Radio Science Bulletin

ISSN 1024-4530

INTERNATIONAL UNION OF RADIO SCIENCE

UNION RADIO-SCIENTIFIQUE INTERNATIONALE

U.R.S.I.

No 346
September 2013

URSI, c/o Ghent University (INTEC)
St.-Pietersnieuwstraat 41, B-9000 Gent (Belgium)

Contents

Front cover: The log-periodic VHF feed antenna (45 MHz to 55 MHz) used at the Arecibo observatory, circa 1980. See the paper by Jürgen Röttger pp. 17-27.

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Editorial

The second part of our special section on "The Role of Radio Science in Disaster Management" will appear in the December issue of the *Radio Science Bulletin*, instead of in this issue, as originally planned. Instead, in this issue we have a paper on the conservation of spectrum as it relates to radio astronomy. We also have two papers that introduce what will become a recurrent part of the *Bulletin*, focusing on various historical aspects of radio science. In this issue, the focus is on the Arecibo Observatory.

Our Papers

In his invited paper from Commission E, Axel Jessner looks at the necessary requirements for the protection of spectrum for scientific services, and in particular, for radio astronomy. The paper begins with an examination of basic principles of the nature of the radio spectrum, and its inherent properties from a conservation standpoint. Analogies are drawn to other resources that are in the public domain in terms of the benefits and costs, and how these should be borne. Quantitative measures of spectrum efficiency for radio astronomy are introduced and explained. An argument is made that radio astronomy has good spectral efficiency. The spectral requirements for radio astronomy in light of modern scientific knowledge and technological advances are examined. It is shown that the same advances that have substantially improved the sensitivity of radio-astronomical observations have also substantially increased the sensitivity to interference. An analysis is given of what is needed in terms of revisions to current spectrum-protection regulations for radio astronomy, and what needs to be considered for future regulations. Examples of the effects on existing systems are used to illustrate the analysis. The paper concludes with some suggestions on how these issues can be approached in the future. This paper provides a very readily understood and quite interesting explanation of the situation faced by radio astronomy with respect to spectrum utilization and protection.

The efforts of Dave Giri in bringing this paper to the *Bulletin* are gratefully acknowledged.

A New Opportunity: The History of Radio Science

Beginning with this issue, John Mathews is joining the *Bulletin* as Associate Editor for Historical Papers. He will be soliciting (and accepting contributed) papers dealing with the history of radio science. He is going to try to "capture" some of the history of our field while the people who made it are still available to tell the story. If you have an interesting historical contribution, or can suggest one, please get in touch with John via e-mail at jdm9@psu.edu.

To begin this new initiative, John has written a brief overview of the history of the Arecibo Observatory, which is approaching its 50th anniversary. He provides some interesting insight into how the facility came to be, and its early days.

Jürgen Röttger has provided us with a fascinating personal history of his time with the Arecibo Observatory, spanning an exciting decade. His story begins with the beginning of the VHF mesosphere-stratosphere-troposphere (*MST*) radar projects at Arecibo in the latter part of the 1970s. He describes the first observation attempts, what happened, and what was learned from the attempts. This led to improvements in the systems and methods, and several successful observational campaigns in the 1980s. Several new instruments were built, in 1985 resulting in the first troposphere-stratosphere radar observations using the Arecibo VHF radar. Throughout this memoir, the author recounts not only the development of the experimental facilities, but the fascinating science learned from their use. What is perhaps most interesting in all of this is the insight gained into what led to the decisions made: in the development of the instruments, in the steps taken to explore the science, and in what led the author to his career choices.

Our Other Contributions

Kristian Schlegel has brought us a review of a new book on the thermal design and thermal behavior of radio telescopes. The review was done by Jacob Baars.

In his Radio-Frequency Radiation Safety and Health column, James Lin deals with an interesting phenomenon: hypersensitivity to electromagnetic fields. One interesting case involves a former director of the World Health Organization.

We have reports on several conferences that URSI has technically sponsored.

Most importantly, the call for papers for the XXXIth URSI General Assembly and Scientific Symposium, to be held August 16-23, 2014, in Beijing appears in this issue. You should start preparing your papers for this meeting now!

Ross

XXXI General Assembly and Scientific Symposium of the International Union of Radio Science

Union Radio Scientifique Internationale

August 17-23, 2014 Beijing, China (CIE)

Announcement and Call for Papers

The XXXIst General Assembly and Scientific Symposium (GASS) of the International Union of Radio Science (Union Radio Scientifique Internationale: URSI) will be in Beijing. The XXXIst GASS will have a scientific program organized around the ten Commissions of URSI, including oral sessions, poster sessions, plenary and public lectures, and tutorials, with both invited and contributed papers. In addition, there will be workshops, short courses, special programs for young scientists, a student paper competition, programs for accompanying persons, and industrial exhibits. More than 1,500 scientists from more than 50 countries are expected to participate. The detailed program, the link to the electronic submission site for papers, the registration form, the application for the Young Scientists program, and hotel information are available on the GASS Web site: **http://www.chinaursigass.com**

Submission Information

All papers (a maximum of four pages) should be submitted electronically via the link provided on the GASS Web site: http://www.chinaursigass.com. Please consult the symposium Web site for the latest instructions, templates, and sample formats. Accepted papers that are presented at the GASS will be submitted for posting to IEEE Xplore.

Important Deadlines: Paper submission: February 15, 2014 Acceptance Notification: April 15, 2014

Topics of Interest

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

Young Scientists Program and Student Paper Competition

A limited number of awards are available to assist young scientists from both developed and developing countries to attend the GASS. Information on this program and on the Student Paper Competition is available on the Web site.

Contact

For all questions related to the GASS, please contact the GASS Secretary:
Cynthia Lian, e-mail: cynthia_nano@hotmail.com; Lucy Zhang, e-mail: yzha0943@gmail.com;
Yihua Yan, e-mail: yyh@nao.cas.cn; Tel: 008610-68278214

www.chinaursigass.com

AWARDS FOR YOUNG SCIENTISTS
CONDITIONS

A limited number of awards are available to assist young scientists from both developed and developing countries to attend the General Assembly and Scientific Symposium of URSI.

To qualify for an award the applicant:

1. must be less than 35 years old on September 1 of the year of the URSI General Assembly and Scientific Symposium;
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 of the General Assembly and Scientific Symposium.

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 the General Assembly and Scientific Symposium. They will receive free registration, and financial support for board and lodging at the General Assembly and Scientific Symposium. Limited funds will also be available as a contribution to the travel costs of young scientists from developing countries.

The application needs to be done electronically by going to the same website used for the submission of abstracts/papers via http://www.chinaursigass.com/. The deadline for paper submission for the URSI GASS2014 in Beijing is 15 February 2014.

A web-based form will appear when applicants check "Young Scientist 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 GA submission Web site.

Applications will be assessed by the URSI Young Scientist 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 URSI Web site in April 2014.

For more information about URSI, the General Assembly and Scientific Symposium and the activities of URSI Commissions, please look at the URSI Web site at: http://www.ursi.org or the GASS 2014 website at http://www.chinaursigass.com/

If you need more information concerning the Young Scientist Program, please contact:

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Conservation of Spectrum for Scientific Services : The Radio-Astronomical Perspective

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This is an invited contribution from Commission E

Abstract

Scientific services are indispensable for a technical society, but by their nature they have more-stringent protection requirements. They are efficient in their use of allocated bandwidth and utilize the highest possible detection sensitivity, but any detectable manmade signal in their band jeopardizes their operation. There is no free choice of frequencies: these are given by natural molecular-transition frequencies. As a consequence, only the scrupulous regulatory protection of core frequencies for science can ensure the viability of the scientific use of radio spectrum for the benefit of all.

1. Introduction

Radio spectrum, which is the object of much regulatory activity and of increasing commercial interest, has quite a few peculiar properties that set it apart from other commodities. The radio spectrum is a property of space-time and, as such, is an *immaterial* commodity: it cannot be created or destroyed. Because of that, it *cannot be owned* in the same way that we can own a material object, such as a house or even money in a bank account. Radio spectrum can only be *used* for some length of time. Furthermore, the use of radio spectrum is by its nature unavoidably *public*, because it is detectable by others; in most cases, that is actually a very much desired feature of radio waves. However, at the same time, its use is often *difficult to contain* geographically, especially for longer wavelengths. Its use by more than one service in a given band can lead to *interference,* reducing its usefulness to the services in the band. Even though the useful radio spectrum spans about eighteen octaves in frequency, the spectrum is nevertheless finite, and therefore *a scarce commodity* that requires agreements about its *efficient use. Spectrum conservation is a must*, as it maintains the spectrum availability for all services.

Any undertaking – be it commercial (where it is natural), political, social, scientific, even cultural and educational – is nowadays viewed under economic aspects. Depending on the intention and thoroughness of the scrutiny, this will not only include the internal and direct costs and benefits to those who are involved, but also what is externalized to other sectors of society, other countries, future generations, or even the global environment. Pollution and energy generation are classical examples known to everyone. There is a tradition of highlighting only the short-term direct benefits when we are dealing with the privatization and liberalization of the use of common and, by their nature, limited resources. However, at the same time, the proponents often neglect the externalized costs of higher economic efficiency (i.e., pollution), and the long-term benefits public use of resources has given to society. The radio spectrum – and, in particular, its use for scientific purposes – is just another example of this. Nobody denies that, for example, accurate weather forecasts are a means of improving the yields of agriculture, the forecast of natural disasters, and the efficiency of transport. The benefits of meteorological Earth sensing are common for everybody, and the direct costs are borne by the taxpayer. The same is also true for other scientific uses of the radio spectrum, where there is often a considerable delay between scientific research and its impact on society or the economy. However, even for weather forecasts, the economic impacts can only be partially quantified, but nevertheless, no one would deny their significance and benefit. The same is true for the overall impact of the scientific radio spectrum's use, as outlined in the recent RSPG report [1] and the draft ITU report on the scientific use of spectrum [2]. Purely economic arguments quickly lose their objectivity when their metrics become ill-defined, and they become a matter of definition by vested interests. In that context, it becomes apparent that efficient use of spectrum may mean very different things to different people.

2. Spectrum Efficiency as Seen by a Radio Astronomer

In purely technical terms, the question of spectrum efficiency was investigated by the ITU in their Recommendation ITU-R SM.1046-2 ("Definition of Spectrum Use and Efficiency of a Radio System) [9]:

> ...Therefore, the measure of spectrum utilization – spectrum utilization factor, *U*, is defined to be the product of the frequency bandwidth, the geometric (geographic) space, and the time denied to other potential users:
>
> $$U = BST$$
>
> where:
>
> *B*: frequency bandwidth
> *S*: geometric space (usually area) and
> *T*: time.
>
> The geometric space of interest may also be a volume, a line (e.g., the geostationary orbit), or an angular sector around a point. The amount of space denied depends on the spectral power density. For many applications, the dimension of time can be ignored, because the service operates continuously....

For the large distances involved in space research, but even more for radio astronomy, it becomes clear that the metric *U* can lead to numbers that are so much out of the range of any other service that it may not be applicable for the comparison of many scientific services to other more-common uses of the spectrum. Passive services have a predefined intrinsic sensitivity that is a pre-condition of their functioning. However, that has the consequence that their protection area, *S*, depends solely on the signal strengths of the competing services. These are then the only means of controlling the size of exclusion zones. Clearly, the derived spectrum utilization efficiency (*SUE*) of the SM. 1046-2 suffers from the same problems. It was defined in the form of the spectrum utilization factor:

$$SUE = \frac{M}{BST},$$

where *M* is a yet-to-be-determined "useful effect obtained with the aid of the communication system in question," which brings us back to the discussion in the previous chapter.

However, what can be investigated and compared is the communication efficiency of the radio source to the detector link.

Large radio telescopes are highly sensitive, and routinely detect minute signals that have flux densities of the order of $1\ \mathrm{mJy} = 10^{-29}\ \mathrm{Wm^{-2}Hz^{-1}}$. This corresponds to what one would receive from a UMTS mobile phone radiating 1 W at a distance of 40 million km (roughly 100 times the Earth-moon distance).

In 2008, scientists detected water vapor emissions at 6.1 GHz in a distant quasar [3, 4]. With 305 dBW, the narrowband signal emission had 10000 times the total power of the sun. However, after it had traveled for 11.1 Gigayears, it was attenuated by 555 dB, which resulted in a spectral flux density of $S_\nu = 2.5$ mJy, or a spectral power density $S = -323$ dB(W/Hz) for 6.1 GHz at the radio telescope. The system noise level of a radio-astronomical receiver at a system temperature of $T_{sys} = 37$ K is $N = kT_{sys} = -213$ dB(W/Hz). Using Shannon's theorem for the channel capacity,

$$C_S = \Delta\nu \log_2\left(1 + S/N\right) \text{ [bits/s]} \quad (1)$$

for a channel bandwidth of $\Delta\nu = 78$ kHz we get a bit rate of 10^{-6} bit/s. Detecting a spectral line in about $t_{int} = 50000$ s (= 14 h) with a signal-to-noise ratio $S/N = 6$ is indeed a sign of good technical spectrum efficiency, thanks mainly to the high gain of a 100 m diameter radio antenna, and the radio-astronomical measurement technique. The simple calculation of the amount of data obtained from the measurement, $C_S t_{int}$, based on the channel bandwidth $\Delta\nu$, yields only 0.05 bits/s in this case. However, the sensitivity of a radio-astronomical antenna is the accuracy with which the mean noise power can be determined in a given time and bandwidth, and is given by the radiometer equation [5, 6]:

$$\Delta S_\nu = \frac{2kT_{sys}}{\varepsilon_{ant} A_{ant}} \frac{1}{\sqrt{\Delta\nu t_{int}}}, \quad (2)$$

where the aperture efficiency for the 100 m Effelsberg antenna is $\varepsilon_{ant} = 0.53$. With the aperture, A_{ant}, of $7854\ \mathrm{m}^2$ and a system temperature $T_{sys} = 38$ K, we get a $\Delta S_\nu = 0.4$ mJy for the water maser observation. That level is $5\log\left(t_{int}\Delta\nu\right) = 48$ dB below the system noise level of $N_\nu = \frac{2kT_{sys}}{\varepsilon_{ant} A_{ant}} = 245$ Jy.

However, we have to take $N = \Delta S_\nu$ for a radio-astronomical measurement, because the rms deviation, ΔS_ν, of the mean, N_ν, is the effective noise level of the measurement. The signal bandwidth is now the modulation bandwidth of $\Delta\nu_{mod} = 2/t_{int}$, corresponding to the integration time of the detector. The effective link spectral efficiency ($C_S/\Delta\nu_{mod}$) for a radiometric detection is therefore given by

$$\frac{C_S}{\Delta \nu_{mod}} = \log_2\left(1 + S_\nu / \Delta S_\nu\right) \quad . \qquad (3)$$

For this example, we obtain 2.8 (bit/s)/Hz, which is similar to Wi-Fi (IEEE 802.11a/g) or digital TV (DVB-T) [7].

From a technical point of view, radio astronomy has a good spectral efficiency and is making good use of the allocated band.

3. Spectrum Requirements Today

Active and passive services face very different constraints in their operation. The choice of frequencies for active services is initially unconstrained within the bounds of technical feasibility. Design, location, and control of transmitters and receivers are also our choice. Spectrum allocation to radio services is a purely human convention, resulting from a long and complex political process, based on considerations of technical feasibility, economy, politics, and history. However, there is no free choice of frequency for observations of many of the celestial objects. These transmitters and their characteristics are beyond our control. The radiation from molecular clouds and interstellar gas occurs in particular frequency bands, determined by the natural molecular transitions of the matter that is observed by a radio telescope. The cosmological redshift causes these lines to be shifted from their emission frequency, ν_{em}, to lower observation frequencies, ν_{obs}, as a function of the distance from the observer (an example is the 22 GHz water vapor line mentioned above – it was shifted down to 6.11 GHz):

$$\nu_{obs} = \nu_{em}\left(1 - 7.67 \times 10^{-11} d\right) \qquad (4).$$

Giving radio astronomy access to at least one or two radio-quiet frequencies per octave may help to ensure that we can obtain a representative sample of the cosmological-distance scale. The maximum distance, d_{max}, a source with luminosity, L, over a bandwidth, B, can be detected depends on the noise background temperature, T_{sys}, the detection bandwidth, t_{int}, and the integration time, $\Delta\nu$:

$$d_{max} = \left(\frac{L}{4\pi B}\right)^{1/2} \left(\frac{A_{eff}}{kT_{sys}}\right)^{1/2} \left(\Delta\nu t_{int}\right)^{1/4} \qquad (5)$$

The detection of faint spectral lines from distant radio sources requires very-low-noise environments and very long integration times ($\approx 10^4$ s). However, some of the most-energetic processes observed by radio astronomers occur on the shortest possible timescales. Transient giant-radio-pulse emission detected in some pulsars lasts only a few microseconds, and shows peak flux structures shorter than the nanosecond resolution of the Nyquist-limited detector [8]. Peak fluxes from the Crab pulsar (6000 light years away) exceed 50 kJy ($\approx$ 70000 K for the Effelsberg 100 m telescope). Bandwidths of more than a GHz are needed around 8 GHz to 15 GHz to resolve the time structure of the giant pulses, which may hold the key to the understanding of the still enigmatic pulsar radio-emission process. Transient interference, even of very short duration, must be avoided for an efficient detection of the occasional giant pulses, and the recently discovered weak rotating radio transients (RRATs). Astronomers strive for an understanding of physical processes of the celestial sources. For that they require knowledge about the full spectrum of radio emission, spanning eleven octaves, from < 30 MHz to 90 GHz in the case of pulsars. Different types of new instruments have been designed and, in some cases, built in order to widen our horizon of knowledge about the universe we live in.

