of participants from developing countries.

At the close of this very successful Beacon Symposium, Patricia Doherty led a working group meeting where members discussed the way forward, and voted to continue our studies group with URSI Commission G approval. The International Centre for Theoretical Physics in Trieste, Italy, has already agreed to host the next symposium in 2016. The working group also endorsed its present leadership. Finally, since both the traditional and new activities are well within the terms of reference of this working group, the working group did not suggest a change of these terms.

To summarize, the Beacon Satellite Group continues to be active and to have relevance to the interests of URSI Commission G. As such, we request that URSI Commission G approves that the BSG group continues and supports our plan to host the 19th Beacon Satellite Symposium in Trieste, Italy, in 2016.

4.3 G3: Incoherent Scatter Working Group

Chair: M. McCready (USA), Vice Chair: I. McCrea (UK)

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 and previous schedules may be found at http://www.isr.sri.com/wd2014 and ftp://ftp.ngdc.noaa.gov/STP/publications/igc_calendars.

This report will include general information about World Days, the procedure to request World Days, and descriptions of the experiments carried out since the last report and planned for the remainder of 2014.

World Days provide for coordinated operations of two or more of the incoherent scatter radars (ISRs) for common scientific objectives. The ISRs that participate in this program are listed here from geographic south to north.

Jicamarca, Peru
Arecibo, Puerto Rico
MU Radar, Japan
Millstone Hill, USA
Kharkov, Ukraine
Irkutsk, Russia
Poker Flat (PFISR), USA
Sondrestrom, Greenland
EISCAT Mainland, Scandinavia
Resolute-North (RISR-N), Canada
Svalbard (ESR), Norway

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 via prompt submission to the CEDAR, Madrigal, and/or other databases as appropriate. In view of the ongoing activities in this field, we ask URSI to keep this working group active.

4.3.2 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 costs and technical restrictions of ISR operations.

When proposals are received, the ISWG Chair initiates an interactive review process, enabling experimenters to provide additional input as needed. Every effort is made to accommodate all requests. The ISWG meets during the summer of each year to review all proposals with the aid of external reviewers solicited by the Chair as appropriate. The group then determines how the global network of ISRs can best satisfy the approved observational requests, and ensures that the experimental configurations, numbers of radars involved, time distribution, and total time allocated are appropriate for the specified science goals. This process normally takes place at the annual CEDAR meeting.

4.3.3 Observations

A description of the coordinated incoherent-scatter radar runs that were performed during the last three years are given here, with a brief description of their goals.

The 2011 World Day observations totaled 515 hours and are listed here.

Synoptic, three-day runs in February and March to measure basic ionospheric parameters and to capture the end of the extended solar minimum.
ISRs needed: All.
Contacts: J. Sojka, I. Häggström.

Meteors (Global Measurements of the Meteor Input Function), two-day runs in March and September to study the sporadic meteor distribution throughout the hemisphere, and to study sporadic *E*-layer fluctuations not influenced by strong meteor flux variations.
ISRs needed: All.
Contacts: A. Pellinen-Wannberg, C. Szasz, J. Kero, D. Meisel, I. Häggström.

Planetary Waves, a 10-day run in August to investigate planetary-scale waves in the ionosphere. This included measurements of the neutral wind throughout the mesosphere-lower thermosphere region, the response of the *F* region to atmospheric waves, and examining the mechanisms responsible for modulating the global-scale structure of the ionosphere at low and middle latitudes.
ISRs needed: All.
Contacts: S. England, Q. Zhou, G. Liu.

The 2012 World Day observations totaled 484 hours and are listed here.

StratWarm (Stratospheric Warming), a 10-day run during a month-long alert window spanning January and February, to measure neutral winds 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; and to examine the mechanisms responsible for variations in lower thermospheric dynamics and temperatures.
ISRs needed: All, although the response at Arecibo and Jicamarca may be weak.
Contacts: L. Goncharenko, P. Hoffman, S. Azeem, W. Ward.

Synoptic, three-day runs in June, September, and December to measure basic ionospheric parameters and to capture the beginning of the new solar cycle.
ISRs needed: All.
Contacts: J. Sojka, M. McCready.

The 2013 World Day observations totaled 508 hours and are listed here.

StratWarm (Stratospheric Warming), a 10-day run during a one-month alert window spanning January and February, to measure neutral winds 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; and to examine the mechanisms responsible for variations in lower thermospheric dynamics and temperatures.
ISRs needed: All, although the response at Arecibo and Jicamarca may be weak.
Contacts: L. Goncharenko, J. Chau, H. Liu, P. Hoffman.

Synoptic, three-day runs in April and November, to measure basic ionospheric parameters and to capture the beginning of the new solar cycle.
ISRs needed: All.
Contacts: J. Sojka, M. McCready.