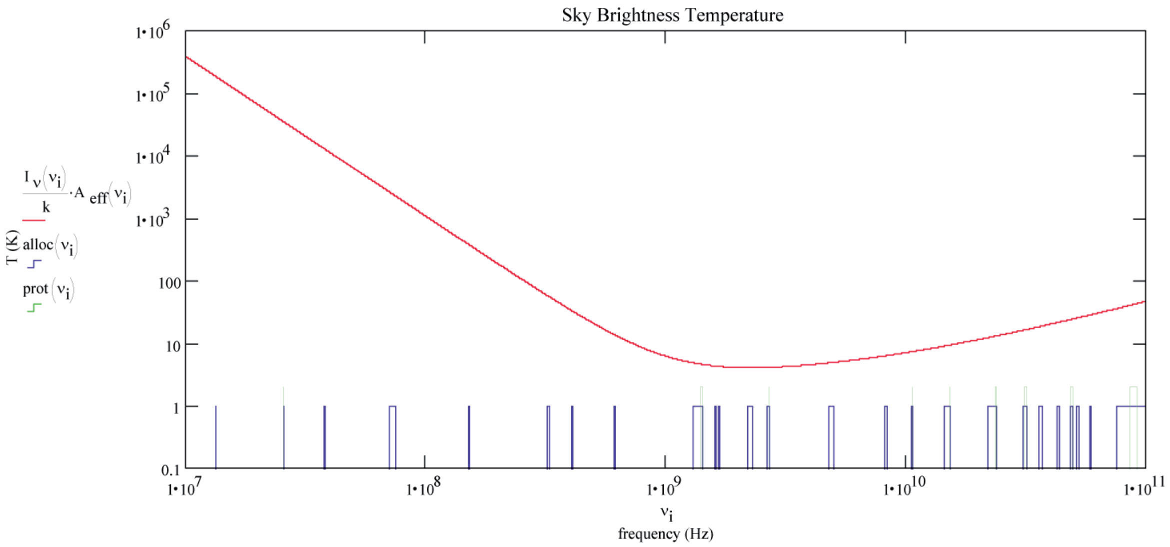

Figure 1. The noise temperature of the sky (red) and the radio-astronomical allocations as a function of frequency. Radio astronomy has exclusive use of only 0.7% of the spectrum below 30 GHz (green), and shares most of the other bands (blue) with other services.

At the lower end, the LOw Frequency ARray multi-purpose sensor array (LOFAR) covers the bands from 10 MHz to 90 MHz and 110 MHz to 250 MHz, using large phased-array antennas. LOFAR is already operating, although only partially finished. Forty-four stations in the Netherlands, Germany, France, United Kingdom, and Sweden are planned to be finally connected with optical fibers to a central correlating BlueGene/P supercomputer in the Netherlands.

At the upper end of the frequency range, the Atacama Large Millimeter/sub-millimeter Array (ALMA), which is being built in Chile, will observe from 31 GHz up to 1000 GHz.

The sky background temperature has its minimum in the L band, around 2.3 GHz. Consequently, radio telescopes will have their greatest natural sensitivity per given bandwidth here (Figure 1). All of the current large radio telescopes use that band as the core of their observational activity. The Square Kilometre Array (SKA), planned for the next decade, will also operate in the cm to dm regime.

The activity of the sun is investigated by solar radio observers. Information about plasma processes at the surface, solar flares, and shock acceleration of particles – as well as monitoring for coronal mass ejection, which can result in violent disturbances of the Earth's ionosphere – requires regular wideband imaging of the sun from 150 MHz to 34 GHz.

Access to UHF frequencies between 300 MHz and 700 MHz is vital for the measurements of interstellar dispersion, which causes a frequency-dependent delay of a distant radio signal. Radio astronomy has pulsar researchers striving to determine the structure of space-time, and trying to discover very-low-frequency gravitational waves by measuring the precise arrival times of pulsar signals. Knowledge of the slowly changing interstellar dispersion delay is of great importance here. Highly red-shifted hydrogen lines from distant galaxies fall into the range 700 MHz to 1400 MHz, which is heavily used by other radio services.

When radio astronomy became a recognized and protected radio service in 1959, the valve-based analog technology of the time allowed the use of only very small bandwidths and simple detection methods. Most of the spectrum allocations below 30 GHz were sufficient in those days, and the later revisions have not significantly improved the situation, or kept pace with technical progress. Digital signal processing has provided not only a "digital dividend" for broadcasting and mobile services, but at the same time, also enhanced and widened the scope of radio-astronomical investigations with respect to sensitivity, bandwidth, as well as time and frequency resolution. Radio astronomers already make astronomy observations using cognitive radio and software-defined radio (CR+SDR) techniques. They opportunistically access even those small and dispersed parts of the spectrum that are not allocated to radio astronomy and are locally free from interference. LOFAR, which operates in bands allocated to many other services, is a good example of that. As one has control over the modulation schemes of man-made radio links, one can reduce their bandwidth requirements ("digital dividend") using more-efficient encoding methods. However, this control is not given over natural sources at great distance. For astronomy, the "digital dividend" is a double-edged sword: We obtain higher frequency agility, higher sensitivities, bandwidths, and resolution, but the higher sensitivity also implies a higher vulnerability to interference. Sadly but unavoidably, the same technical progress has also increased the number and power of interference sources.

4. Interference Protection and Regulation

The sensitivity of a radio antenna is not only proportional to the collecting area, but also to the square root of the receiver bandwidth multiplied by the time duration of the measurement. In order to detect distant cosmic radio sources, radio observatories require sufficient bandwidth that is free of man-made radiation for a sufficiently long time (and that includes even weak and distant sources). Modern signal processing can provide some interference mitigation in the form of compensation for a few steady local sources, as well as flagging and excision in cases where interference is clearly detectable and not too strong to saturate the receiver. However, that comes at a cost: Data loss and loss of sensitivity are inevitable consequences and anathema to the desire to obtain the highest sensitivity and signal-to-noise ratio. They also increase the requirements for computer power and manpower, and can result in research not being undertaken for sheer lack of resources. Irrespective of the technical and financial efforts that may be made by radio astronomers, their radio vision can be blinded by simple equipment that emits on their frequencies and operates in the vicinity of the observatory.

This is particularly true for license-free industrial equipment, where CISPR emission standards are often less stringent than the radio regulations that cover ordinary radio equipment. The CISPR-11 emission standard prescribes a limit of 30 dBμV/m for $f < 230$ MHz, and 37 dBμV/m for $230 \text{ MHz} < f < 1 \text{ GHz}$ measured from a distance of 10 m. No limits are given for frequencies above 1 GHz, but fast-switching electronic equipment is quite capable of radio-frequency interference (RFI) above 1 GHz. The required path loss for compatibility with the ITU-R RA-769 [5] interference limit pertaining to a radio telescope is of the order of 120-130 dB, and separation distances are correspondingly large.

A variety of ultra-wideband (UWB) sensor equipment has been introduced into the mass market in car short-range radar, location-tracking, and building-tool applications. All of these devices are unlicensed and uncontrolled. In its simplest form, they are just sources of fast rise-time pulses coupled to an antenna. Their frequency range spans 1 GHz to 10 GHz, and the (CEPT) permitted EIRP (effective isotropic radiated power) spectral density of -90 dBm/MHz to -41 dBm/MHz is low enough to not affect most communication systems. However, that is not true for sensitive passive services, and the principal incompatibility has been recognized in CEPT reports [8]. Nevertheless, not enough was done by regulators to enforce consistent protection. As a result, the single-interferer protection distances are now of the order of a few km, with aggregate emissions of license-free equipment being even more unpredictable. Here, one is just hoping for the best. It is clear that modern – but quite ordinary and legal – household, farming, or building-site equipment can be the source of significant interference. That is indeed what has been observed in a multitude of cases.

It is the understandable aim of governments and industry to use the available radio spectrum everywhere to its full capacity. Spectrum demand is increasing, and the trend towards fewer and fewer undisturbed parts in the radio spectrum is unbroken, even for remote rural regions.

Governments of Australia, Chile, South Africa, and the US have created radio quiet zones for their current or future sites of radio observatories in order to achieve some degree of protection. Of course, this is not feasible in densely populated European countries, and of only limited effect against airborne and space-borne transmitters. These are not shielded by topography, and therefore present one of the biggest problems. Because big antennas are highly directional, they are much less sensitive to radiation from local sources in directions towards which the telescope is not pointed, but they still receive radiation from local sources with little or no extra gain. That means that a hypothetical 1 W, transmitter broadcasting on 2.7 GHz from a geostationary orbit 36000 km above the site of a radio telescope, could be seen with a strength similar to a weak cosmic radio source, even when the antenna is not pointing at that transmitter!

Satellite and airborne radio services are hence another threat to radio observatories, for the very helpful shielding of terrestrial transmissions by the local terrain is not available here. There have been numerous cases in the past where a satellite system was responsible for strong emissions into radio astronomical bands, effectively blinding the radio antennas in parts of the sky or for some time. Radio astronomy has suffered from interference caused by out-of-band emissions of broadcasting satellites (ASTRA-1D), navigation satellites (GLONASS), and is still badly affected by interference from the IRIDIUM mobile satellite system. However, with the advent of new and very powerful radar Earth-sensing satellite systems (EESS), there is even a possibility that telescope receivers may be damaged or destroyed by the reception of strong radar pulses. The Cloudsat system operates at 94.05 GHz. It comprises five satellites, orbiting at a height of 705 km. Its downward-pointing radar has a pulse power of 1800 W, and an antenna gain of 2×10^6. It can deliver 50 mW of pulse power into an ALMA antenna on mutual-beam coupling, which fortunately has only a 10^{-7} probability, as the antenna needs to point to the zenith when the satellite passes overhead. However, observatories like the Pico Velata sub-mm station had to implement "Cloudsat warning and avoidance" into their telescope-drive routines. The newly proposed TERRA-SAR system will be even more powerful. It will operate on 9.6 ± 0.3 GHz, having a pulse power of 2500 W, and with an antenna gain of 50000, it will deliver a peak power of 125 MW. For a 100 m parabolic dish such as Effelsberg, the ground-level radio flux density of $0.035\ \mathrm{mW/m^2}$ translates into 275 mW of pulse power. This is sure to destroy any sensitive receiver front end, even when only a single pulse is received, when the satellite passes through the main beam. The satellite does not operate on frequencies belonging to the radio-astronomy or to the space-research services themselves. However, its extraordinarily strong pulse power will affect the receivers in the 8.3 GHz and 10.6 GHz bands. A radio-astronomical receiver is a custom-built device, requiring thousands of person-hours to design, build, and optimize. When the very-low-noise front end is defective, the receiver has to be taken out of the antenna, and its cryogenic front end rebuilt. When the satellite flies in its designated orbit, there will be a 0.1% probability of it passing through the beam of the telescope for each radar illumination of the telescope area. Good coordination between satellite and telescope operators will be necessary to avoid costly damage to the observatory's receivers. This is no doubt feasible for a small number of dedicated satellites, but should they proliferate, then the imaging of radio-astronomical stations by radar satellites should be ruled out by appropriate regulations.

5. Conclusions

Scientific use of radio spectrum, including radio astronomy is *ipso facto* of public interest: It is paid for by the taxpayer as a result of political consensus. It is also clear that spectrum protection for radio astronomy transcends national borders, and is a truly long-term global issue. The protection requirements are exceptionally stringent, and vital bands are protected by a "no emissions permitted" clause in the radio regulations. These regulations do not account for short-time variable (TDMA or UWB) interference sources. However, in modern times, additional *peak pulse energy limits* are also required for interference-free observations of transient sources, and even for protection of equipment from accidental damage. The spectrum allocations that give radio astronomy only 0.7% exclusive use below 30 GHz were a compromise in the sixties and seventies. They are clearly insufficient now, as they do not reflect the technical progress and recent scientific discoveries. Radio astronomers try to counter that by being flexible and trying to observe in unused parts of the spectrum allocated to other services. Being a passive use of spectrum, this creates no interference for anyone, but the inevitable greater spectrum utilization by active services in the future will soon close that escape route. It is very difficult, if not impossible, to increase the allocations to scientific services, or to adapt their protection to modern developments in the current climate of high commercial exploitation of radio spectrum. However, even something like the fully efficient use of spectrum by active services, or low-level emissions from industrial or consumer equipment near a radio observatory, will impose crippling constraints on an observatory's scientific research portfolio. A *laissez faire* or "market approach" to spectrum management is particularly inappropriate for scientific services, as the protection requirements are given by nature and therefore not negotiable. They are also long-term and global, instead of short-term and local, and the "returns" are unpredictable. We have also seen the spectacular failure of the market paradigm many times before, even on its home ground in recent times, when applied by professionals in the banking sector. Science is part of the infrastructure of society. It was already known to Adam Smith in 1776 that nonprofit endeavors for public benefit have to be undertaken by the state. That clearly applies to scientific spectrum use, which can only be safeguarded by robust and wide-ranging regulatory protection measures. These ought to be guided only by the inherent technical and scientific practicalities. They should make no difference for the nature of interference, be it from industrial equipment, consumer goods, or in-band or out-of-band emissions from other radio services. CRAF for radio astronomy in ITU region 1 and IUCAF for radio astronomy in all regions cooperate with other scientific users of radio spectrum (such as EUMETNET, ESA, WMO). They engage with spectrum regulators on national, European, and a global scale to explain the very special regulatory requirements of scientific services.

6. Acknowledgments

The author acknowledges discussions and helpful comments from Michael Lindquist (Onsala Space Observatory), Adrian Tiplady (SKA South Africa), and Roberto Ambrosini (INAF).

7. References

1. "RSPG-06-144: EC Radio Spectrum Policy Group (RSPC) Opinion on Scientific Use of Spectrum" (at http://ec.europa.eu/information_society/policy/ecomm/radio_spectrum/_document_storage/other_docs/rspp%20rspg/rspg10_330_rspp_opinion.pdf).

2. Draft ITU "Report on the Essential Role and Global Importance of Radio Spectrum Use for Earth Observations and for Related Applications" (at http://www.itu.int/pub/R-REP-RS.2178-2010).

3. C. M. Violette Impellizzeri, John P. McKean, Paola Castangia, Alan L. Roy, Christian Henkel, Andreas Brunthaler, and Olaf Wucknitz, "A Gravitationally Lensed Water Maser in the Early Universe," *Nature*, December 18, 2008.

4. MPIfR press release: http://www.mpifr-bonn.mpg.de/ public/pr/h2o2008/pr-h2o2008-en.html.

5. ITU-R RA 769-2, ITU, Geneva, 2003.

6. ITU, *ITU Handbook for Radio Astronomy, Second Edition*, Geneva, ITU, 2004.

7. http://en.wikipedia.org/wiki/Bandwidth_efficiency.

8. "ECC Report 064 on Ultra-Wide-Band Devices," (2005), at http://www.erodocdb.dk/Docs/doc98/official/ pdf/ECCREP064.PDF.

9. Recommendation ITU-R SM.1046-2: "Definition of Spectrum Use and Efficiency of a Radio System," Geneva, ITU, 2006.

Fifty Years of Radio Science at Arecibo Observatory : A Brief Overview

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Abstract

As the 50th anniversary of the Arecibo Observatory (AO) approaches, it is appropriate to note the vast influence the many radars and ionospheric heaters that have been deployed on or near the 305 m dish have had on radio science and related fields. Of course, William E. (Bill) Gordon's original idea concerning incoherent scattering is the seed from which all this grew; although, that Gordon was Henry Booker's student and then colleague, set the stage. Much of this history is found in a recent paper by the author [1]. Here, we summarize a few high points and include some material – particularly concerning the ionospheric-heating facilities – that was not available for the earlier publication. As noted in the earlier paper, this history surely has some gaps. The community is encouraged to fill these gaps, and to help complete the history.

Introduction

As is true in all areas of research, we benefit from understanding the history of the subject, and often become aware of still open but forgotten questions. Put another way, the radio-science community will benefit from understanding how various science and engineering questions arose and were solved or left open. Perhaps most importantly, we gain insight into the personalities who pioneered, in this case, Arecibo Observatory. The journal *History of Geo- and Space Sciences* (HGSS: http://www.history-of-geo-and-space-sciences.net) has initiated a special series on "The History of Ionospheric Radars" [2]. Here, we introduce this series to the URSI community, as well as introduce an occasional "History of Radio Science" series to appear in the URSI (International Union of Radio Science) *Radio Science Bulletin* (*RSB*).

In their *History of Geo- and Space Sciences* article, Pellinen and Brekke [2] gave a thumbnail history of radar, beginning with the first patent for what we now know as radar and, not surprisingly, by citing Marconi as a pioneer of the field. A more-complete history of radar was given by Buderi [3], with various more-specialized histories given by Butrica [4] and in the introduction of another of the author's papers [5]. Again, this article on Arecibo Observatory serves to introduce the *RSB* history series, and to update [1], which gave a much more complete history of geophysical radar at Arecibo Observatory. In this paper, we give some details from a famous – to this community – 1958 URSI meeting held at Penn State, as well as update the evolution of Arecibo Observatory on-dish HF heater feeds and transmitters.

Before Incoherent-Scatter Radar

As is well documented ([1] and references therein), the initial manifestation of the Arecibo Ionospheric Observatory (AIO) was built over the period from June 1960 through August 1963, with the formal dedication of the facility occurring on November 1, 1963. Cornell managed Arecibo Ionospheric Observatory – first for the US Air Force and then, beginning in 1969, for the US NSF (National Science Foundation) – from its inception through September 30, 2011, after which new management, under the lead of SRI International, began operations.

Arecibo Ionospheric Observatory, with the 305 m dish and 430 MHz radar, was primarily intended for incoherent-scatter radar studies of the Earth's ionosphere. The story of the path William E. Gordon traversed on the way to Arecibo Ionospheric Observatory's first light was given by [1, 6-8], and others. Prof. Gordon conceived of the concept of incoherent scattering, and ultimately of the Arecibo 305 m dish, in the spring of 1958. The rapid evolution of Gordon's idea of incoherent scattering from free electrons in the Earth's ionosphere was reflected in the May 29, 1958, Cornell School of Engineering seminar announcement reproduced as Figure 6 in Cohen [8]. Cohen also reported

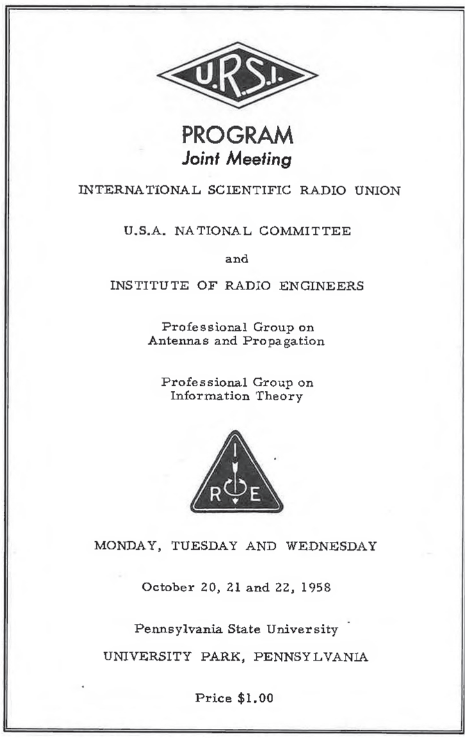


Figure 1. The cover of the URSI/IRE 1958 Meeting program, found at the National Academies archives

an April 1958 presentation to the Cornell ionosphere group on these earliest ideas. The idea progressed further with Gordon's submission of the first paper on the subject to the Institute of Radio Engineers (IRE). This was received on June 11, 1958, and published in November 1958 [9].

While Gordon was refining the Arecibo designs, he was famously in contact with Dr. Kenneth Bowles, a recent Cornell PhD, then at the National Bureau of Standards (NBS) in Boulder, Colorado. Bowles had access to an NBS 41 MHz forward-scatter transmitter/antenna system, located near Long Branch (Havana), Illinois. All he needed was a suitable zenith-looking antenna system of sufficient gain and capability to handle the 4 MW to 6 MW peak power. The 116 m ´ 140 m half-wave dipole array (1024 elements) was quickly built, and the experiment to test for incoherent scattering was conducted with positive results [10]. On October 22, 1958, Gordon, then Chair of the US National Committee of URSI and attending the URSI/IRE Joint Meeting at Penn State University, gave the fourth paper of the 2:00-5:00 pm Session 3 on "Scattered Signals," entitled "Incoherent Scattering of Radio Waves by Free Electrons with Applications to Space Exploration by Radar" [11]. This talk featured the announcement that Ken Bowles had earlier that day observed incoherent scattering from the ionosphere [6]. Bowles' paper on this result was received at *Physical Review Letters* on November 12, 1958, and published in the December 15, 1958, edition [10]. Figure 1 shows the cover page of the Penn State meeting program, while Figure 2 gives the USNC-URSI meeting attendees: a veritable *Who's Who* of our community. Figure 3 gives the abstract of Gordon's talk, during which Bowles's detection

USA NATIONAL COMMITTEE, URSI

Minutes of October 20, 1958 meetings
Pennsylvania State University
University Park, Pennsylvania

The first meeting was called to order by Chairman W. E. Gordon at 9:30 a.m. October 20 in Room 111, Electrical Engineering Building; the second meeting at 5:00 p.m. in the same place.

The following members were present at one or both sessions:

W. E. Gordon, Chm.	H. E. Dinger	A. H. Schooley
E. W. Allen	I. H. Gerks	A. H. Shapley
J. I. Bohnert	R. A. Helliwell	Samuel Silver
W. Q. Crichlow	G. D. Lukes	R. J. Slutz
J. H. Dellinger	L. A. Manning	J. B. Smyth
F. H. Dickson	E. F. McClain	A. H. Waynick
	M. G. Morgan	

Others present were: D . W. W. Atwood, Jr., Director, Office of International Relations, National Academy of Sciences-National Research Council, Mrs. A. MacIntyre.

The following members were not present: S. L. Bailey, R. W. Beatty, L. V. Berkner, H. H. Beverage, Marvin Chodorow, R. G. Fellers, H. W. Grant, F. T. Haddock, J. P. Hagen, A G. Jensen, E. C. Jordan, J. E. Keto, K. A. Norton, Brian O'Brien, J. D. O'Connell, W. G. Shepherd, L. C. Van Atta, Frank Virden, Ernst Weber, H. W. Wells.

Agenda Item 1. Minutes of April 25, 1958 meeting

The minutes were approved as mailed out with modification as follows: On page 3, lines 13 to 15, "President" should be "Chairman". On page 10, an item should be inserted between paragraphs numbered 2 and 3: "The list of officers should include the Associate Editor of Information Bulletin."

Agenda Item 2. Report of the Secretary

Dr. Silver expressed satisfaction with the functioning of the D. C. office.

Dr. Atwood outlined the present responsibility of the Academy with respect to the office of the USA National Committee in Washington and stated that at the earliest practicable date the Academy would take over the full responsibility of providing Secretariat services which the Committee needs. The plan is that the office of the USA National Committee will be incorporated into the Office of International Relations in cooperation with the Division of Physical Sciences. This is for several reasons:

(1) If OIR is to be of greatest help to a Union, its experience with the others should be readily available and this may be best accomplished if the work of all the Unions is handled under one office. However, Dr. Atwood recognized that the USA National Committee's meetings twice a year impose a larger work load than the other Unions.

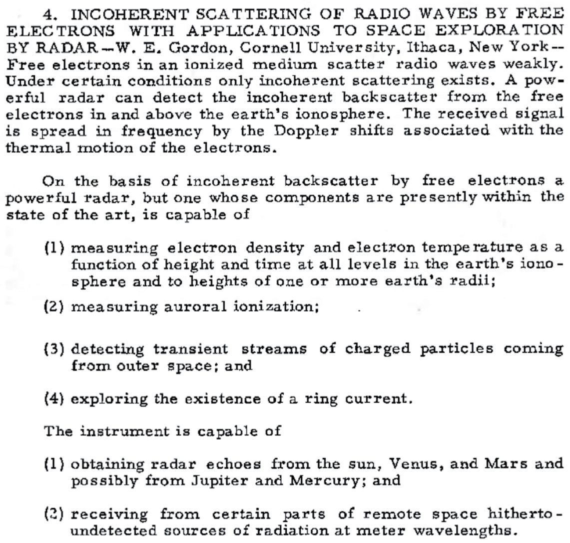
(over)

Figure 2. A list of the USNC-URSI business meeting attendees October 20, 1958.

of incoherent scattering was announced. The full program for the meeting and the URSI meeting minutes will be available online.

From Early On-Dish HF Heating to Now

Ionospheric heating occurs when intense medium-frequency through HF (high-frequency) and even VHF [12] and UHF [13] radio waves accelerate the electrons in the ionosphere, causing collisional heating, plasma-wave generation, and related interesting phenomena. As the heating or modification levels can be controlled, ionospheric modification *experiments* – rather than the usual incoherent-scatter radar *observations* of the natural ionosphere – become possible. The Arecibo Ionospheric Observatory incoherent-scatter radar was uniquely capable of probing heating phenomena, and thus use of the Arecibo Ionospheric Observatory dish for ionospheric heating was of great early interest. Further details were given in [1]; however, missing in the earlier paper was a photo of the earliest heating system over the Arecibo Ionospheric Observatory dish. This is given in Figure 4, which shows the 5.62 MHz crossed-dipole with reflector (dual-polarization, two-element Yagi) system described in Gordon et al. [14]. The Gordon et al. article described O-mode HF ionospheric heating with this system at transmitter power levels of 100 kW CW or pulsed (at any duty cycle) and an ~10°


4. INCOHERENT SCATTERING OF RADIO WAVES BY FREE ELECTRONS WITH APPLICATIONS TO SPACE EXPLORATION BY RADAR—W. E. Gordon, Cornell University, Ithaca, New York-- Free electrons in an ionized medium scatter radio waves weakly. Under certain conditions only incoherent scattering exists. A powerful radar can detect the incoherent backscatter from the free electrons in and above the earth's ionosphere. The received signal is spread in frequency by the Doppler shifts associated with the thermal motion of the electrons.

On the basis of incoherent backscatter by free electrons a powerful radar, but one whose components are presently within the state of the art, is capable of

(1) measuring electron density and electron temperature as a function of height and time at all levels in the earth's ionosphere and to heights of one or more earth's radii;

(2) measuring auroral ionization;

(3) detecting transient streams of charged particles coming from outer space; and

(4) exploring the existence of a ring current.

The instrument is capable of

(1) obtaining radar echoes from the sun, Venus, and Mars and possibly from Jupiter and Mercury; and

(2) receiving from certain parts of remote space hitherto-undetected sources of radiation at meter wavelengths.

Figure 3. Prof. Gordon's 1958 URSI abstract on incoherent scattering.

beamwidth. L. M. LaLonde designed and built the feed. Further results derived from this system were given in [15].

As the Figure 4 crossed-dipole feed was restricted to a single frequency (5.62 MHz), it was replaced by a dual-polarization log-periodic HF feed system, mounted at zenith above the Arecibo dish. This system, shown in [1, Figure 6], was plagued by arcing and other reliability issues. Additionally, both this feed and the earlier dipole feed were mounted at the center of the elevation track, and thus restricted carriage house #1 pointing to zenith angles greater than ~ 4° , thereby limiting access to the full heated volume. This blocking issue is visible in Figure 4. These issues, together with the need for even higher heater power, led to the construction of the very successful, offsite Islote heater, described in Section 6 of [1].

The standalone Islote HF heater array was located ~ 17 km NNE of Arecibo Observatory on the Atlantic coast of Puerto Rico. Construction on the Islote heater facility began mid-1980, with operations commencing in September 1981 [16]. In its initial manifestation, this system operated at frequencies of 3 MHz to 12 MHz, with an effective radiated power (ERP) of up to ~120 MW. This was accomplished with HF transmitters supplying up to 600 kW (4 ´ 150 kW transmitters), continuous power depending on the diesel generators and the state of the transmission lines to the two sets of ~ 20 dBi gain, 4 ´ 4 log-periodic antenna arrays shown in [1, Figure 7].

Various issues resulted in peak-power limitations, with a maximum at or below 400 kW. Later upgrades allowed reliable use at the full 600 kW CW. Early use of the Islote heater included the November 25 and December 8, 1981, observations of HF-enhanced plasma lines using the 140 kW peak-power 46.8 MHz Max-Planck radar on the 305 m Arecibo Observatory dish [17, 18]. Many of the science results from the Islote heater and the main instrument cluster were discussed in [1] and references therein.

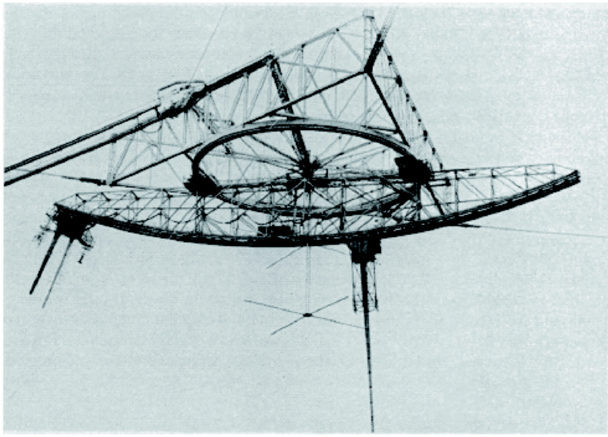


Figure 4. Antenna feeds deployed over the Arecibo Observatory dish, circa 1970. The crossed-dipole feed with reflector elements at the center of the elevation arc is the first HF (5.62 MHz) heating antenna described sans photo in Section 5 of [1]. L. M. LaLonde designed and built this feed. Results from this early heating system were given in [14] and in [15]. Carriage house #1, to the right of center, supported the original square-cross-section 430 MHz linefeed and the coaxial 40.12 MHz radar Yagi feeds. Carriage house #2, now replaced with the Gregorian dome system, shows a variety of radio astronomy feeds (photo courtesy of D. B. Campbell and Cornell University).

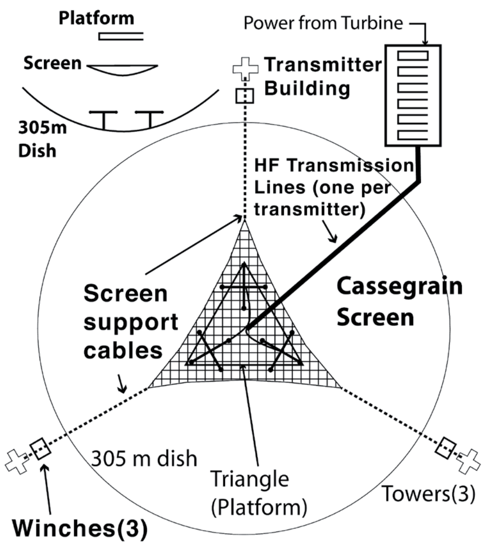


Figure 5. A schematic cartoon of the new Arecibo Observatory on-dish heating facility. The upper left schematic shows the side view, with dipoles just above the dish's surface, and the convex subreflector mounted below the platform. The top view shows the wide-mesh Cassegrain subreflector, and three of the six crossed dipoles. The transmission lines are ~1000 ft in length (figure courtesy of M. P. Sulzer, Arecibo Observatory).

Figure 6. The first of six crossed-dipole HF feeds to be deployed on the Arecibo Observatory 305 m dish. These feeds will illuminate a wire subreflector, to be suspended from the towers that will in turn illuminate the dish. Three feeds are sized for 5.1 MHz ($\lambda = 58.8$ m) and three feeds are for 8.175 MHz ($\lambda = 36.7$ m). Modeling of the configuration suggested a 22.2 dBi one-way gain at 5.1 MHz (~12° FWHM beamwidth), and a 25.5 dBi gain at 8.175 MHz (~8° FWHM beamwidth). As six 100 kW CW transmitters are available, each polarization of each of the three feeds at a single frequency will be separately driven, permitting full polarization flexibility. The transmitters are class-A. However, pseudo-pulsed operation will be possible. Later operations at 3.175 MHz may become possible (photo July 21, 2013, JDM).

Unfortunately, the Islote facility was severely damaged by Hurricane Georges on September 21-22, 1998 (NAIC/AO Newsletter No. 26, November 1998.) This, combined with the government decision to return the wetlands on which the facility was located to a natural state, led to decommissioning of the facility in 1999.

It is only in the last eight years that serious planning and now construction of a new on-dish HF heating facility has commenced. The new heating facility will operate in a campaign mode initially at only 5.1 MHz and 8.175 MHz, as the feeds will be crossed dipoles. The reason for this is that the design is radical, as the feeds will be mounted just above the dish, with the dish surface as ground plane. They will illuminate, in Cassegrain geometry, the convex subreflector suspended under the line/Gregorian feed system already in place. Figure 5 (upper left) shows the side-view geometry in schematic form. The remainder of Figure 5 shows the whole system viewed from above. Each individual dipole will be fed from an individual, circa-1989, 100 kW (class A) Continental transmitter via ~ 1000 ft of 3 in, unjacketed heliax cable. Figure 6 shows the first fully deployed 5.1MHz dipole system. The arrangement at the top of the tower allows the dipoles themselves to fold umbrella-like, down and against the tower, for normal observing operations of the observatory. In a similar fashion, the subreflector mesh of stainless-steel cables will be winched in/out of position by a set of winches at the base of each of the three towers. The five-foot mesh spacing of the subreflector will allow the 430 MHz (70 cm) radar to work through the mesh. The same will be true for some radio and S-band radar-astronomy observations, if needed.

Conclusions

This brief history has served to introduce the "History of Radio Science" initiative of the *Radio Science Bulletin*, as well as to note and celebrate the 50th anniversary of the dedication of the Arecibo Observatory. A more formal version of this history [1] was given in the journal *History of Geo- and Space Sciences* (HGSS: http://www.history-of-geo-and-space-sciences.net), which has initiated a special series on "The History of Ionospheric Radars" [2]. Here, we have added a few items missing from the earlier history.

As is inevitably the case, this history remains incomplete, with gaps and mysteries that the community should fill and solve. However, in this paper we updated the earlier history to give some details from the portentous 1958 URSI meeting held at Penn State. We have also given an update on the evolution of on-dish HF heater feeds and transmitters. The latter included a few details regarding the new on-dish heater now under construction.

Acknowledgements

The Arecibo Observatory is operated by SRI International, under a cooperative agreement with the National Science Foundation (AST-1100968), and in alliance with Ana G. Méndez-Universidad Metropolitana, and the Universities Space Research Association. This particular effort was supported under grants ATM 07-21613 and ATM 12-02019 to the Pennsylvania State University.

References

1. J. D. Mathews, "A Short History of Geophysical Radar at Arecibo Observatory," *History of Geo- and Space Sciences*, **4**, 2013, pp. 19-33, doi:10.5194/hgss-4-19-2013.

2. R. Pellinen and A. Brekke, "Introduction: The History of Ionospheric Radars," *History of Geo- and Space Sciences*, **2**, 2011, pp. 113-114, doi:10.5194/hgss-2-113-2011.

3. R. Buderi, *The Invention that Changed the World: How a Small Group of Radar Pioneers Won the Second World War and Launched a Technological Revolution*, New York, Simon & Schuster, 1996.

4. A. J. Butrica, *To See the Unseen: A History of Planetary Radar Astronomy, Volume SP-4218*, Washington, DC, NASA History Office, 1996.

5. J. D. Mathews, "Radio Science Issues Surrounding HF/VHF/UHF Radar Meteor Studies," *Journal of Atmospheric and Solar-Terrestrial Physics*, **66**, 3, 2004, pp. 285-299, doi:10.1016/j.jastp.2003.11.001.

6. A. Butrica, "Oral History Transcript – Dr. William Gordon: 28 November 1994," March 2013, available: http://www.aip.org/history/ohilist/22789.html.

7. R. M. Robinson, A. v. Eyken, and D. T. Farley, "Fiftieth Anniversary of the First Incoherent Scatter Radar Experiment," *EOS Transactions, American Geophysical Union*, **90**, 2009, p. 267, doi: 10.1029/2009EO310005.

8. M. H. Cohen, "Genesis of the 1000-Foot Arecibo Dish," *Journal of Astronomical History and Heritage,* **12**, 2009, pp. 141-152.

9. W. E. Gordon, "Incoherent Scattering of Radio Waves by Free Electrons with Applications to Space Exploration by Radar," *Proceedings of the Institute of Radio Engineers,* **46**, 1958, pp. 1824-1829, doi: 10.1109/JRPROC.1958.286852.

10. K. L. Bowles, "Observation of Vertical-Incidence Scatter from the Ionosphere at 41 Mc/sec," *Physical Review Letters*, **1**, 1958, pp. 454-455, doi: 10.1103/PhysRevLett.1.454.

11. W. E. Gordon, "Incoherent Scattering of Radio Waves by Free Electrons with Applications to Space Exploration by Radar," URSI/IRE Fall Meeting, Penn State University, 1958.

12. R. L. Showen, "Artificial Heating of the Lower Ionosphere," *Journal of Geophysical Research*, **77**, 1972, pp. 1923-1933, doi:10.1029/JA077i010p01923.

13. M. P. Sulzer, J. D. Mathews, and A. A. Tomko, "A UHF Cross-Modulation D Region Heating Experiment with Aeronomic Implications," *Radio Science*, **17**, 1982, pp. 435-443, doi: 10.1029/RS017i002p00435.

14. W. E. Gordon, R. Showen, and H. C. Carlson, "Ionospheric Heating at Arecibo: First Tests," *Journal of Geophysical Research*, **76**, 1971, pp. 7808-7813, doi:10.1029/JA076i031p07808.