Latitudinal variation of the vertical electric field in the *E* region, a four-day run in July to measure the vertical and geomagnetic zonal ion drifts in the *E* and *F* regions in order to study the height variation of the *E*-region electric field and its relationship to the *F*-region electric field.
ISRs needed: All.
Contact: Q. Zhou

The 2014 World Day observations are planned to total 525 hours and are listed here.

StratWarm (Stratospheric Warming), a 10-day run during a one-month alert window spanning January to February, to measure neutral winds 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; and to examine the mechanisms responsible for variations in lower thermospheric dynamics and temperatures.
ISRs needed: All, although the response at Arecibo and Jicamarca may be weak.
Contacts: L. Goncharenko, J. Chau, H. Liu, P. Hoffman.

Hemispheric and Latitudinal Storm Time Behavior, one four-day run during either alert period near both equinoxes, to measure the latitudinal variations and the east-west hemispheric differences during solar storms. This run was performed in early April.
ISR needed: All, and coordinated with the Chinese meridian chain of instruments.
Contact: S. Zhang, G. Yang, Z. Huang, J. Foster.

Northern Deep Winter Observations, this seven-day run will be performed in December near new moon to exploit the high-latitude dark skies near winter solstice, to study polar cap aurora; sun-aligned arcs; global trans-polar coupling; polar cap patch evolution, decay, structure and transport; reversed flow events; flow channel propagation; the formation, evolution and decay of SAPS (sub-auroral polarization streams) and SED (storm-enhanced densities) by measuring the penetration electric fields at low latitudes; and the formation of SAPS electric fields and SED at mid-latitudes.
ISRs needed: All.
Contact: K. Oksavik, Y. Dåbakk, H. Dahlgren, J. Semeter, A. Wood, H. Carlson

4.4 GF: Middle Atmosphere

Acting Co-Chairs for Commission G: Jorge L. Chau, Erhan Kudeki
Co-Chair for Commission F: none

(The following was reported by co-Chair for Commission G, Juergen Röttger, who has now stepped down.)

The MST-13 Workshop (13th International Workshop on Technical and Scientific Aspects of MST Radar) was held March 2012 in Kühlungsborn (Germany). It was noted that the first international workshop on this subject was organized at the MPAe in Lindau-Katlenburg. That workshop should be called "MST-0." Sponsors were URSI and SCOSTEP.

The 7th International School on Atmosphere-Ionosphere Radar ISAR-NCU-2012 took place from November 12-17, 2012, at the National Central University in Jhongli (previously Chung-Li) Taiwan. The 8th Radar School ISAR-NCU-2013 took place from November 11-20, 2013, also at the NCU. In both schools, Dr. Juergen Röttger acted as International Director and as NCU Chair-Professor. These Schools are designed for attendees from Southeast Asia and are financed completely by the NCU and the NSC (National Science Council) of Taiwan. Ideally, they are sponsored by SCOSTEP and URSI.

4.5 GH: Active Experiments in Space Plasmas

Co-Chair for Commission G: Todd R. Pedersen
Co-Chair for Commission H: M. Kosch

During the period from 2012 to 2014 there were a number of developments in active experiments in space plasmas. In particular, several rocket experiments were carried out at Kwajalein Atoll and new results continued to come in from the HAARP facility.

The Equatorial Vortex Experiment (EVEX) used tri-methyl aluminum (TMA) and lithium clouds released from sounding rockets as tracers in the equatorial dusk sector to examine neutral winds and plasma convection forming a vortex-like structure in the pre-reversal enhancement in the ionosphere. During this same campaign, the Metal Oxide Space Clouds (MOSC) experiment created artificial plasmas in the bottomside equatorial ionosphere in an attempt to prevent the natural Rayleigh-Taylor instability from occurring and generating plasma turbulence, which adversely impacts radio-based communication and navigation systems. A variety of RF propagation measurements were also performed during the experiments.

The new two-frequency heater at the Arecibo Observatory in Puerto Rico, which utilizes the large dish reflector to create a powerful vertically-oriented beam, has been mostly installed in the dish, and is expected to be available for experiments by the end of 2014. Continuing research at the High-Frequency Active Auroral Research Program (HAARP) facility has resulted in creation of artificial layers that persist for long periods. Optical measurements have allowed the energy spectrum of accelerated electrons to be estimated. However, based on media reports, the future of the HAARP facility is uncertain, as the Air Force has indicated that it no longer intends to be the operator of the facility.

4.6 URSI/COSPAR on International Reference Ionosphere (IRI)

Chair: Dr Lee-Anne McKinnell (South Africa), Vice Chair for COSPAR: Dr Shigeto Watanabe (Japan), Vice Chair for URSI: Dr Vladimir Truhlik (Czech Republic), Secretary: Dr Dieter Bilitza (USA)

4.6.1 Key Events

The newest version of the IRI model was released in 2012 with a number of improvements and additions:

(1) A new model was introduced for the bottomside electron density based on a large volume of ionosonde data resulting in an improvement of up to 40% (Altadill et al., Ebro, Spain).