15. H. C. Carlson, W. E. Gordon, and R. L. Showen, "High Frequency Induced Enhancements of the Incoherent Scatter Spectrum at Arecibo," *Journal of Geophysical Research*, **77**, 1972, pp. 1242-1250, doi:10.1029/JA077i007p01242.

16. J. A. Fejer, C. A. Gonzales, H. M. Ierkic, M. P. Sulzer, C. A. Tepley, L. M. Duncan, et al., "Ionospheric Modification Experiments with the Arecibo Heating Facility," *Journal of Atmospheric and Solar-Terrestrial Physics*, **47**, 1985, pp. 1165-1179, doi: 10.1016/0021-9169(85)90086-8.

17. J. A. Fejer, H. M. Ierkic, R. F. Woodman, J. Röttger, M. P. Sulzer, R. A. Behnke, et al., "Observations of the HF-Enhanced Plasma Line with a 46.8-MHz Radar and Reinterpretation of Previous Observations with the 430-MHz Radar," *Journal of Geophysical Research*, **88**, 1983, pp. 2083-2092, doi: 10.1029/JA088iA03p02083.

18. J. Röttger, P. Czechowsky, and G. Schmidt, "First Low-Power VHF Radar Observations of Tropospheric, Stratospheric and Mesospheric Winds and Turbulence at the Arecibo Observatory," *Journal of Atmospheric and Terrestrial Physics*, **43**, 1981, pp. 789-800, doi: 10.1016/0021-9169(81)90056-8.

My Time with Arecibo Observatory : An Exotic Experimental, Scientific, and Personal Challenge

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Abstract

The Arecibo Observatory celebrates its 50th anniversary, and a great variety of cutting-edge instrumentation, observations, and outstanding scientific results. Research using radars was only part of these achievements. Besides the powerful UHF and S-band radars, the VHF radar comprised only a minor contribution. The historical development of this ionosphere-atmosphere science direction at Arecibo Observatory is briefly remembered in this paper. My connections to Arecibo Observatory, summarized in this article, cover only just one decade out of the total of five decades of the Arecibo Observatory.

The Initialization of MST VHF Radar Projects at Arecibo Observatory

My relations with the Arecibo Observatory (AO) actually started at the Jicamarca Radio Observatory in Peru (JRO). I visited there in 1974 and 1975 to analyze spread-F and vertical-drift data, to search for further support of the spatial-resonance effect of traveling ionospheric disturbances seeding equatorial spread-F. I used this chance to discuss with Ron Woodman about the new SOUSY-VHF Radar (SOUnding SYstem) project. This was under construction at my home institution, the Max-Planck Institute for Aeronomy (MPAe) in Lindau, Germany. We also did some MST radar experiments with the Jicamarca Radio Observatory radar for training operations, data collection, and analysis, to be prepared for later application to SOUSY-VHF Radar observations.

At Jicamarca, I met Bob Harper, who was very interested to learn about the new SOUSY radar project. He told me about his mesosphere radar observations at the Arecibo Observatory (AO), which we discussed in depth. He convinced me that I should change my return itinerary to Germany for a stopover at the Arecibo Observatory, and also at Rice University in Houston, to meet Prof. William Gordon, Dean of Electrical Engineering at Rice. This was a challenging proposal, which I accepted with pleasure. Bob Harper then prepared these valuable stopovers.

At the Arecibo Observatory, Jim Walker, head of the atmosphere-ionosphere group, introduced me to the observatory activities and, in particular, to the incoherent-scatter radar (ISR) operations. We also discussed the VHF radar, which was under construction in Germany. He mentioned first how well such a VHF radar would complement the UHF radar operations at the Arecibo Observatory, providing an extended aperture and more flexible steering. Being convinced by these arguments, and also being introduced to the Arecibo staff, who would be supportive of such an enterprise, we kept this idea in mind. On my return trip from Puerto Rico to Germany, I then visited Bill Gordon in Houston. He expressed deep interest concerning our VHF radar work, and encouraged us to extend our experiments to the Arecibo Observatory.

During a later visit of Jim Walker to the Max-Planck Institute for Aeronomy (MPAe), he was shown the SOUSY-VHF Radar, which was in its initial operation in the Harz Mountains, in 1978. The radar was contained in three standard trailers, to allow some mobility. Having in mind the scientific gain expected from a VHF radar at the Arecibo Observatory, we agreed to discuss the possibility of transporting the SOUSY radar to Arecibo Observatory. As there was concern regarding the volume and the extensive logistics surrounding such a relocation, along with losing the scientific results expected from a local radar at its location in mid-latitudes, it was agreed that MPAe would build a second – though less-powerful – VHF radar, to be transported to and used at Arecibo Observatory. The first step was to build a low-power transmitter and a simple Yagi feed, to be used with the Arecibo radar-control and data-acquisition system.

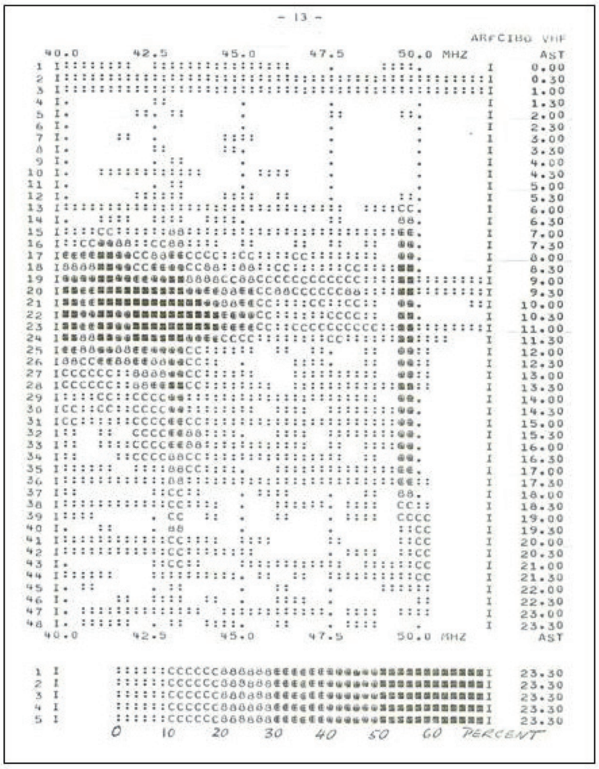


Figure 1. Frequency surveillance at 40.0 MHz to 52.5 MHz at Arecibo Observatory, 14.12.1979 to 06.01.1980.

The First Attempts to Observe in 1979-1980

The initial operations of this new radar at Arecibo Observatory took place with my MPAe colleagues' assistance in the middle of 1979, together with Ron Woodman, who was the Head of the Atmosphere-Ionosphere group at Arecibo Observatory at that time. However, Murphy's Law prevented successful experiments. This was mainly due to incompatibility of interfacing the Arecibo Observatory's control system with the SOUSY 4 kW mini-transmitter, and also due to intense interference due to local ham-radio operators. The allocated operating frequency was 49.92 MHz, similar to Jicamarca. Operating short pulses evidently spread out the transmitted energy far beyond 50 MHz, which was an allocated amateur-radio band. The radar consequently had to shut down. It was a minor disaster, since data taking failed.

We then decided on four important improvements: (1) to select an optimum operating frequency in the low VHF band; (2) to construct a new antenna feed for the finally allocated frequency; (3) to build our standalone radar-control and data-acquisition system; and (4) to optimize the transmitter to higher peak power.

In December 1979 and January 1980, a small preparatory campaign was performed at Arecibo Observatory to continuously survey the frequency occupancy between 40.0 MHz and 52.5 MHz [1]. The receiver and chart recorder were set up in the AO-VSQ room B-2, where we stayed over Christmas. This passive operation did not affect or depend on the normal Arecibo Observatory schedule. Figure 1 shows the results, which not unexpectedly verified a variety of interference signals with a pronounced diurnal variation. Besides local traffic on the island, this directly pointed to signals that had propagated via the ionosphere, namely taxi and truck radio traffic from the US mainland. The signal just below 50 MHz could have been from another radar. The optimum frequency with minimum interference was between 46 MHz and 47 MHz.

Figure 2. The log-periodic VHF feed antenna (45 MHz to 55 MHz).

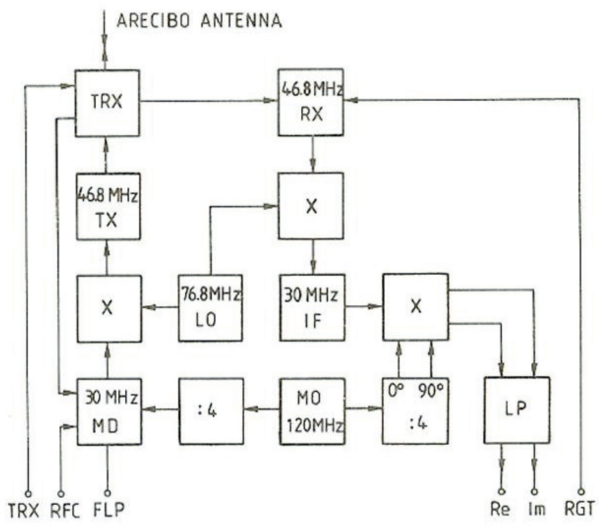


Figure 3. The SOUSY mini-VHF radar transmitter-receiver unit.

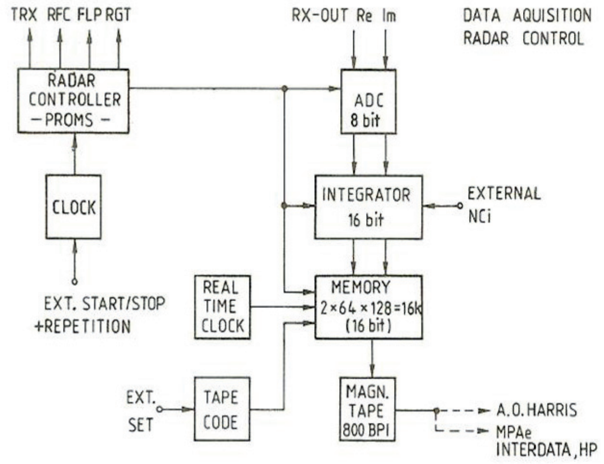


Figure 4. The digital radar-control and data-acquisition unit.

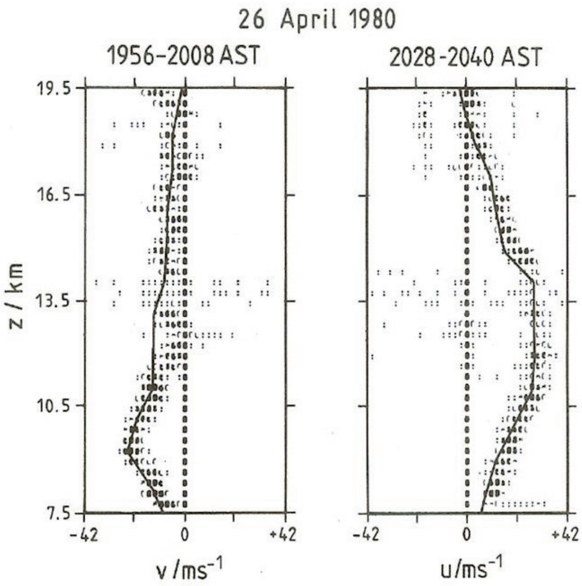


Figure 6. The first height profiles of scatter plots of meridional and zonal wind velocities. The solid lines are radiosonde winds.

Since we did not know which frequency would finally be allocated for our continuing operations, a wideband log-periodic feed antenna was constructed, which is shown in Figure 2. It was mounted on the Arecibo Observatory's platform in the spring of 1980, and was first used in a new campaign in April-May 1980. The licensed center operating frequency was 46.8 MHz, and the total antenna gain was estimated at 35 dB. The complete radar control and data acquisition, as well as the receiver, transmitter, and transmit-receive duplexer, were newly designed by the Max-Planck Institute, and installed in the Arecibo Observatory transmitter hall. The transmitter power was only 4 kW at a 4% duty cycle. The block diagram of this setup is shown in Figures 3 and 4. Raw data were dumped on tape, which then were read and analyzed using the Harris (24-bit) computers of the observatory.

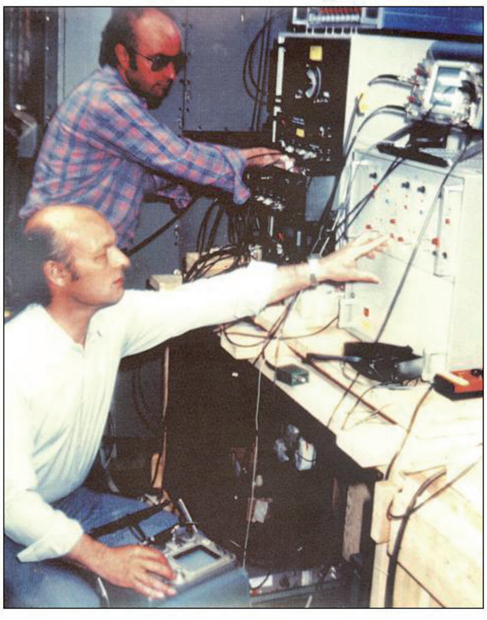


Figure 5. The SOUSY mini-radar, operated in the Arecibo Observatory transmitter hall by P. Czechowsky and J. Röttger.

Figure 5 shows this new system, operated by Peter Czechowsky and Jürgen Röttger. The detailed VHF radar system setup and the observational results were described by Röttger, Czechowsky, and Schmidt in "First Low-Power VHF Radar Observations of Tropospheric, Stratospheric and Mesospheric Winds and Turbulence at the Arecibo Observatory" [2].

In Figure 6, the first wind profiles between 7 km and 19 km, measured with this AO-MPAe low-power VHF radar, are displayed. In Figure 7, the first VHF radar echoes from the mesosphere are presented. These results could be achieved in almost real time, namely the time to sample data, write on tape, transport tape from the transmitter hall to the Arecibo Observatory Harris computers, read the tape, and do a quick-look analysis, i.e., < 30 min.

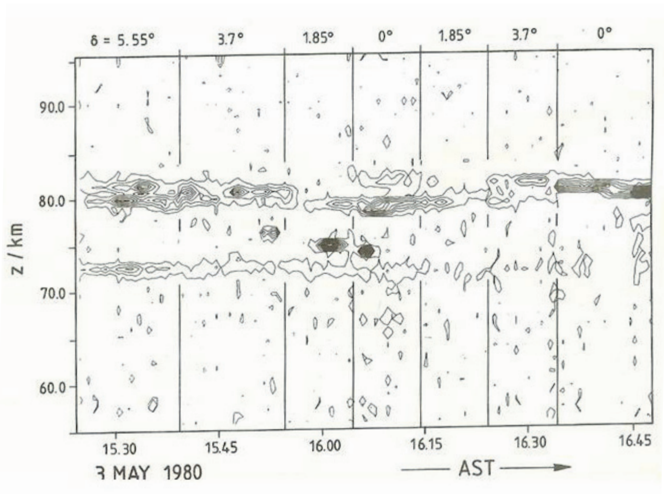


Figure 7. The first mesosphere echoes recorded on May 3, 1980, with the mini-VHF Radar with different zenith angles, δ .

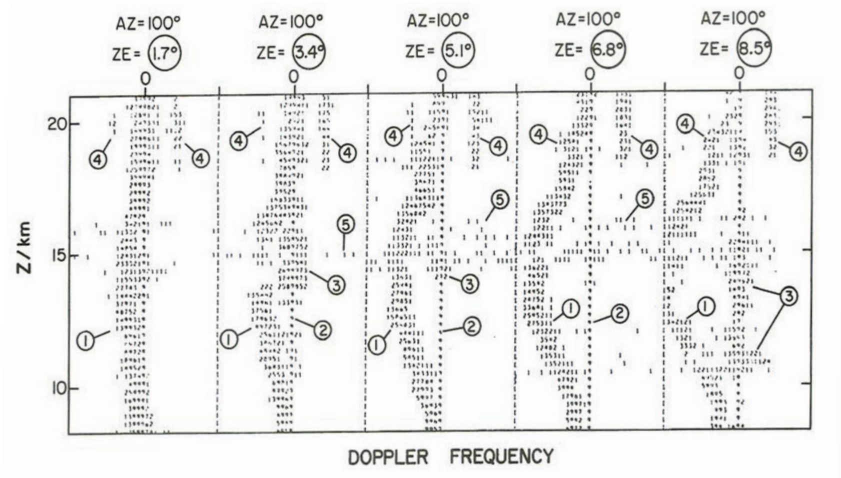


Figure 8. Spectral plots measured at different zenith angles (ZE), showing contaminations by: (2) non-fading ground clutter, (3) sidelobe atmosphere echoes, (4) sea clutter. and (5) noise interference; (1) the wanted atmosphere echoes.

The Main Campaign 1980-1981

The important experience of well-functioning collaboration and the promising initial results encouraged us to continue the VHF radar operations at the Arecibo Observatory. We were encouraged to even expand them by preparing a special container with a high-power transmitter (140 kW peak), and a more-capable computer system: the mobile SOUSY-VHF Radar.

In July 1980, this 20 ft container was transported in a Boeing 747 side-loader from Frankfurt to New York, to continue to San Juan. The container was lost for several days in an unplanned odyssey, which almost caused the project to be abandoned. This occurred due to some logistic malfunctions for reloading the container in New York for shipment to San Juan. Instead, the container was flown to Miami, from where it was impossible to get it directly to San Juan. After a planned diversion via Caracas, the shipment had to be cancelled, and the airline decided to shuffle it in a three-day truck tour from Miami back to New York, from where it finally reached its destination in San Juan. It then was soon installed in its location outside the Arecibo Observatory control-room building. Unfortunately, due to uncontrolled improvisation in multiple re-loadings, and the unnecessarily extreme temperature and subtropical humidity changes, the equipment in the container was partly destroyed. Fortunately, repair and replacement was possible, although time consuming, and the planned campaign could start only several weeks later than anticipated.