(2) For the first time, auroral boundaries are included based on TIMED/GUVI data (Y. Zhang et al., APL JHU, USA).

(3) Data from another TIMED instrument, SABER, were used to develop a model for the storm effects on the auroral E-region (Mertens et al., NASA LRC, USA).

(4) The electron temperature model was improved with the inclusion of solar cycle effects based on satellite in situ measurements (Truhlik et al., IAP, Czech Republic).

(5) A new model for the ion composition in the bottomside based on the well-established photochemistry for this region as applied in the FLIP model (Richards et al., GMU, USA).

(6) In addition, IRI-2012 includes the newest version of the standard atmosphere model, NRLMSISE00, and the Correct Geomagnetic (CGM) coordinate system.

The other keystone event during this time period was the unanimous vote by the member countries of the International Standardization Organization (ISO) to make IRI the official ISO standard for the ionosphere (April 15, 2014).

4.6.2 Meetings

The 2011 IRI Workshop was held at the South African Space Agency's Space Science Directorate in Hermanus, South Africa, focusing on the performance and improvements of the IRI model over the African sector. In 2012, a session during the COSPAR General Assembly in Mysore, India, was organized by the IRI team on the topic of the Global and Regional Representation of Ionospheric Peak parameters for Space Weather Applications. The 2013 IRI Workshop was held at the University of Warmia and Mazury in Olzstyn, Poland, from June 24 to 28 on the topic of GNSS Inputs for IRI. The meeting was well organized by Andrzej Krankowski and his team, and was attended by over 80 participants with a good percentage of students and young scientists. Several new models for the F-peak height hmF2 were presented, based on ionosonde and on COSMIC radio occultation data, also including a formulation that describes the effect of ionospheric storms on hmF2. These models will be included as new options in a future version of IRI. Reports from these meetings are available online at http://irimodel.org/docs/iri_workshops.html. Plans and preparations are under way for the 2015 IRI Workshop in Bangkok, Thailand, which is being proposed as a COSPAR Capacity Building Workshop.

The Real-Time IRI Task Force meetings continued in early 2014 with a one-day meeting at the University of Massachusetts Lowell on May 19. Good progress has been made by the UML team with the IRTAM system that assimilates foF2 and hmF2 data from the GIRO digisonde network (real time data from over 40 stations) into the IRI-CCIR models for the peak characteristics (see http://giro.uml.edu/IRTAM/).

4.6.3 Publications

A selection of refereed papers from the 2009 IRI Workshop held in Kagoshima, Japan, was published in two issues of the journal *Earth, Planets and Space*, **63**, 4, 2011, and **64**, 6, 2012. Papers from the IRI session during the 2010 COSPAR meeting in Bremen, Germany, were published in *Advances in Space Research* (**51**, 4, February 2013) on the topic of the "Representation of the Auroral and Polar Ionosphere in the International Reference Ionosphere." More recently, a special issue of *Advances in Space Research* presented the papers from the 2011 Workshop held in Hermanus, South Africa (**51**, 10, November 2013). The issue included 15 articles that gave a good overview of IRI improvement activities, with special focus on the African sector.

4.6.4 New Members

John Bosco Habarulema (Uganda) was proposed and accepted as a new member for the IRI Working Group. He has worked extensively on TEC and IRI related research. He was one of the organizers of the 2011 IRI Workshop in Hermanus, and is co-editor of the ASR issue with papers from the Hermanus meeting. His main field of interest is in improving the predictability of TEC using neural networks.

Irina Zkharenkova (Russia) was elected to become a member of the IRI team. Irina is a researcher from the West Department of IZMIRAN in Kaliningrad, Russia, currently working at the Geodynamics Research Laboratory of the University of Warmia and Mazury in Olsztyn, Poland. Irina has made important contributions to determining the plasmaspheric electron content (PEC) from GNSS measurements, and to studying the variability of the PEC. As a member of the Local Organizing Committee for the 2013 IRI Workshop, she helped to make this a very successful and productive meeting.

4.7 Report of VERSIM (VLF/ELF Remote Sensing of Ionosphere and Magnetosphere) 2011-2014 URSI/IAGA Joint Working Group

URSI Co-Chair for Commission H and G: J. Lichtenberger (Hungary)
IAGA Co-Chair: 2011-2014 C. Rodger (New Zealand), 2014- J. Bortnik (USA)

The working group on VLF/ELF Remote Sensing of the Ionosphere and Magnetosphere (VERSIM) is an international group of scientists interested in studying the behavior of the magnetosphere and ionosphere by means of ELF (300 Hz to 3 kHz) and VLF (3 kHz to 30 kHz) radio waves, both naturally and artificially generated. The group was set up in 1975 by IAGA (International Association of Geomagnetism and Aeronomy) and URSI (International Union of Radio Science).

The activity of our working group can summarized as follows.