For this main campaign, the feed shown in Figure 2 was used. The higher transmitter power (140 kW peak) not only delivered improved signal detectability, but also some

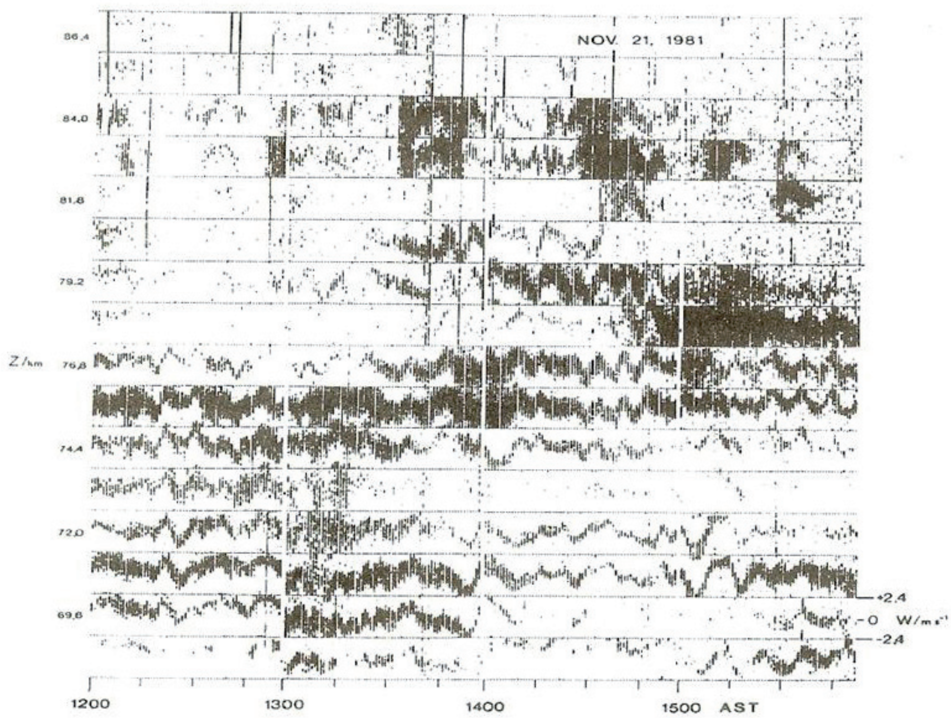


Figure 9. Waves and turbulence in the mesosphere observed on with the 140-kW SOUSY VHF Radar.

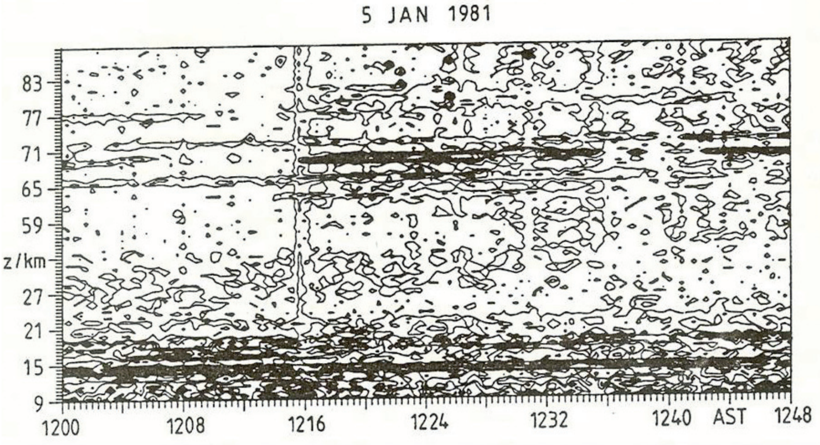


Figure 10. Enhancement of mesosphere echoes during increased ionization due to solar flare.

more unwanted signals, which are presented in the following Figure 8. Besides the atmospheric echo, we noticed ground clutter and sea clutter, which changed frequency with the ocean tide, and antenna sidelobe echoes from the ground. We developed a special routine to remove these unwanted signals. It was then possible to record signals well up to more than 20 km with 150 m altitude resolution. Changing the pointing angle of the antenna proved that – according to theory – the Doppler shift due to the projection of the horizontal wind into the beam direction increased with zenith angle. Comparison with simultaneous observations with the 430 MHz radar, as well as with the San Juan radiosonde, showed very good agreement. The comparison of the VHF and UHF radar wind and reflectivity profiles were also very agreeable [3]. We were thus satisfied, and prepared for longer MST radar observing periods at the Arecibo Observatory.

Echoes from the mesosphere were observed during daytime hours, when the D-region ionization was sufficiently high. This allowed studies of diverse impressive wave events and turbulence, as shown in the set of dynamic spectra of Figure 9 (see for discussion, "VHF Radar Measurements of Small-Scale and Meso-Scale Dynamical Processes in the Middle Atmosphere" [4, 5]). A Kelvin-Helmholtz instability, generating gravity waves in the lower-stratosphere jet stream, was observed with the AO-SOUSY VHF radar [6].

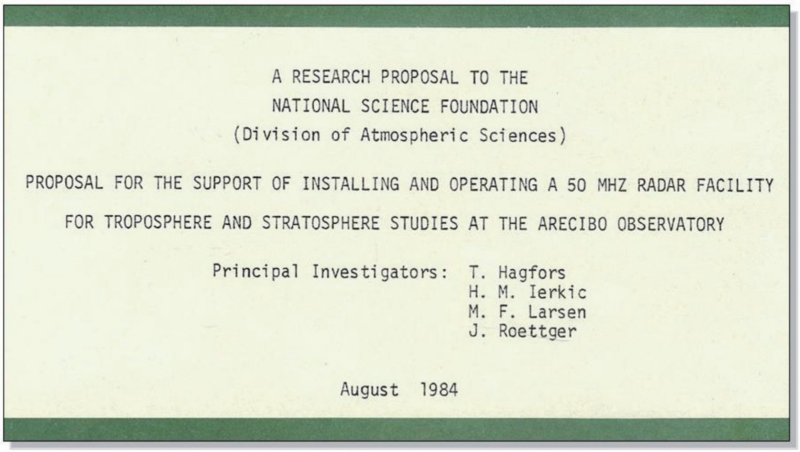
A particular highlight (Figure 10) was detected when the SOUSY 46.8 MHz radar (coherent scatter) was simultaneously operated with the Arecibo Observatory 430 MHz radar in the incoherent-scatter mode. Close to 12:16 AST on January 5, 1981, a solar flare occurred, which increased the electron density (as measured with the 430 MHz radar) and the coherent scatter power of the mesospheric 46.8 MHz radar echoes. This event was well analyzed by Rastogi et al. [7].

The results of Figure 10 were first published by Röttger et al. [8]. In that paper, wind-velocity observations over an extended Arecibo Observatory observing period, from December 10, 1980, until January 18, 1981, took place to search for tides and long-period waves in the stratosphere and mesosphere. There were clear signatures of the diurnal tide in the height region from 60 km to 80 km. A long-period oscillation of six days, found in the zonal but not in the meridional winds in the mesosphere, was explained as a Kelvin wave. This would have been the first observation of an appearance of a tropical wave in the middle atmosphere.

Cooperative synchronous observations of winds and tides were done at the end of November 1981, using the VHF radars at Jicamarca and Arecibo [9]. It was found that the lower stratospheric diurnal tide was similar, consistent with models, at locations symmetrical north (AO) and south (JRO) of the equator. The mesospheric diurnal tide was occasionally observed in the daytime at Arecibo, but was not so pronounced at Jicamarca.

Towards the end of the campaign "The Mobile SOUSY VHF Radar at the Arecibo Observatory," Jules Fejer, at that time Head of the Ionosphere-Atmosphere Group at Arecibo Observatory, suggested applying the VHF radar as a diagnostic tool for ionosphere heating. This took place at the end of November 1981. Echoes of the up-shifted HF enhanced plasma line were observed at 51.9 MHz, but could not be explained equivalently to observations with the Arecibo Observatory 430 MHz radar. Suitable explanations had to be assessed by later experiments [10].

Figure 11. Tor Hagfors and Jürgen Röttger in the French alps.


A RESEARCH PROPOSAL TO THE
NATIONAL SCIENCE FOUNDATION
(Division of Atmospheric Sciences)

PROPOSAL FOR THE SUPPORT OF INSTALLING AND OPERATING A 50 MHZ RADAR FACILITY
FOR TROPOSPHERE AND STRATOSPHERE STUDIES AT THE ARECIBO OBSERVATORY

Principal Investigators: T. Hagfors
H. M. Ierkic
M. F. Larsen
J. Roettger

August 1984

Figure 12. The proposal to NSF for a VHF radar system at Arecibo Observatory.

Our successful operations would not have been possible without the invaluable help and assistance of the Arecibo staff, such as Jose Maldonado, Ron Tower, John Pappas, Ray Medina, Mike Sulzer, Jon Hagen, Bob Zimmerman, and many others. The SOUSY radar group operating at the observatory consisted of the scientists P. Czechowsky, R. Rüster, G. Schmidt, and myself (J. Klostermeyer kept project contacts from MPAe in Germany), as well as the MPAe engineering group: K. Meyer, H. Becker and K. D. Preschel, and G. Monecke as computer operator.

My Continuation at Arecibo Observatory 1984-1985

The mobile SOUSY VHF Radar was safely returned from the Arecibo Observatory to its home at MPAe in Germany. There, it was refurbished in 1982 to be relocated to Andoya/Norway for the Middle Atmosphere Program Campaign Winter in Northern Europe MAP-WINE. J. Röttger moved to the Arctic as well in March 1982 to serve as Associate Director Science of EISCAT (European Incoherent Scatter Scientific Association) in Kiruna, Sweden.

It soon happened during the First EISCAT Workshop, held in Aussois in the French Alps, September 5-8, 1983, that Tor Hagfors, Director of the National Astronomy and Ionosphere Center (NAIC) and I (Jürgen Röttger), went on a mountain tour (Figure 11), which T. Hagfors used to convince me to again return to the Arecibo Observatory. After a special agreement was reached between NAIC and MPAe (my home institute), I returned to the Arecibo Observatory at the end of 1984. It was written in the Arecibo Observatory/NAIC Newsletter No. 4, October 1984:

> Jürgen Röttger has arrived to continue his investigations of the lower and middle atmosphere and to serve as Acting Head of the Atmospheric Science Group. Jürgen comes from the Max-Planck-Institute for Aeronomy in Lindau. He spent two years at EISCAT as Associate Director for Science.

When it became certain in 1984 that I would join the Arecibo Observatory, we started to work in detail on a proposal for a standalone VHF radar, which was submitted to the National Science Foundation (Figure 12). The scientific reasons for such a VHF radar system were summarized in [11]. The Arecibo Science Advisory Committee (ASAC) was pleased to note the addition of a new VHF radar and the addition of myself to the Arecibo Observatory staff. ASAC encouraged further progress in MST radar studies as supported by the new 46.8 MHz VHF radar installation.

From the beginning of my work at the observatory in October 1984, I attended the regular Department Heads' meetings, with the observatory Director Don Campbell and the NAIC Director Tor Hagfors, when he visited the observatory. The first meetings concentrated on preparations for the forthcoming visits of the Arecibo Scientific Advisory Committee and the Arecibo Advisory Board, meeting at the El Dorado beach hotel, near San Juan. We also had regular meetings of the Atmospheric Science Group with Mike Sulzer, Craig Tepley, Mario Ierkic, Roger Burnside (joined later), and visitors, when needed. These meetings were essential in helping me to learn about the observatory structure, work, and observations. Besides assuring best performance of the radars and optical instrumentation, one of our main goals was to advance the VHF radar project. This needed new equipment and software. This was done in close cooperation with Jon Hagen and Bob ("Zimmo") Zimmerman, and by very helpful support of the staff of the Arecibo Observatory electronics, maintenance, and computer departments, in particular Aixa Remires, Jose Vives, Ron Tower, Jose Maldonado, Barry Paine, Dan Holden from Clemson University, and Wolfram Birkmeyer, as well. Last not least, the support by Phil Perillat during operations, and the continuous help by the secretaries, Aida Carrasquillo, Marie Delgado, Mercedes Vives, and the librarian, Carmen Segarra, need to be acknowledged.

One of the early tasks was to construct a new VHF radar system, using the 305 m dish and the controller and the existing data acquisition, which had to be modified for VHF radar applications The revised concept was to locate the transmitter on the platform and control it remotely. Block

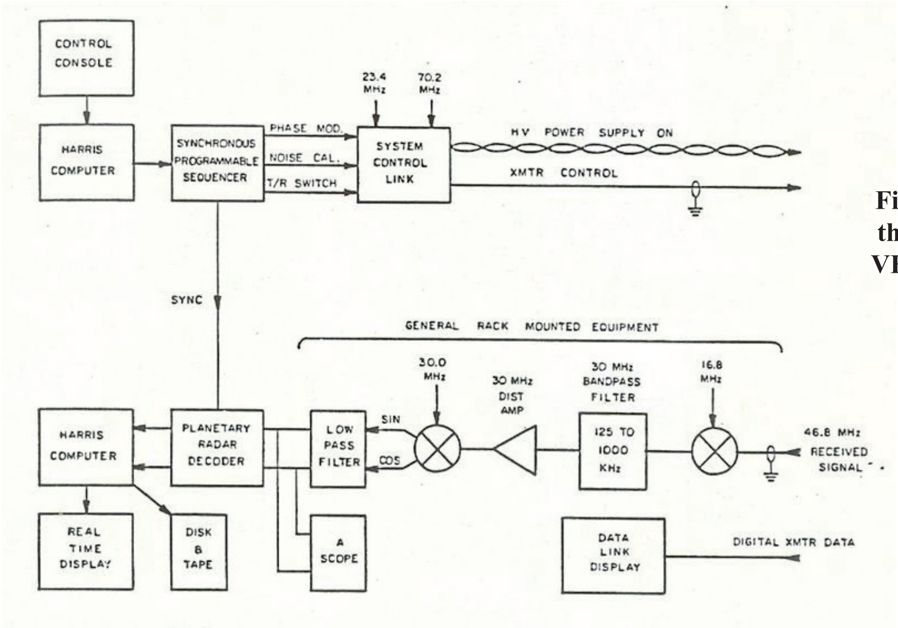


Figure 13. The instruments of the new Arecibo Observatory VHF radar, located in the control and computer room.

diagrams of the system part in the control and computer rooms on the ground are shown in Figure 13, in the carriage house 1 on the platform in Figure 14, and the antenna feed combination in Figure 15.

The new VHF radar transmitter (40 kW delivered by Tycho Tech), purchased under NSF grant, was prepared for testing in early 1985. The design of the new VHF radar feed was almost completed in the first half of 1985. Detailed descriptions can be found in "Investigations of the Lower and Middle Atmosphere at the Arecibo Observatory and a Description of the New VHF Radar Project" by J. Röttger, H. M. Ierkic, K. Zimmerman, and J. Hagen, and in "Method to Determine the Optimal Parameters of the Arecibo 46.8 MHz Antenna System" by H. M. Ierkic, J. Röttger, J. B. Hagen, and R. K. Zimmerman. Both papers were presented at the 3rd MST Radar Workshop in October 1985, and published in the Proceedings of the 3rd International Workshop on Technical and Scientific Aspects of MST Radar [12, 13].

Numerical calculation codes were used to facilitate the exhaustive evaluation of the characteristics of this 46.8 MHz feed. Some estimation of the mutual coupling between this feed and the 1667 MHz and 430 MHz feed was done as well. Figure 16 shows the close position of these feeds. Drift-scan measurements of the 46.8 MHz total antenna pattern showed some minor asymmetry caused by the coupling. The total gain was estimated to be 41 dBi, and the half-power beamwidth was estimated to be 1.8°. Just at that time, planning for the Gregorian feed was started, but it was not regarded as suitable for a low-frequency VHF radar.

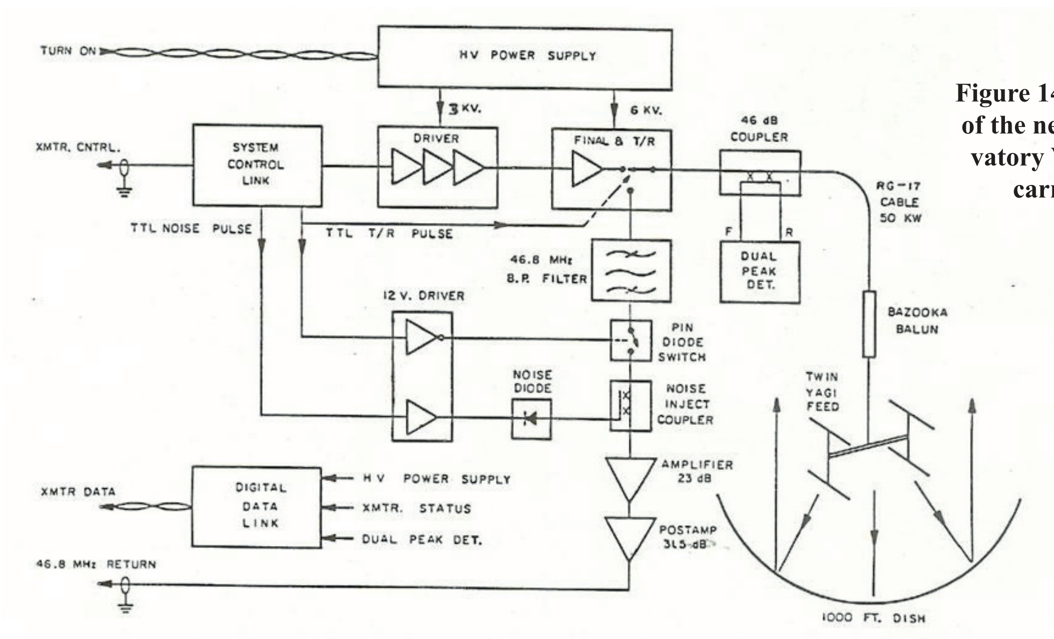


Figure 14. The instruments of the new Arecibo Observatory VHF radar in the carriage house 1.

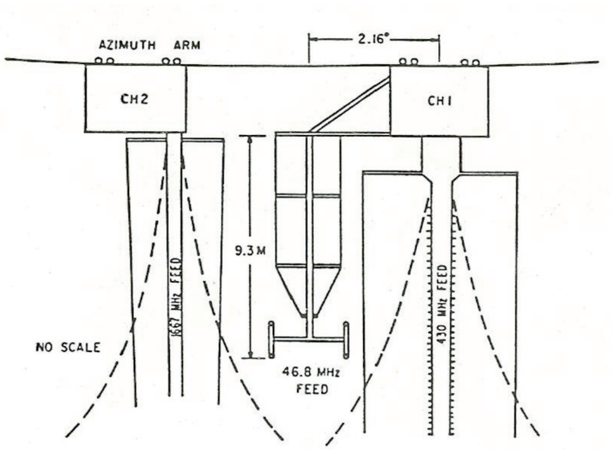


Figure 15. The new VHF radar feed, located close to carriage house 1.

First AO-VHF-Radar Observations

On July 27, 1985, the first troposphere-stratosphere data were taken with this new AO-VHF Radar, applying a four-bit complementary code, 750 m range resolution, 1.3% duty cycle, and about 45 kW peak power. The antenna pointed at 10° zenith angle and 90° azimuth to measure the zonal wind component. Figure 16 shows a distribution profile of normalized Doppler spectra (velocities), deduced from the data taken in the time period 1330-1415 AST. A zonal-wind maximum of about 20 m/sec at range 21 (equal to 11 km altitude) was clearly discernible, which was most likely due to the subtropical jet stream. The zonal-wind velocity decays considerable with height, resulting in a strong wind shear. The Doppler-spectra time series indicated pronounced gravity-wave oscillations at about six minutes period, with amplitudes up to 0.5 m/sec. (An unbalance of quadrature detection caused some symmetrical spectral components, which should be disregarded here, as well as the fading clutter component seen at zero Doppler frequency.) The phase of the gravity-wave oscillations reversed in the strong shear region between range gate 24 and 25. This reversal was a clear indicator of a Kelvin-Helmholtz instability generating these atmospheric gravity waves. The signal power distribution indicated a maximum in the region of smallest zonal wind shear. The average signal power was regarded as not being affected by the Kelvin-Helmholtz-instability-generated turbulence. We found that the atmospheric signal power was always smaller than the ground clutter power. Above 21 km range, very strong scatter from ocean waves (sea-clutter) completely dominated the atmospheric echo.

A set of MST radar analysis programs for the 46.8 MHz radar (VHF1 to VHF7; Figure 16 is an example of VHF3) and the 430 MHz radar (UHF1 to UHF3) and SD1 to SD3 for displaying analyzed data were developed, tested, and made public available under 2220AEROJUR. They were developed to allow a fast assessment of the collected data, as well as to yield first estimates of physical parameters. In order to avoid misinterpretation that could arise from more-sophisticated processing procedures, these programs and their source codes were kept as straightforward as possible. They were regarded as "check-out" programs, to be replaced later by more-elaborate schemes.

Due to our new tropospheric science work at the observatory, air-traffic controllers of the San Juan airport approached us with an interesting phenomenon that they were bothered with. Then and now, aircraft approaching San Juan from the north disappeared on their radar screens, which was surprising to them, and dangerous, as well. We could show, after looking up radiosonde profiles, that likely the reason for this signal loss was the high elevation of their surveillance radar on the El Yunque mountain, near San Juan. A low-level strong maritime temperature inversion, at a few hundred meters to some kilometers height, would divert the low-angle ray path upward, thus not reaching the aircraft coming in below this inversion This was one of the meteorological applications of our scientific research. A solution could have been to add a second radar at lower altitude, which of course was not the scope of this small second-priority project.

Other activities kept me very busy, such as contributing to the quarterly reports, and evaluating ideas and proposals for the five-year plans for the observatory. I remember many valuable input suggestions to these documents, for instance from discussions with the visitors Toru Sato (Kyoto), Ron Woodman (Jicamarca), Jules Fejer (Tromsø), Chao Han Liu (Urbana, Illinois), Al Scheffler (Urbana), John Mathews (Cleveland, Ohio), Wen-Ping Ying (Cleveland), Jim Breakall (Cleveland), Miguel Larsen (Clemson), Frank Djuth, Jerry

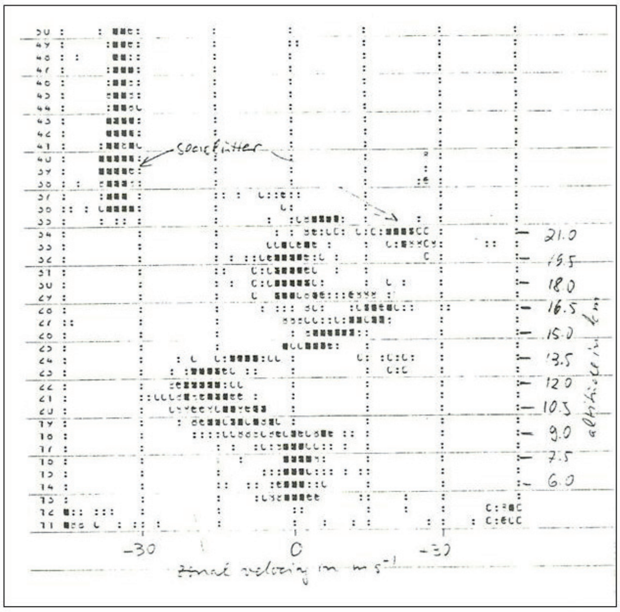


Figure 16. The first velocity-distribution profile of the new Arecibo Observatory VHF radar, recorded on July 27, 1985, 13:30-14:15 AST.

Jost, and Prabhat Rastogi (Boston), just to name a few. Presentations to summer students took place on MST radar science and operation. Reports on our atmosphere science proposal to the National Science Foundation and the general development of atmosphere-ionosphere science were presented, as well. Carmen Torres and Mercedes Vives were very helpful in preparing the presentation documentation. Don Campbell, Observatory Director, always had open ears to our reports and questions, and well supported our projects. Radio- and radar-astronomers, such as Mike Davis, Willem Baan, Alex Wolszczan, and others, were stimulating with interest in our radar atmosphere/ionosphere science work.

From the second and fourth quarterly report on the atmosphere/ionosphere projects I-211 ("Further Investigations of the Scattering/Reflection Mechanisms of 50 MHz Radar Echoes from the Tropical Troposphere and Stratosphere" by Röttger and Ierkic), I-214 ("Measurements of Wavenumber Spectra of Tropospheric, Stratospheric and Mesospheric Velocities" by van Zandt, Röttger, Ierkic, Mathews, Ying, and Smith), I-215 ("Determination of the Influence of the Doppler Effect on Frequency Spectra of Tropospheric-Stratospheric and Mesospheric Velocities" by Liu, Scheffler Franke, Röttger, Ierkic, Mathews, and Ying), and I-217 ("Range-Doppler Study of Shear Instabilities in the MST Region Using Fine Resolution Techniques at Arecibo" with Rastogi, Ierkic, and Röttger), it could be shown that useful data could mostly be recorded with the new VHF radar system. This allowed a number of experiments to study the middle- and upper-troposphere (and, partially, the lower stratosphere). We also expected to detect mesospheric echoes under favorable conditions in future runs. A new data-taking program for use of the 430 MHz radar for stratosphere and troposphere investigations was developed. It used the VOS operating system, and was basically similar to the programs used with the 46.8 MHz radar. A first test performed with a 16-baud complementary code showed good results.

Some More Science

Several other observations took place using the 46.8 MHz and 430 MHz radars for MST investigations. These were measurements of wavenumber spectra of tropospheric, stratospheric, and mesospheric velocities by van Zandt, Röttger, Ierkic, Mathews, and Ying (only mesospheric 430 MHz experiments were done, which were quite unsuccessful because of interference); determination of the influence of the Doppler effect on frequency spectra of tropospheric, stratospheric, mesospheric, and thermospheric velocities by Liu, Sheffler, Franke, Rottger, Ierkic, Mathews, and Ying (only 430 MHz mesospheric and thermospheric experiments were successful); range-Doppler studies of shear instabilities in the MST region using fine-resolution techniques by Rastogi, Röttger, and Ierkic; and further investigations of the scattering/reflection mechanism of 46.8 MHz radar echoes from the tropical troposphere and stratosphere by Röttger and Ierkic .

Further analyses of the data taken in 1981 with the AO-MPAe SOUSY-VHF Radar were done. It was shown that the Brunt-Vaisala frequency can be estimated from gravity-wave spectra, allowing a determination of the profile of the temperature gradient in the mesosphere. Using the width of the Doppler spectra, one then can deduce the eddy diffusion coefficient [14]. Studies of tropospheric convection using the VHF and UHF radar also indicated strong anomalous echoes from regions of large downdraft velocities, which was a sign of scatter from precipitation [15, 16].

The Third MST Radar Workshop

Towards the end of my stay at the Arecibo Observatory, the 3rd SCOSTEP and URSI Workshop on Technical and Scientific Aspects of MST Radar was held at the El Parador Hotel in Aguadilla, October 21-25, 1985. The local organization, lead by me and Frank Six, was under the Arecibo Observatory. More than 100 papers were presented by more than 100 participants. The topics covered all aspects of MST radar, from gravity waves and turbulence, analysis and modulation methods, progress reports and planned MST radars, campaigns and networks, to numerical weather prediction using VHF radar data, for instance.

Extended abstracts were published in the proceedings. An excerpt from the foreword to this documentation by S. A. Bowhill read:

> The Third Workshop on Technical and Scientific Aspects of MST (mesosphere-stratosphere-troposphere) radar was held in Aguadilla, Puerto Rico, on October 21-25, 1985. This was the first time that the Workshop was held outside the continental United States; the previous Workshops (in May 1983 and May 1984) were held in Urbana, Illinois. My Co-Organizer, Dr. C. H. Liu, and I are extremely grateful to the staff of the Arecibo Observatory of Cornell University for arranging and supporting a week of very intensive technical activities. I would particularly like to thank the Director of the Arecibo Observatory, Dr. Tor Hagfors, for the courteous and sympathetic reception he accorded to the participants; and also Dr. Jürgen Röttger for his unstinting efforts in the Workshop organization.

Adios AO

My final MST VHF radar operations at the Arecibo Observatory, planned as my farewell between December 13 and December 22, 1985, were an almost complete failure. At the beginning, the 46.8 MHz transmitter broke. During the time of repair, we tested the new 430 MHz data-acquisition program under VQS. After some planetary radar-decoder problems, we were able to take about 30 minutes of data, using a 16-baud complementary code with the 430 MHz radar. The data quality was reasonable, and we could prove that 430 MHz ST data could also be acquired under VQS. After the 46.8 MHz transmitter was repaired (modified by circumventing the built-in digital control), we tried to take data. Again, the planetary decoder did not work (this time it was synchronization problems). Following several tests by Jon Hagen, we decided to cancel further radar operations after December 20. Part of the remaining telescope time was used to undertake further antenna calibrations, which, however, were not particularly successful, due to considerable interference.

This was not a good Christmas present, and not a pleasant farewell to the Arecibo Observatory, as well. However, it was consistent with the Extended Murphy's Law: "If a series of events can go wrong, it will do so in the worst possible sequence." Was there a sign to return to Arecibo Observatory for later successful experiments to counteract the latter? We were confident: Despite these short-term problems, which happened a few days before Christmas eve and could not be fixed in the final hurry, the radar systems were left in a well-upgraded, tested, and functioning status, as had been proved in the months before. It was expected that the AIDA campaign, performed later by the new Head of the Atmospheric Science Department, Colin G. Hines (also author of the novel, *Murder at Arecibo, Life and Death at the Arecibo Observatory*, 2008) would be more successful in using the VHF radar for middle-atmosphere studies.

Epilog

However, due to my following commitment to EISCAT, I did not participate in this later campaign. It would have been a challenge, since some years later Colin G. Hines followed up the need for lower and middle atmosphere science at Arecibo in his document on "AIDA: The Arecibo Initiative in Dynamics of the Atmosphere" (1987) by writing:

> *Coherent scattering is preferably done at more than one wavelength, in order to detect more than one structure size in the turbulence spectrum. The facility already provides this capability for this, having in addition to its 430 MHz scatter radar the S-band planetary radar and a 46.8 MHz system as well, the latter two revealing atmospheric turbulence up to 19 and 25 km, respectively, at times. All three radars have been used in the past for such studies, and all have been valuable in what they have revealed – even what would be needed, for a true complement, would be a dedicated VHF scatter system analogous to other such systems in the growing grid of MST radars. Such a system was in fact proposed for the Observatory a short time ago in the minimal form of an ST system but, despite highly favourable reviews, was not funded at that time. Now, however, it can be seen as an integral part of the long-term planning represented by AIDA; it is very much still in our minds, not just as the appropriate complement to a lidar for height coverage up into the E region (if its full potential for revealing turbulence is exploited), but also for a more detailed investigation of lower-atmospheric meteorological processes already put into evidence by the existing systems*

Finally I should recollect now that already a few weeks after I started work at the observatory, I was confidentially approached by Michel Petit, who visited in November 1984 as a member of the Arecibo Advisory Board. At that time, he was Chair of the EISCAT Council. He told me that EISCAT wanted me to return to become its Director. This very attractive offer did not affect my efficiency at the Arecibo Observatory, but required many personal discussions with Tor Hagfors. Our final, mutually agreed decision, that I should accept the offer of the EISCAT Directorship was alleviated by the fact that there was no positive decision by the National Science Foundation for funding the VHF MST radar project (Figure 12), despite three very good and two excellent ratings by the peer reviewers.

My position as Director of EISCAT thus actually commenced at the Arecibo Observatory. At EISCAT, I acted more than a sunspot cycle as Director, also starting and constructing the EISCAT Svalbard Radar (ESR), then returning to the MPAe to establish the SOUSY Svalbard Radar (SSR) with its core instrumentation (Mobile SOUSY VHF Radar) already used at the Arecibo Observatory over 1980-1981. This closed the circle of my final scientific career: MPAe – Jicamarca – Arecibo – MPAe – EISCAT – Arecibo – EISCAT – Svalbard – MPAe, until I had, according to German rules, to retire in February 2002.

In concluding, I want to thank John Mathews for asking me to write this article on my personal experiences at the Arecibo Observatory. Although it became longer than originally planned, it contains only a little, selected information on the multitude of experiences and the dedicated work during this time. It cannot comprise any well-qualified scientific, technical paper or memoir. It was just compiled quasi-randomly from my diaries, notes, photos, copied reports, publications, and, particularly, my memory.

References

1. J. Röttger, "Utilization of the Lower VHF Band for Radar Experiments at the Arecibo Observatory," Technical Report MPAE-T-00-80-01, 1980.

2. J. Röttger, P. Czechowsky, and G. Schmidt, "First Low-Power VHF Radar Observations of Tropospheric, Stratospheric and Mesospheric Winds and Turbulence at the Arecibo Observatory," *J. Atmospheric & Terrestrial Physics*, **43**, 1981, pp. 789-800.

3. J. Röttger, "Comparison of Reflectivity and Wind Profiles Measured on 46.8 MHz and 430 MHz at the Arecibo Observatory," Proceedings of the 3rd International Workshop on Technical.

and Scientific Aspects of MST Radar (MAP Handbook), **20**, 1986, pp. 307-308.

4. J. Röttger, "VHF Radar Measurements of Small-Scale and Meso-Scale Dynamical Processes in the Middle Atmosphere," *Philosophical Transactions of the Royal Society*, **A323**, 1987, pp. 611-628.

5. J. Röttger, "The Relation of Gravity Waves and Turbulence in the Mesosphere," *Advances in Space Research*, **7**, 1987, pp. (10)345-(10)348.

6. R. Rüster and J. Klostermeyer, "A Kelvin-Helmholtz-Instability Generating Gravity Waves in the Lower Stratosphere Jet Stream," *Geophysical & Astrophysical Fluid Dynamics*, **26**, 1983, pp. 107-116.

7. P. K. Rastogi, J. D. Mathews, W.-P. Ying and J. Röttger, "Simultaneous VHF and UHF Radar Observations of the Mesosphere at Arecibo During a Solar Flare: A Check on the Gradient-Mixing Hypothesis," *Radio Science*, **23**, 1988, pp. 97-105.

8. J. Röttger, J. P. Czechowsky, R. Rüster and G. Schmidt, "VHF Radar Observations of Wind Velocities at the Arecibo Observatory," *J. Geophysics*, **52**, 1983, pp. 34-39.

9. Y. Maekawa, T. Aso, J. Röttger, P. Czechowsky, R. Rüster, G. Schmidt, I. Hirota, R. F. Woodman, and S. Kato, "A Cooperative Synchronous Observation of Winds and Tides in the Tropical Lower Stratosphere and Mesosphere Using VHF Radars at Jicamarca and Arecibo," *J. Geomagnetism & Geoelectricity*, **38**, 1986, pp. 81-97.

10. J. A. Fejer, H. M. Ierkic, R. F. Woodman, J. Röttger, M. Sulzer, R. A. Behnke and A. Veldhuis, "Observations of the HF-Enhanced Plasma Line with a 46.8-MHz Radar and Reinterpretation of Previous Observations with the 430-MHz Radar," *J. Geophysical Research*, **88**, A3, 1983, pp. 2083-2092.

11. J. Röttger, M. F. Larsen, H. M. Ierkic, and T. Hagfors, "Need for a Subtropical Wind Profiler System," Proc. 3rd International Workshop on Technical and Scientific Aspects of MST Radar (MAP Handbook), **20**,1986, pp. 86-89.

12. H. M. Ierkic, J. Röttger, J. B. Hagen and R. K. Zimmerman, "Method to Determine the Optimal Parameters of the Arecibo 46.8-MHz Antenna System," Proc. 3rd International Workshop on Technical and Scientific Aspects of MST Radar (MAP Handbook), **20**, 1986, pp. 420-424.

13. J. Röttger, H. M. Ierkic, K. Zimmerman, and J. Hagen, "Investigations of the Lower and Middle Atmosphere at the Arecibo Observatory and a Description of the New VHF Radar Project," Proc. 3rd International Workshop on Technical and Scientific Aspects of MST Radar (MAP Handbook), **20**, 1986, pp. 349-359.

14. J. Röttger, "Contributions of Radar Observations of Winds, Waves, Turbulence and Composition to Study Transport Processes in the Middle Atmosphere," in Visconti and Garcia (eds.), *Transport Processes in the Middle Atmosphere*, D. Reidel Publishing Company, 1987, pp. 439-457.

15. D. N. Holden, C. W. Ulbrich, M. F. Larsen, J. Röttger, H. M. Ierkic, and W. Swartz, "UHF and VHF Radar Observations of Thunderstorms," Proc. 3rd International Workshop on Technical and Scientific Aspects of MST Radar (MAP Handbook), **20**, 1986, pp. 288-292.

16. M. F. Larsen and J. Röttger, "Observations of Thunderstorm Reflectivities and Doppler Velocities Measured at VHF and UHF," *J. Atmospheric & Ocean Technology*, **4**, 1987, pp. 151-159.

Radio-Frequency Radiation Safety and Health

The Effect of Electromagnetic Field Exposure on Hypersensitivity Responses in Humans

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A version of this appeared in the *IEEE Antennas and Propagation Magazine*, **55**, 4, August 2013; copyright 2013 IEEE.