Workshops: The community organizes biannual topical workshops. During the period of 2011-2014, we have organized two workshops. The 5th VERSIM Workshop was held between 3-6 September 2012 in Sao Paulo, Brazil, where more than 50 participants attended from five continents, assisted by a special session on “Radio Science, Natural Disasters, and Space Weather” on the last day of the workshop. The workshop was organized by the Universidade Presbiteriana Mackenzie. More details can be found on the workshop Web site (http://http://www.craam.mackenzie.br/versim2/index.html).

The 6th VERSIM workshop was held between January 20-23, 2014, in Dunedin, New Zealand, organized by the University of Otago. The workshop attracted 35 participants from 14 countries, with 58 abstracts; see http://www.physics.otago.ac.nz/versim/ VERSIM_workshop_Dunedin_2014.html for more details. Reports on the workshops have been/will be published in the URSI *Radio Science Bulletin*.

Business Meetings: The community regularly holds business meetings at IAGA/URSI General/Scientific Assemblies and VERSIM Workshops. We thus had a business meeting at the XXXth URSI General Assembly, Istanbul, Turkey, and at the 12th IAGA Scientific Assembly in Mérida, Mexico, as well as at both recent VERSIM Workshops.

Newsletters: The VERSIM community has a regular, yearly newsletter, edited by the IAGA co-chair. It is based on the submitted report of VERSIM research groups. The newsletters can be downloaded from http://www.physics.otago.ac.nz/versim/#newsletter.

4.8 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: K. Schlegel (Germany)
- EGH: Seismo Electromagnetics (Lithosphere-Atmosphere-Ionosphere Coupling); Co-Chair for Commission G: S. Pulinets (Russia)
- FG: Atmospheric Remote Sensing Using Satellite Navigation Systems; Co-Chair for Commission G: Dr. Cathryn Mitchell (G)

5. Sponsored Meetings

5.1 Mode A Sponsorship

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

- ICEAA-APWC-EMS (September 9-13, 2013) Torino, Italy
- RADIO 2012 (September 24-27, 2013) Mauritius
- HF 13 (LW 13) (August 12-14, 2013) Faro Island, Baltic Sea
- SPIN 2014 (February 20-21, 2014) Noida-Delhi India
- RADIO 2014 (April 7-10, 2014) Mauritius
- ICEAA-IEEE APWC (Aruba August 3-9, 2014)
- RADAR 2014 (October 13-17, 2014) Lille, France

5.2 Mode B Sponsorship

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

- IRI Workshop (October 10-14, 2011), Hermanus, South Africa
- ISEA-13 (March 12-16, 2012), Paracas, Peru
- 5th VERSIM Workshop (September 3-6, 2012) Sao Paulo, Brazil
- International Reference Ionosphere (IRI) Workshop 2013 (June 24-28, 2013) Olsztyn, Poland
- ICONSPACE2013 (July 1-3, 2013) Malacca, Malaysia
- Beacon Satellite Symposium (July 8-12, 2013) Bath UK
- AP-RASC 2013 (September 3-7, 2013) Taipei, Taiwan
- Regional URSI meeting (January 2-5, 2014) Pune, India
- 6th VERSIM Workshop (January 20-23, 2014) Dunedin, New Zealand
- 40th COSPAR Scientific Assembly (August 2-10, 2014) Moscow

6. Sponsored Travel for URSI Participation

Commission G additionally supported travel to the Beijing GA of an Early Career Representative (ECR) candidate and of a participant from Africa.

Chair: J. D. Mathews, USA
E-mail: jdm9@psu.edu

COMMISSION J

This is a brief summary of the activities of Commission J and the developments in radio astronomy during this triennium. Conferences and workshops that were supported financially and technically are listed, as are the topics for sessions at the Beijing GASS. Commission J does not currently have any Working Groups.

1. Officers of Commission J for This Triennium

Chair: Justin Jonas, Rhodes University, South Africa

Vice Chair: Willem Baan, ASTRON, Netherlands

Past Chair: Subramaniam Ananthakrishnan, Pune University, India

2. Terms of Reference for Commission J

The activities of the Commission include:

- observation and interpretation of cosmic radio emissions from the early universe to the present epoch and

- radio reflections from solar system bodies.

Emphasis is placed on:

- The promotion of science-driven techniques for making radio-astronomical observations and data analysis,

- Support of activities to protect radio-astronomical observations from harmful interference.

3. Finances

To date, a total of €3600 has been used to support Young Scientist attendance at selected meetings (see table below). This leaves a balance of €5400.

4. Support of Meetings and Workshops

The meetings and workshops shown in Table 1 were provided with moral and/or financial support.

5. Vice-Chair and Early Career Representative Nominees

Yihua Yan (NAO, China (CIE)) and Richard Bradley (NRAO, USA) were the two nominees for Vice Chair of Commission J. Andrew Siemion (UC Berkeley, USA) and Stefan Wijnholds (ASTRON, Netherlands) were nominated as Early Career Representatives.

6. Square Kilometre Array

Having been conceptualized within a Commission J working group on large telescopes, the SKA has now progressed to a stage of significant maturity. The SKA Organization has been established under the leadership of Phil Diamond as Director General, with headquarters based in the UK. The SKAO is working in conjunction with international consortia to deign the elements of the SKA. Australia and Africa have been selected as the hosts for the SKA telescopes, and precursor instruments are being commissioned on both sites. Phil Diamond presented one of the General Lectures at the Beijing GASS.

7. Beijing URSI GASS Scientific Sessions

The topics of the scientific sessions for the Beijing GASS were chosen to match the exciting developments in radio astronomy across the globe, and indeed in space, too. There were a total of 89 oral presentations (excluding the tutorial and general lectures) and 25 poster papers. The sessions are shown in Table 2.

8. Awards

The following distinguished radio astronomers were awarded deserved honors during the triennium, and we congratulate them:

2014 Catherine Wolfe Bruce Gold Medal:
Kenneth Kellermann, NRAO, USA

Order of Oranje-Nassau:
Arnold van Ardenne, ASTRON, Netherlands

Grote Reber Medal:
Nicolay Kardashev, Lebedev Physical Institute, Russia (2012)
James Moran, Harvard, USA (2013)
Ron Ekers, CSIRO, Australia (2014)

Ron Ekers will be presented the 2014 Reber Medal at the Beijing GASS, prior to giving the Commission J Tutorial Lecture.

Justin Jonas
E-mail: j.jonas@ru.ac.za

Meeting	Country	Date	Support for Young Scientists
Radio and Antenna Days of the Indian Ocean (RADIO 2012)	Mauritius	Sept 24-27, 2012	€1000
IconSpace 2013	Malaysia	July 1-3, 2013	
AP-RASC'13	Taiwan	Sept 3-7, 2013	€1000
IEEE AFRICON 2013	Mauritius	Sept 9-12, 2013	€1000
International Conference on Microwaves and Photonics (ICMAP 2013)	India	Dec 13-15, 2013	
Regional Conference on Radio Science	India	Jan 2-5, 2014	€600
Radio and Antenna Days of the Indian Ocean (RADIO 2014)	Mauritius	April 7-10, 2014	

Table 1. Meetings and workshops supported by Commission J.

Session	Title	Papers
J01	Radio Astronomy in China	4
J02/03	Observatory Reports	10
J04/05	New Generation Radio Telescopes	11
J06	Polarization and magnetic fields from the solar system to the CMBR	6
J07/08	Observing the mm and sub-mm Universe: from the CMBR to local molecules	7
J09/10	Probing the Hydrogen Universe	9
J11/12	Correlation, calibration and imaging across all wavelengths	11
J13	Solar radio emission: astrophysics and space weather applications	6
J14/15	Time Domain Radio Astronomy: An example of Big Data in astronomy	5
J16/17	Latest observations and results	8
J18/19	Antennas, detectors and receivers for new generation radio telescopes	7
JT	Enabling technologies for modern radio astronomy	
JP	Poster Session	25
EJ10/02	Spectrum Management (joint with Commission E)	5

Table 2. The Beijing GASS Commission J sessions.

COMMISSION K

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 a joint workshop of URSI Commission K and ICNIRP as the URSI Commission K midterm meeting (Paris, August 2013)
d) Organizing two business meetings in June 2013, during BioEM2013 in Thessaloniki (Greece) and August 2013, on the occasion of the Mid-Term International Workshop in Paris (France)
f) Contributing to and funding AP-RASC'13 in Taipei (China SRS)
g) Preparing for the General Assembly and Scientific Symposium in Beijing, China (CIE), with 10 oral sessions, a poster session of Commission K, and seven joint sessions lead by Commission K with Commissions A, B, and E

2. Contributions to the *Radio Science Bulletin* (*RSB*)

2.1 Associate Editor

Erdem Topsakal (USA) has served as an Associate Editor for the *RSB*.

2.2 Publication in *RSB*

The following articles were published as a series in the "Radio-Frequency Radiation Safety and Health" column, owing to the great efforts of Prof. James C. Lin:

Zhangwei Wang and James C. Lin, "Radio-Frequency Radiation Safety and Health: Partial-Body SAR Calculations in Magnetic-Resonance Image (MRI) Scanning Systems," *Radio Science Bulletin*, **341**, June 2012, pp. 22-27.

James C. Lin, "Radio-Frequency Radiation Safety and Health: Reassessing Exposure Safety Requirements for Mobile Phones," *Radio Science Bulletin*, **344**, March 2013, pp. 32-34.

James C. Lin, "Radio-Frequency Radiation Safety and Health: Wireless Battery-Charging Technology or Energy Harvesting to Power Mobile Phones or Other Mobile Communication Devices, and Health Effects," *Radio Science Bulletin*, **344**, March 2013, pp. 34-36.