Abstract

The syndrome of electromagnetic hypersensitivity (EHS) consists of nervous-system symptoms, such as headache and fatigue; skin symptoms, such as facial irritations and rashes; as well as other nonspecific health-related symptoms. One of the most renowned case of EHS is the reported hypersensitivity of Gro Harlem Brundtland, the former Prime Minister of Norway. She was the Director-General of the World Health Organization (WHO) from 1998 to 2003. She had not publicly talked about her EHS for more than 10 years. However, that ended when she told a reporter, "I avoid talking on mobile phone," in response to a newspaper article alleging that she now uses a mobile phone, according to a former top aide at WHO, Jonas Gahr Støre, the current Norwegian Minister of Health.

Electromagnetic hypersensitivity, or EHS, was the subject of many scientific studies about a decade ago [1]. Several research investigations have appeared since then. The syndromes of EHS consist of nervous-system symptoms, such as headache and fatigue; skin symptoms, such as facial irritations and rashes; as well as other nonspecific health-related symptoms. There have also been reports of problems with concentration, loss of memory, and dizziness. Exposure of the affected persons was generally below the recommended standard promulgated in internationally accepted guidelines.

The reported evidence suggests that while the phenomenon of hypersensitivity may be real, the questions as to whether the symptoms are associated with cell-phone use or how best to study EHS in a controlled laboratory investigation remain controversial.

Some suggest that routine provocation types of investigations, such as are employed for chemical or food allergies, may not be sufficient or appropriate for EHS, given the potential variances between artificial compared to indigenous environments and their possible influences on human psycho-physiological responses under different conditions. Published laboratory research to date on hypersensitivity from exposure to cell-phone electromagnetic fields thus remains limited and inconclusive.

While not blatantly obvious, experimental designs may sometimes introduce confounding factors. The statistical strength is often weakened by a small number of subjects in these studies, resulting in mixed assessment.

Perhaps one of the most – if not the most – renowned cases of EHS is the reported hypersensitivity of Gro Harlem Brundtland, the former Prime Minister of Norway. She is a medical doctor who had served as Prime Minister of Norway for 10 years. She was the Director-General of the World Health Organization (WHO) from 1998 to 2003. At the WHO, she banned the use of cell phones in her office because, she said, they gave her headaches [2].

She had not publicly talked about her EHS for more than 10 years. However, that ended when she told a reporter, "I avoid talking on mobile phone" [3], in response to a newspaper article alleging that she now uses a mobile phone, according to a former top aide, Jonas Gahr Støre, the current Norwegian Minister of Health [4]. Støre worked for Brundtland at the WHO in Geneva, Switzerland.

It is not clear whether Støre, the Health Minister, had misrepresented Brundtland in an effort to promote government policy that radio-frequency (RF) radiation is safe and causes no health effects. Apparently, Støre's views on RF were based on the Norwegian government's decision, which concluded that electromagnetic fields from mobile-phone radiation, wireless networks, and mobile towers do not cause health problems or electromagnetic hypersensitivity [5, 6], and there is overall no evidence from scientific research to claim that mobile phone and similar radiation is harmful.

At the same time, between 75,000 and a half million Norwegians claim to have EHS syndromes. The total population of Norway is about five million.

It is interesting to note that a recent publication in the *International Journal of Neuroscience* from the Department of Neurology, Louisiana State University Health Sciences Center, in Shreveport, concluded that EHS can occur as a bona fide environmentally inducible neurological syndrome [7]. The study sought direct evidence that acute exposure to environmental-strength electromagnetic fields (EMFs) could induce somatic reactions (i.e., EHS). The case in point involved a female medical doctor, self-diagnosed with EHS. In a double-blind provocation procedure designed to minimize unintentional sensory cues, the subject developed temporal pain, headache, muscle twitching, and skipped heartbeats within 100 s after initiation of electromagnetic-field exposure. The symptoms were associated primarily with field transitions (switching either on or off), rather than the presence of the field. The investigation included comparing the frequency and severity of the effects of pulsed and continuous fields to sham exposure. It was reported that the subject had no conscious perception of the electromagnetic field, as assessed by her inability to report its presence more often than in the sham control. The authors' conclusion was that the subject demonstrated statistically reliable ($p < 0.05$) somatic reactions (EHS) in response to electromagnetic-field exposure under conditions that reasonably excluded a causative role for psychological processes.

Actually, what first brought my attention to this issue of late were, one, the statement about "Brundtland now uses a mobile phone" from the Norwegian Health Minister, and the genteel challenge, two days later, by Brundtland, "I avoid talking on mobile phone;" and two, the apparent, official Norwegian-government-sanctioned conclusion, "The large total number of studies provides no evidence that exposure to weak RF fields causes adverse health effects," or "There is overall no evidence in research to say that mobile and similar radiation is harmful."

It is factual that more research studies showed no health effect. However, except for some animal studies, a majority of the studies were short-term investigations. That includes epidemiological studies of head and neck cancers in cell-phone users. A fair summary of the biological research results would be that they do not conclusively demonstrate evidence that proves or disproves a health risk from cell-phone exposure.

Why are the assessments and conclusions then so mixed? Perhaps, one could ascribe the Norwegian Health Minister's remarks as politics as usual, where in current societies, truth typically is in short supply. The objectives here often are to advance one's parochial and political agendas.

How about science? Isn't science and the scientific approach a search for truth and nothing but the truth? If yes, why would different groups of scientists reviewing the same data or papers end up with very divergent conclusions? The answer, in part, may come from the complexity and variability of biological systems. Moreover, biological and health-science research takes place in a messy environment! Compared to physical testing, many more biological experiments are needed to confirm phenomenological and/or quantitative observations, sometimes, over an extended length of time or generations of life spans.

Moreover, like culture and society, some science and scientific communities have evolved to be comprised of multiple stakeholders, each with its own disparate interests, biases, and preferences. At times, scientific research has run the risk of getting entangled (ensnared) in value judgment or value relativism, where the search for scientific truth becomes secondary to what is expedient or more gratifying, perhaps, as in political science.

References

1. J. C. Lin, "Subjective Symptoms and Hypersensitivity to Cellular Telephones," *IEEE Antennas and Propagation Magazine*, **46**, 5, October 2004, pp. 167-169.

2. "Mobile Fears of World Health Leader," *BBC News World Edition*, UK, July 2, 2002.

3. T. Ergo, "I avoid talking on mobile phone," *Aftenbladet,* Norway, June 30, 2013.

4. T. Ergo, "Gro Harlem Brundtland has begun to use mobile phone," *Aftenbladet,* Norway, June 28, 2013.

5. T. Ergo, "Government: Mobile radiation does not harm or bother you," *Aftenbladet,* Norway, May 18, 2013.

6. Report 2012:3, "Low-Level Radiofrequency Electromagnetic Fields – An Assessment of Health Risks and Evaluation of Regulatory Practice," Norwegian Institute of Public Health, Oslo, Norway, 2012.

7. D. E. McCarty, S. Carrubba, A. L. Chesson, C. Frilot, E. Gonzalez-Toledo, A. A. Marino, "Electromagnetic Hypersensitivity: Evidence for a Novel Neurological Syndrome," *International J. Neuroscience*, **121**, 2011, pp. 670-676.

Book Reviews for Radioscientists

Thermal Design and Thermal Behaviour of Radio Telescopes and Their Enclosures

by Albert Greve and Michael Bremer, Berlin, Astrophysics and Space Science Library **364**, Springer, 2010;
ISBN 978-3-642-03866-2; 420 pp.; US$159.00, €128.35

Be it a radio telescope or a communication station, it is important to maintain a stable reflector-surface contour and pointing direction under the variable influence of gravitational and environmental effects for the optimal operation of a reflector antenna. Over the years, the requirements have tremendously increased through the construction of ever-larger reflectors, operating at ever-shorter wavelengths. Currently, there exist radio telescopes of 100 m diameter useable at 3 mm wavelength, 30 m to 50 m reflectors operating at 1 mm, and 10 m to 12 m antennas capable of observing at frequencies of 1 THz and beyond.

With respect to the minimization of gravitational deformations, which are dependent on the elevation angle of the reflector, this has been achieved through the application of homologous design, developed by von Hoerner in the 1960s. Here, one does not aim for a sufficiently stiff structure to curb the deformations, but forces the structure to deform in such a way that the resulting reflector maintains a parabolic shape of high quality, albeit with an unavoidable change in focal length and axis direction. In the focal plane, the receptor is thus actively controlled as a function of elevation angle to occupy the focal position. This method was first applied in the design of the 100 m-diameter radio telescope of the Max-Planck Institut für Radioastronomie in Effelsberg, Germany. In the current state of design with Finite-Element Analysis (FEA), residual gravitational deformations of only a few micrometers are achieved in economic antennas of 10 m diameter or more.

The significant increase in operational frequency led to the experience that environmental influences often determined the limiting boundaries of reliable telescope use. In particular, variations in temperature, be they changes between day and night or gradients through the structure caused by asymmetric illumination by the sun, often caused deformations well in excess of gravitational errors. Von Hoerner performed early studies in this area. The control of thermal deformations became a major task in the design of the 30 m-diameter millimeter-wavelength telescope of IRAM in the mid-seventies. The senior author of the book under review, Albert Greve, became deeply immersed in this effort. He proceeded to become an expert in this area, participating in the thermal design and experimental analysis of several other radio telescopes. Over the years, together with co-author Michael Bremer, a large body of data on the thermal behavior of reflector antennas was collected, in particular of the author's home-institute telescopes, the IRAM 30 m telescope in Spain, and the 15 m antennas in France. The measurements on these instruments form the backbone of numerical data for the analysis and the discussion of thermal effects.

This material is presented along with the theoretical background and the influence of thermally induced structural deformations on the electromagnetic performance of the antenna, as gain, sidelobe structure, and pointing stability. The material is divided over 15 chapters, and presented in an order that in my opinion is not optimal. The first three chapters introduce the different types of radio-telescope design and protective enclosure. Already there thermal effects are mentioned, but not worked out in detail. In Chapters 4 and 5, the variable thermal environment and the solar illumination of the telescope are treated in considerable detail. Unfortunately, the level of detail is not uniform throughout the text. For instance, Chapter 5 starts with a detailed but straightforward setup of the coordinate system, but Equation (5.17) is not explained in any way. This happens in more places, and its effect on the reader will vary with the reader's specific prior knowledge of the different subjects at hand.

In Chapter 6, actual temperature measurements are used in the Finite-Element Model to predict structural deformations, and then compared to actual deformation measurements. A rather impressive example of the capabilities of this approach is presented.

This is followed by two chapters on the theory of heat transfer (Chapter 7) and radiative coupling to the environment (Chapter 8). The treatment is somewhat lacking of structure (some equations are introduced "ad hoc" and only derived pages later), which is partially due to the extensive use of reference to the standard text by Chapman. There are some useful tables of material and heat-transfer parameters.

After these rather theoretical chapters, the authors return to the discussion of the measured behavior of antennas and enclosures in Chapters 9 and 10. At this point, one feels that the continuity in the discussion would have been helped if the theoretical chapters, Chapters 7 and 8, had been placed before the presentation of measurements in Chapter 6, which are in essence being extended and more fully discussed in Chapters 9 and 10.

In the design process of a telescope, the use of model calculations, along with the finite-element analysis, plays an important role. The construction of the thermal model of the different structural sections of the antenna is the subject of Chapter 11. This interesting chapter provides a good introduction to the art of modeling. The details and the incorporation into the modeling computer programs are touched on lightly. Because these details are different for each telescope design, this is an acceptable limitation in the context of the book.

Chapter 12 deals with the relationship between the thermal deformation and the resulting electromagnetic characteristics of the telescope. These are discussed on the basis of a large body of measurements, mainly on the IRAM 30 m mm-wavelength telescope. This is quite instructive, both for demonstrating quantitatively how thermal effects influence the antenna's beam characteristics, and how counteractive measures, such as climatization, can limit beam deterioration to acceptably low levels.

There are some errors that might confuse the reader who is unfamiliar with antenna theory, but the gist of the discussion hardly suffers under this. For instance, on page 309, Equation (12.9) is wrong: the length of PF definitely is not equal to the focal length, F. At the end of the first paragraph on page 311, the taper values, p, should be the reciprocal of those given. In the caption of Figure 2.18, the last line should read "...changes by 90° between the two out-of-focus positions." In Equations (12.27) and (12.28), the correlation length, L. should be replaced by $L/2$ (the correlation radius), and Equation (12.29) becomes $1.06\lambda/L$ which one expects.

The example of the effect of buckling in surface panels (Figures 12.09 and 12.10) is quite impressive. Summarizing, this chapter shows convincingly that the influence of thermal effects on the electromagnetic parameters can be understood and counteracted. This is further elaborated in Chapter 13 on "thermal tolerances," in particular, the effect of the climatization on pointing and focus changes.

Most of the examples are taken from the extensive measurements on the 30 m telescope. The chapter closes with an instructive "error budget table," which could have used some more discussion and explanation for the uninitiated reader.

The book closes with an eight-page summary, and indications of further studies. It is completed with some appendices and extensive indices.

This volume presents a comprehensive treatment of the thermal behavior and design of radio telescopes, reflector antennas, and their enclosures. The authors have worked for years on collecting data from existing instruments, analyzing these, and incorporating the thermal environment in the thermal modeling and Finite-Element Analysis of existing and new telescopes. The book contains a wealth of interesting and useful material in the form of graphs and tables. Because of the somewhat "unusual" order of the chapters, these are often referred to at different places in the text. These data can also be of interest for a particular aim the reader might have in mind, for instance, collecting data on a particular telescope or a physical phenomenon. It is a pity that the otherwise excellent indices have not been augmented with a list of tables and figures. The usefulness of the book as a reference volume would have been significantly enhanced. I have suggested to the authors that such a list might be placed for download on the Web page of the book in the Springer Web area.

The style of the narrative is quite verbose, and the book could have benefited from a good copy editor. Unfortunately, these have all but been abandoned in the area of specialized works with limited sales, despite the high price of the final product.

Notwithstanding these small shortcomings, this book will be of indispensable help to designers and operators of telescopes, as soon as a thermal influence needs to be considered.

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Have you written a book? Do you know a book written by a colleague that might be of interest for the URSI community? We would be glad to publish a review of such books in our URSI *Radio Science Bulletin*. Please contact our Associate Editor on book reviews, Kristian Schlegel (ks-ursi@email.de).

Conferences

CONFERENCE REPORTS

2012 International Conference on Electromagnetics in Advanced Applications
2012 IEEE AP-S Topical Conference on Antennas and Propagation in Wireless Communications
URSI Electromagnetic Environment and Interference Symposium

Cape Town, South Africa, 2 - 7 September 2012

The fourteenth International Conference on Electromagnetics in Advanced Applications (ICEAA), the second IEEE AP-S Topical Conference on Antennas and Propagation in Wireless Communications (IEEE APWC), and the first Electromagnetic Environment and Interference Symposium (EEIS, organized by Commission E of URSI, the International Union of Radio Science) were held at Cape Town, South Africa, on September 2-7, 2012. ICEAA had the IEEE Antennas and Propagation Society, the Istituto Superiore Mario Boella, and the Torino Wireless Foundation as principal cosponsors, and the International Union of Radio Science (URSI) as a technical cosponsor.

Figure 1. Silvio Barbin at a coffee break.

Figure 2. Matthias Hein at a coffee break.

IEEE APWC was the first conference of the IEEE Antennas and Propagation Society held on the African continent. The three conferences shared common registration, organizing, and scientific committees; common venues, receptions, and banquet; and social events.

The 455 submissions received by the three conferences were reviewed by an international scientific committee composed of 26 scientists from 12 countries. The 350 accepted papers were scheduled in 46 technical sessions: 33 sessions in ICEAA (including 22 special sessions and two sessions joint with EEIS), 11 sessions in APWC (including six special sessions), and four sessions in EEIS (including three special sessions). Most papers came from the USA (13.7%), followed by South Africa (13.4%), Germany (12.9%), Japan (6.6%), China (5.7%), Australia (5.1%), and Italy and the UK (4.9% each). Among the conference papers, approximately 45% came from Europe, 20% from Asia, 16% from the Americas, 14% from Africa, and 5%

Figure 3. (l-r) Daniel Ioan, Lucretia and Arthur Yaghjian, and Olov Brienbjerg at the welcome reception, with Table Mountain in the background.

from Australia-Oceania. There were 363 registered attendees and several accompanying persons from 42 countries. The proceedings of the conferences were published on two CDs and on IEEE Xplore.

There were two short courses: one on "Balun Designs for RF and Microwave Applications," taught by Johannes H. Cloete of the University of Stellenbosch, South Africa; and one on "Practical Aspects of EMC for Engineers," taught by Christos Christopoulos of the University of Nottingham, UK. The IEEE Antennas and Propagation Society sponsored two plenary talks by AP-S Distinguished Lecturers, both given immediately after the opening ceremony on September 3. The first distinguished lecture was on "OTA-MIMO Measurements in Reverberation Chamber: New Developments and Appropriate System Models Including OFDM" by Per-Simon Kildal of the Chalmers University of Technology, Sweden. The second distinguished lecture was on "Efficient Shaped-Beam Synthesis in Phased Arrays and Reflectors" by Arun K. Bhattacharyya of the Northrop-Grumman Corporation, USA. On the last day of the conferences, a full-day workshop, sponsored by CSIRO, Australia, and entitled "Phased Array Feed Developments Towards SKA," was organized by Carole Jackson of CSIRO.

Figure 4. Howard Reader at the welcome reception.

The ICEAA technical sessions covered topics such as radio astronomy; imaging, inversion and optimization; RCS and asymptotic techniques; inverse scattering; EM properties of materials; metamaterials and other novel electronic materials; nanotechnology; EM measurements; optoelectronics and photonics; antennas and arrays; fields and waves; network methods in EM; EMC/EMI/EMP; modeling of devices and circuits; wireless power transmission; advanced mathematical and computational methods in EM; integral-equation methods; finite methods; fast computational methods; numerical, asymptotic, and hybrid methods; bioelectromagnetics and medical applications; electromagnetic theory (joint with EEIS); effects of EM pulses on digital systems (joint with EEIS). Two all-day sessions on radio astronomy (including SKA) and on imaging arrays for radio astronomy were especially significant because of the development of the Square Kilometre Array in South Africa.

Figure 5. (l-r) Marcel Nauta, Barbara Okoniewska, Michal Okoniewski, and Ewa Okoniewska at the welcome reception.