James C. Lin, "Radio-Frequency Radiation Safety and Health: The Effect of Electromagnetic Field Exposure on Hypersensitivity Responses in Humans," *Radio Science Bulletin*, **346**, September 2013, pp. 28-29.

James C. Lin, "Radio-Frequency Radiation Safety and Health: "Reevaluating Research on Cell Cultures Exposed to Low-Frequency Electromagnetic Fields," *Radio Science Bulletin*, **348**, March 2014, pp. 67-69.

3. Sponsoring Scientific Meetings

Commission K provided support for the scientific meetings listed in Table 1.

4. Joint Workshop of URSI Commission K and ICNIRP

The URSI Commission K mid-term meeting was held on August 29-30, 2013, in Paris, France. The meeting was jointly organized with the International Commission on Non-ionizing Radiation Protection (ICNIRP). Following the introduction of URSI K by Masao Taki, Chair of Commission K, and the introduction of ICNIRP by Rüdiger Matthes, Chair of ICNIRP, 16 presentations were given on the first day, and 10 presentations on the second day.

5. Mid-term Business Meetings of Commission K

Two mid-term business meetings were held. The first one was held in Thessaloniki, Greece, during BioEM2013 in June 2013. The second one was held in Paris during the URSI K mid-term meeting in August 2013. The activities of Commission K were reviewed with fruitful discussion. Preparation for the GASS in Beijing in 2014 was also intensively discussed at each meeting.

6. Preparations for GASS2014, August 16-23, 2014, Beijing, China

The preparation for the General Assembly in Beijing was successfully done with 10 oral sessions, a poster session of Commission K, and seven joint sessions lead by Commission K with partner Commissions A, B, and E. The program of sessions lead by Commission K consisted of 75 oral presentation, one tutorial lecture, and 13 poster presentations. The tutorial lecture was given by Prof. Shoogo Ueno, the University of Tokyo/Kyushu University. The title of the lecture was "New Horizon in Bioelectromagnetics and Bio-Imaging."

Event Name	Site and Event Date	Mode
ICEAA-APWC 2011 International Conference on Electromagnetics in Advanced Applications and IEEE APS Topical Conference on Antenna and Propagation in Wireless Communications	Torino, Italy, 12-17 September 2011	A
META'12 3rd International Conference on Metamaterials, Photonic Crystals and Plasmonics	Paris, France 16-19 April 2012	A
EMC Europe 2012 International Symposium on Electromagnetic Compatibility	Rome, Italy 17-21 September 2012	A
ISAP2012 2012 International Symposium on Antenna and Propagation	Nagoya, Japan 29 October- 2 November 2012	A
MSMW'2013 and TeraTech'2013 The Eighth International Kharkov Symposium on Physics and Engineering of Microwaves, Millimeter and SubMillimeter Waves and Workshop on Terahertz Technologies	Kharkiv, Ukraine, 23-28 June 2013	A
AP-RASC'13 2013 Asia-Pacific Radio Science Conference	Taipei, Taiwan, 3-7 September 2013	B
ICEAA 2013 International Conference on Electromagnetics in Advanced Applications	Torino, Italy, 9-13 September 2013	A
ICMAP 2013 International Conference on Microwaves and Photonics	Dhanbad, India, 13-15 December 2013	A
ICEAA 2014 and IEEE APWC 2014 International Conference on Electromagnetics in Advanced Applications and IEEE APS Topical Conference on Antenna and Propagation in Wireless Communications	Palm Beach, Aruba 3-9 August 2014	A
EMC'14/Tokyo 2014 International Symposium on Electromagnetic Compatibility	Tokyo, Japan, 12-16 May 2014	A

Table 1. Scientific meetings supported by Commission K.

7. Election for the Triennium 2014-2017

7.1 Election of Vice Chair

Two candidates were nominated. The final voting took place at the business meeting on August 18 during the URSI GASS in Beijing in 2014.

7.2 Election of Early Career Representative

Four candidates were nominated. The final voting was done at the same business meeting as the Vice Chair election.

8. White Paper on Wireless Communication and Health

The task was taken over at the previous GASS in Istanbul in 2011. A strategy to overcome the difficulty was discussed during the GASS in 2011. A decision was made at the business meeting during the 2011 GASS in Istanbul that "We continue editing the White Paper but propose a 'new' White Paper: 'EMF and Health.' A set of articles on the state of knowledge in research will be prepared, even looking forward toward future tendencies and possibilities. Those articles will then be published in the *Radio Science Bulletin* during the next two years. The White Paper will be the a compilation of those articles with a collective preface."

The challenge was unsuccessful, after all. More efforts should have been devoted. This challenge was discussed during the 2014 GASS in Beijing. Prof. James C. Lin has continually contributed articles in the *RSB* as a series of "Radio-Frequency Radiation Safety and Health" columns. The articles should provide resources to the White Paper.

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Report on GASS Commission Business Meetings

COMMISSION B (FIELDS AND WAVES)

Commission B held three business meetings during the Beijing GASS. There were around 50 participants present on the Monday meeting, 34 on Wednesday, and 20 on Friday. Unfortunately no attendance list was circulated on Monday, and hence the number 50 is an estimate.) Giuliano Manara (Chair of Commission B) chaired the meetings, assisted by Ari Sihvola (Vice Chair of Commission B).

1. Results of Election of Vice Chair

Two candidates were running for the position of Vice Chair for Commission B for 2014-2017. In the vote during the Monday evening business meeting, Prof. Kazuya Kobayashi received 43 votes, against 30 votes for the runner-up (Prof. Sembiam Rengarajan). Altogether, 25 official Members participated in the vote (two ballots were cast onsite). Prof. Kobayashi was later confirmed on Tuesday as the incoming Vice Chair by the Council.

2. Results of Election of Early Career Representative

Likewise, two candidates were running for the ECR representative for Commission B for 2014-2017. In the vote during the Monday evening business meeting, Prof. Lianlin Li received 27 votes, against 26 votes for the runner-up (Dr. Joseph Constantine). Altogether, 18 Member countries participated in the vote (six ballots were cast onsite). Due to the very close result, Commission B decided to leave the final selection to the Council. The Council selected Professor Li in its Tuesday meeting as the Early Career Representative for Commission B.

3. Appointment of Associate Editor for *Radio Science Bulletin*

Both the new Vice Chair, Kazuya Kobayashi, and the Early Career Representative, Lianlin Li, were nominated as Associate Editors for the *Radio Science Bulletin*.

4. Updates/Status of Working Groups

The status of Working Groups was not discussed.

5. Updates to Terms of Reference of Commission

The Commission B Terms of Reference were discussed. No updates were necessary.

6. Meetings Proposed to be Supported in the Coming Triennium

The main event of Commission B is the triennial Electromagnetic Theory Symposium (EMTS). This will be held in Espoo, Finland, August 14-18, 2016. The funding for the Commission from URSI (9000€) will be reserved for supporting the Young Scientists to the EMTS 2016 meeting.

Commission B will also work actively in the preparation and organization of the symposia of the parent organization: URSI GASS (Montréal, 2017) and the emerging AT-RASC (Gran Canaria, 2015).

Concerning the 2017-2020 triennium, the proposal by the USNC of URSI to hold the 2019 EMT Symposium in San Diego, California, was accepted. The proposal was presented by Prof. Sembiam Rengarajan, the US Member Committee representative in Commission B.

7. Report and Comments on the Scientific Program of the Commission for the Current GASS

Commission B organized 14 oral sessions and two poster sessions. In addition, Commission B was the lead Commission in seven oral sessions, and participated in 12 other joint sessions. Altogether, 98 oral papers and 107 posters were accepted. Only one no-show occurred in the oral sessions.

The Commission B Tutorial Lecture, "Controlling Waves on Metasurfaces," was given by Prof. Stefano Maci of the University of Siena, Italy.

Overall, the sessions organized by Commission B were extremely successful. The quality of the presentations was very high and the sessions attracted a large number of participants, over one hundred at peak.

Commission B also organized an eight-hour School for Young Scientists on Saturday and Sunday before the symposium. The instructor was Prof. Nader Engheta (University of Pennsylvania). The topic of his lectures was "Fields and Waves in Metamaterials."

Among the 10 finalists of the Student Paper Competition in URSI GASS, there were three candidates from Commission B. They won the first three prizes:

First prize: Filipa Prudêncio (University of Lisbon, Portugal; supervisor Prof. Carlos Paiva). Her presentation was entitled, "The Most General Classes of Tellegen Media Reducible to Simple Reciprocal Media: A Geometrical Approach"

Second prize: Simon Adrian (Télécom Bretagne, France, and Technische Universität München, Germany; supervisor Prof. Francisco Andriulli). His presentation was entitled, "Hierarchical Bases on the Standard and Dual Graph for Stable Solutions of the EFIE Operator"

Third prize: Andreas Ericsson (Lund University, Sweden; supervisor Prof. Daniel Sjöberg). His presentation was entitled, "A Resonant Circular Polarization Selective Structure of Closely Spaced Morin Helices"

Concerning the URSI awards presented in the opening ceremony of the Beijing GASS, two awardees were closely affiliated with Commission B: Prof. Nader Engheta (Balthasar Van der Pol Gold Medal) and Prof. Francesco P. Andriulli (Issac Koga Gold Medal). Furthermore, the research work by the recipient of the John Howard Dellinger Gold Medal, Prof. Jean-Pierre Bérenger, was directly linked to the domain of Commission B.

8. Other Business

The Commission B officials for the 2014-2017 triennium are as follows:

Chair: Prof. Ari Sihvola
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Vice Chair: Prof. Kazuya Kobayashi
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Early Career Representative: Prof. Lianlin Li
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Past Chair: Prof. Giuliano Manara
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Ari Sihvola
E-mail: ari.sihvola@aalto.fi

Conferences

URSI CONFERENCE CALENDAR

September 2014

EMC Europe 2014
Gothenburg, Sweden, 1-4 September 2014
Contacts: Symposium Chair: jan.carlsson@sp.se, Technical Program Chair: peterst@foi.se, http://www.emceurope2014.org/

Geospace Revisted 2014
Rhodes, Greece, 15-20 September 2014
Contact: Ioannis A. Daglis, University of Athens, Fax +30 210-7276725, E-mail: iadaglishys.uoa.gr
http://geospacerev.space.noa.gr/index.php

October 2014

RADAR 2014 - International Radar Conference 2014 - "Catching the invisible"
Lille, France, 13-17 October 2014
Contact: Ms. Monique DECHAMBRE, LATMOS, Quartier des Garennes 11, Bd des Garennes F 78280 Guyancourt, France, monique.dechambre@latmos.ipsl.fr and exporadar2014@see.asso.fr
http://www.radar2014.org

ISRSSP 2014 - The Fourth International Symposium on Radio Systems and Space Plasma
Ruse, Bulgaria, 30-31 October 2014
Contact: Contact: Prof. Blagovest Shishkov, Institute of Mathematics and Informatics at Bulgarian Academy of Sciences, 1113 Sofia, Bulgaria, Fax :+359 2 971 3649, E-mail: bshishkov@math.bas.bg
http://www.iicrest.org/isrssp/

November 2014

APMC 2014 – Asia-Pacific Microwave Conference
Sendai, Japan, 4-7 November 2014
Contacts: Prof. Noriharu Suematsu [Chair, Steering Committee] c/o Real Communications Corp., 3F Shinmatsudo S bldg., 1-409 Shinmatsudo, Matsudo 270-0034, Japan, Fax: +81-47-309-3617, E-mail: 2014secrt@apmc2014.org, http://apmc2014.org/

January 2015

International Conference on Foundations and Frontiers of Computer, Electrical Engineering : commemorating 150 years of Maxwell's Equations
Hooghly, Westa Bengal, India, 9-10 January 2015
Contact: Prof. B.N. Biswas, Sir J.C. Bose School of Engineering, Supreme Knowledge Foundation Group of Institutions, 1, Khan Road, Mankundu, Hooghly-712139, West Bengal, India

May 2015

URSI Mid-Atlantic Meeting 2015 - AT-RASC
ExpoMeloneras Convention Centre, Gran Canaria, Spain, 18-25 May 2015
Contact: Prof. Peter Van Daele, URSI, Sint-Pietersnieuwstraat 41, B-9000 Gent, Belgium, E-mail: peter.vandaele@intec.ugent.be

September 2015

Metamaterials 2015
Oxford, United Kingdom, 7-10 September 2015
Contact: Prof. Richard W. Ziolkowski, Litton Industries John M. Leonis Distinguished Professor, Electrical and Computer Engineering Professor, College of Optical Sciences, University of Arizona, Tucson, AZ 85721, E-mail: ziolkowski@ece.arizona.edu
http://congress2015.metamorphose-vi.org

An up-to-date version of this conference calendar, with links to various conference web sites can be found at http://www.ursi.org/en/events.asp

News from the URSI Community

NEWS FROM A MEMBER COMMITTEE

INDIA
Inaugural A.P. Mitra Lecture

The National Physical Laboratory, New Delhi India, has announced that a lecture series in memory of Dr. A. P. Mitra will be held each year. The inaugural lecture was held on Ozone Day, Tuesday, the September 16, 2014, at the NPL Auditorium. The lecture was given by Prof. Govind Swarup.

Dr. Mitra was a former President of URSI (1984-1987) and an Honorary President of URSI (2002-2007).

URSI GASS
Student Paper Competition Winners

The Third URSI International Student Paper Competition was held at the URSI GASS in Beijing, China, in August, 2014. (l-r) Prof. Rodolfo S. Zich, Italy, co-author of the book signed and given to the ten student finalists; Wei Xu, Pennsylvania State University, USA, Honorable Mention; Yijian Gong, Swiss Federal Institute of Technology, Switzerland, Honorable Mention; Ke Guan, Beijing Jiaotong University, China, Honorable Mention; Haonan Chen, Colorado State University, USA, Honorable Mention; Chris Mannix, University of Birmingham, United Kingdom, Honorable Mention; Sean Elvidge, University of Birmingham, United Kingdom, Fifth Prize; Jiangfeng Wu, University of Michigan, USA, Fourth Prize; Andreas Ericsson, Lund University, Sweden, Third Prize; Simon Adrian, Télécom Bretagne, France and Technical University of Munich, Germany, Second Prize; Filipa Prudêncio, University of Lisbon, Portugal, First Prize; Prof. Steven C. Reising, Colorado State University, USA, Chair of the competition.

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.

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