Figure 6. A white rhino with calf at Kapama Game Reserve, near Kruger National Park (photo by George Uslenghi).

Figure 7. Baby lions in the bush at Kapama Game Reserve, near Kruger National Park (photo by George Uslenghi).

Figure 8. A royal couple in the bush at Kapama Game Reserve, near Kruger National Park (photo by George Uslenghi).

The topics covered in the IEEE APWC technical sessions were antennas and arrays; antennas, propagation, systems, and applications; multi-band antennas; ultra-wideband antennas; functional antennas; channel modeling; celebrating 60 years of GTD; EMC and related technologies; UWB systems in biomedical diagnostics; and wireless networks.

In addition to the two joint sessions with ICEAA, the EEIS had two sessions covering complexity and uncertainty in EMC, and HPEM environments, modeling, and measurements. There was a business meeting of URSI Commission E, devoted in part to the organization of the 2014 URSI GASS in Beijing.

As in previous ICEAA editions, the number of parallel sessions was limited to four or five, in order to facilitate the exposure of attendees to a variety of scientific topics. All sessions, industrial exhibits, and luncheons were held at the Cape Sun Hotel, a very elegant venue in central Cape Town. Coffee breaks were held in the industrial-exhibits area (Figures 1 and 2). A magnificent welcoming reception (Figures 3-5) was held at a restaurant on the harbor, and a sumptuous gala dinner was held at a downtown restaurant.

Figure 9. An elephant approaching the vehicle at Kapama Game Reserve, near Kruger National Park (photo by Paul Lagasse).

Figure 10. The opening ceremony: (l-r) David Davidson, Doug Rawlings, Steven Best, Peter Staecker, Paul Lagasse, George Uslenghi, and Roberto Graglia.

Figure 11. Peter Staecker, IEEE President Elect, at the opening ceremony.

Figure 12. Steven Best, AP-S President, at the opening ceremony.

Figure 13. Paul Lagasse, URSI Secretary General, at the opening ceremony.

Sunny skies and uncommonly warm weather allowed participants and accompanying persons to enjoy the museums, shops, restaurants, gardens, harbor, and environment of Cape Town, including trips to Robben Island, to the top of Table Mountain, to the coastline and a national park nearby, to a preserve where cheetahs could be touched, and to Stellenbosch and the wine district. Many participants visited national parks in South Africa before and after the conferences (Figures 6-9). The assistance of Karen Salter of Destination Alliance in coordinating the tourist excursions is gratefully acknowledged.

At the opening ceremony, several dignitaries addressed the participants: David Davidson, Chair of the Local Organizing Committee; Doug Rawlings, as the representative of Stellenbosch University; Roberto Graglia, Chair of the Organizing Committee; Steven Best, President of the IEEE Antennas and Propagation Society; Peter Staecker, President-Elect of IEEE; Paul Lagasse, Secretary General of URSI; and George Uslenghi, Chair of the Scientific Committee (Figures 10-13).

At the gala dinner held at the Pigalle Restaurant in downtown Cape Town, the Young Scientist Best Paper Award was given. It consisted of a certificate and a monetary prize of 8,000 Rand. The awards committee, composed of Matthys Botha, Ludger Klinkenbusch, Paul Smith, Alexander van Deursen, and Don Wilton, selected the winner – among entrants aged less than thirty-six – on the basis of originality, clarity, and timeliness of the contribution. There were a number of outstanding entries from young scientists. The winner was Kynthia K. Stavrakakis of the Technische

Figure 14. The Young Scientist Best Paper Award ceremony at the gala dinner: (l-r) Roberto Graglia, George Uslenghi, Kynthia Stavrakakis, David Davidson, Paul Lagasse, Matthys Botha, and Steven Best.

Figure 15. Kynthia Stavrakakis with her award.

Figure 16. Amor and David Davidson at the gala dinner.

Figure 17. Per-Simon Kildal at the gala dinner.

Universität Darmstadt, Germany, for her paper entitled, "Fast Parameter Sweeps for the Calculation of *S* Parameters in Electromagnetic Field Simulations," coauthored with T. Wittig, W. Ackermann, and T. Weiland (Figures 14-20).

Figure 18. Prabhakar Pathak and Giuliano Manara at the gala dinner.

Figure 20. Hisamatsu Nakano (center) "holding court" at the gala dinner.

The three conferences owe a large debt of gratitude to the Local Organizing Committee: David Davidson as Chair, Matthys Botha as his right-hand and co-Chair, Keith Palmer as Treasure), Sam Clarke and Robert Kellerman Industrial Exhibits and Sponsorship, Suné van Rooyen and Nelda Rousseau of CONSULTUS in the Secretariat, and their colleagues, for their hard work in preparing and running a magnificent event.

Figure 19. At the gala dinner: (foreground, l-r) Giulia and Cinzia Graglia with Shelly Uslenghi; (background, l-r) Silvia Manara, Matthys Botha, and Paul Smith.

The next edition of ICEAA – IEEE APWC was held at Torino, Italy, September 9-13, 2013. It was in coordination with the first Electromagnetic Metrology Symposium (EMS), organized by Commission A of URSI. The three conferences had a common venue, registration, luncheons, banquet, and social program.

Piergiorgio L. E. Uslenghi
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International Conference on Mobile Communication and Embedded Technology (MECON 2013)

Noida, India, 17 - 18 January 2013

The First International Conference on Mobile Communication and Embedded Technology (MECON 2013) was organized by the Department of Electronics and Communication Engineering at Amity School of Engineering and Technology, Noida (adjoining New Delhi), India, January 17-18, 2013. It was organized in collaboration with the Department of Science and Technology (DST), and technically sponsored by the International Union of Radio Science (USRI).

This conference aimed to set a platform for scientists and academicians to share their experiences and research with the technical fraternity from various walks of life. During the two-day-long conference, students were apprised with the practical know-how shared by industry leaders through various technical sessions that were held, related to the theme of the conference. Figure 1 shows the traditional Indian art welcome to all MECON delegates.

Figure 1. The welcome to MECON 2013 through Indian traditional art.

Over 300 research papers were submitted, out of which 63 papers were accepted by an esteemed panel of reviewers for presentation. Dignitaries and paper presenters from seven different countries, including the Czech Republic, Bangladesh, Italy, the UK, and Malaysia made this conference a truly global experience. MECON 2013, a promising endeavor to reach new technological heights, opened its gates on January 17, 2013, to dignitaries from all over the country and abroad. The keynote speakers were Dr. Vinod Sharma (IISc-Bangalore, India), Dr. Radim Burget (BRNO University, Czech Republic), and Mr. C. S. Rao (President, Reliance Communications, India). Figure 2 shows the dignitaries on the dais during the inaugural session of MECON. Through the invigorating sessions, the conference witnessed speakers presenting new, innovative ideas. The various sessions had a multitude of speakers from India and abroad. There was participation from IIT-D, IIT-M, IIT-Roorkee, over 8 NITs, and several other universities across India.

The topics discussed in the various sessions ranged over "4G," "Wireless Communication," "Technological Advancements in Antennas," "Novel Applications in Embedded Systems," "New Techniques in Instrumentation," "Image Processing and Networking," "Wireless Sensor and Ad Hoc Networks," "Intelligent Embedded Systems, etc. Such ground-breaking sessions would not have been possible without speakers of national and international repute.

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Figure 2. The inauguration session of MECON 2013.

Report on MSMW 2013, TERATECH 2013 and CCWS 2013

The Eighth International Kharkov Symposium On Physics and Engineering of Microwaves, Millimeter, and Sub-Millimeter Waves (MSMW 2013)

Workshop on Terahertz Technologies and Radio-Spectroscopy of Complex Media (TERATECH 2013)

Workshop on Complex Conductivity and Wave Symmetry of Fe-Based Superconductors (CCWS 2013)

Kharkov Ukraine, 24 - 28 June 2013

The MSMW 2013 symposium took place at the V. N. Karazin Kharkov National University, Ukraine on June 24-28, 2013. It was organized by the Scientific Council of the National Academy of Sciences of Ukraine (NASU) on Radio-Physics and Microwave Electronics, in cooperation with the following organizations:

- A. Usikov Institute of Radio-Physics and Electronics of NAS of Ukraine (IRE NASU)
- Institute of Radio Astronomy of NAS of Ukraine (IRA NASU)
- V. Karazin Kharkov National University (KhNU)
- Kharkov National University of Radio-Electronics (KhNURE)
- Institute of Magnetism of NAS and Ministry of Education and Science of Ukraine (IM NASU and MESU)
- Young Scientists Council of IRE NASU
- IEEE AP/MTT/ED/AES/GRS/NPS/EMB Societies East Ukraine Joint Chapter
- IEEE IRE-Kharkiv Student Branch and associated AP-S, ED-S and MTT-S Student Chapters
- National URSI Committee of Ukraine

It was technically cosponsored by the IEEE Microwave Theory and Techniques Society and URSI, and sponsored by the IEEE AES/AP/ED/GRS/MTT/NPS Societies East Ukraine Joint Chapter, the IEEE AP and MTT Societies, and the European Microwave Association (EuMA).

The working days of the symposium were June 25-27. Every day the program started with a plenary session of five or six 30-minute invited lectures in a large auditorium. After that, three or four parallel day-long sessions of 15-minute contributed papers were presented. The working language of the symposium was English. June 27 and 28 were filled in with social events. The number of registered participants was 164, including 124 from Kharkov; 27 from the rest of Ukraine; 32 from Russia; two each from Germany, France, and Japan; nine from Mexico; one each from China, Sweden, USA, Italy, Czech Republic, Turkey, Taiwan, and Australia; four from the United Kingdom; and three from Belarus. The total number of papers presented during the symposium was about 213, included 28 invited papers.

Figure 1. The MSMW 2013 Organizing Committee.

Figure 2. The MSMW 2013 opening ceremony. The Chair, Prof. Vladimir M. Yakovenko, addressed the participants with opening words.

A CD-ROM version of the MSMW 2013 proceedings was prepared before the symposium. The MSMW 2013 symposium program contained papers submitted by worldwide-known experts in microwaves and shorter-wavelength science and technology, so participation in the symposium became a unique experience for Ukrainian participants. The holding of the symposium became possible thanks to the support of its sponsors: the IEEE AES/AP/ED/GRS/MTT/NPS Societies East Ukraine Joint Chapter, the IEEE IRE-Kharkiv Student Branch and associated AP-S, ED-S, and MTT-S Student Chapters, the IEEE AP and MTT Societies, the European Microwave Association (EuMA), as well as efforts of the traditional founders and organizers of MSMW (Figure 1). The European Microwave Association donated a special grant for the funding of the EuMA-MSMW Microwave Prizes, awarded to the young scientists who presented outstanding papers during the symposium.

As was done three years ago for MSMW 2010, this year, the Workshop on Terahertz Technologies and Spectroscopy of Complex Media (TERATECH 2013) was organized in the framework of the MSMW'2013 symposium, in the format of a special session. We strongly hope that it had a remarkable impact on the ongoing and future R&D in this novel area. This is fully in line with the traditionally strong emphasis placed by the MSMW program on millimeter and sub-millimeter-wave physics and technology. This extremely captivating and challenging area of nanophysics and nanoelectronics, considered the key technology of the current century, was also included in the agenda of the workshop.

Taking into account the urgency of the problem and many requests from participants and research organizations, the MSMW 2013 Organizing Committee also decided to organize the Workshop on Complex Conductivity and Wave Symmetry of Fe-Based Superconductors (CCWS'13) as a special session in the framework of the MSMW 2013.

June 24

June 24 was the day of symposium registration, for meeting and settling of participants. A tour of the city was also organized for symposium participants.

June 25

MSMW 2013 started at 9:00 am on June 25, 2013, with the opening ceremony in the Sinelnikov Room auditorium

Figure 3a, Photo 3b. The plenary session

Figure 4. Discussion in the session "Wave propagation, radar, remote sensing and signal processing"

of the Kharkov National University. The first to address the participants was MSMW 2013 Chair and Director of IRE NASU, Vice Chair of the Ukrainian National URSI Committee, Prof. Vladimir M. Yakovenko (Figure 2). He was followed by the welcoming words of Prof. Nokolai A. Azarenkov, Vice-Rector of Kharkiv National University. The next to make a welcoming speech was Dr. Kostyantyn Ilyenko (IRE NASU), who spoke in the name of the IEEE AP/MTT/ED/AES/GRS/NPS Societies East Ukraine Joint Chapter, as previous Chair.

The first morning plenary session (Figures 3a, 3b) consisted of five invited talks:

- "Tamm States and Variety of their Analogs in Electrodynamics," S. Tarapov and D. Belozorov, Kharkov, Ukraine
- "Development of High-Frequency Gyrotrons in FIR FU Covering Sub-THz to THz Range for Applications to High-Power THz Spectroscopy," Toshitaka Idehara and Svilen P. Sabchevski, Fukui-shi, Japan
- "A New Effective Modal Method by B-Splines Expansion for Crossed Surface-Relief Gratings," G´erard Granet, Clermont-Ferrand, France
- "Control of Electromagnetic Waves in Metamaterials: From Microwaves to Optics," Yuri Kivshar, Canberra, Australia
- "Powerful Free-Electron Masers with Novel Bragg Resonators," N. Peskov, N. Ginzburg, A. Sergeev, A. Arzhannikov, S. Sinitsky, A. Kaminsky, and S. Sedykh, N. Novgorod, Russia

Furthermore, after a lunch, the symposium continued working with four simultaneous sessions:

Session WT: "Workshop on Terahertz Technologies and Spectroscopy of Complex Media"

Session A: "Electromagnetic Theory and Numerical Simulation"

Figure 5. Prof. V. O. Nichiporenko, University of Nizhny Novgorod (Russia), and Prof. Toshitaka Idehara, University of Fukui (Japan)

Session C: "Wave Propagation, Radar, Remote Sensing and Signal Processing" (Figure 4)

Session G: "Scientific, Industrial and Biomedical Applications"

In session WT, the following invited paper was presented:

- "Modern Resonator Spectroscopy at Sub-mm Wavelengths," V. Parshin, M. Tretyakov, M. Koshelev, and E. Serov, N. Novgorod, Russia.

In session G, the following invited papers were presented:

- "Millimeter Waves for Determination of Composition of Biodisel Fuel," V. Meriakri, E. Chigryai, M. Parkhomenko, R. Denisyuk, and S. V. von Gratowski, Fryazino, Russia
- "Towards Microwave and Millimeter-Wave Biosensors," N. Klein, T. H. Basey-Fisher, W. J. Otter, N. Guerra, C. Triulzi, A. Gregory, S. M. Hanham, and S. Lucyscyn, London, United Kingdom
- "Microdosimetry and Physiological Effects of Millimeter-Wave Irradiation in Isolated Neural Ganglion Preparation," S. Romanenko, V. Pikov, P. H. Siegel, Pasadena, USA

Later that evening, at 7:00 pm, a welcome party was organized at the university restaurant. At the welcome party, Ukrainian sparkling wine was served. This event created a perfect atmosphere to relax and shake off the troubles of the long and sometimes tiring journeys that participants had to undertake to reach MSMW 2013 (Figure 5).

June 26

At the plenary session, the following invited papers were presented (Figure 6):

Figure 6. Prof. Dmitro M. Vavriv of IRA NAS (Ukraine) told about problems of the interactions of high-frequency and low-frequency oscillations

- "Spin-Torque Microwave Detectors: Fundamentals and Applications," O. Prokopenko, G. Melkov, V. Tiberkevich, and A. Slavin, Kyev, Ukraine

- "Tunable Metamaterial Structures for Controlling THz Radiation," Mikhail Odit, Irina Vendik, Dmitry Kozlov, Irina Munina, and Viacheslav Turgaliev, Saint-Petersburg, Russia

- "Engineering Low-Cost THz Technologies for Ubiquitous Applications," S. Lucyszyn, London, United Kingdom

- "Developments of Microwave HTS-Based Devices and Subsystems for Applications in Civilian Satellites," Y. Wu, L. Sun, C. Li, X. Zhang, Q. Zhang, J. Wang, Y. Bian, T. Yu, B. Cui, G. Li, H. Li, and Y. He, Beijing, China

- "Interaction of High-Frequency and Low-Frequency Oscillations: Threats and Benefits," V. Buts and D. Vavriv, Kharkov, Ukraine

- "High-Harmonic THz Gyrotrons and Gyro-Multipliers," I. Bandurkin, V. Bratman, A. Fedotov, Yu. Kalynov, A. Savilov, N. Novgorod, Russia

That day, regular sessions of contributed papers consisted of:

Session J: "Microwave Superconductivity"
Session B: "Microwave Solid State Physics and Applications"
Session D: "Vacuum Electronics"
Session H: "R-Functions, Atomic Functions, Wavelets, Fractals"
Session WS: "Workshop on Complex Conductivity and Wave Symmetry of Fe-Based Superconductors"

In session D, the following invited papers were presented:

- "Development and Experimental Investigation of High Power THz Gyrotrons," M. Glyavin, A. Luchinin, and M. Morozkin, N. Novgorod, Russia

- "Techniques of Non-Collinear Electro-Optic Sampling for Efficient Detection of Pulsed Terahertz Radiation," M. Tani, T. Kinoshita, T. Nagase, S. Ozawa, S. Tsuzuki, D. Takeshima, E. Estacio, K. Kurihara, K. Yamamoto, and M. Bakunov, Fukui, Japan

- "Medium Power Compact Sources of Electromagnetic Radiation in Millimeter and Sub-Millimeter Ranges," A. Kuleshov and B. Yefimov, Kharkov, Ukraine

In session H the following invited papers were presented:

- "Correlation Functions Interpolation by Generalized Kravchenko-Kotelnikov Sampling Series," V. Kravchenko and D. Churikov, Moscow, Russia

- "Novel Methods in Denoising, Resolution Enhancement, and Object Reconstruction of Multidimensional Signals and Objects," V. Ponomaryov, Mexico, Mexico

In session WS the following invited papers were presented:

- "Complex Electronic Structure of Iron-Based Superconductors as a Key to High-Temperature Superconductivity," A. Kordyuk, Kyiv, Ukraine

- "Tunneling into Two-Band Superconductors: The Case of Magnesium Diboride and Fe-Based Superconductors," M. Belogolovskii, P. Sidel, Donetsk, Ukraine

- "Pseudogap in SmFeAsO (0.85) in Comparison with S-Wave Symmetry Theories," A. Solovjov, V. Svetlov, V. Stepanov, S. Sidorov, V. Tarenkov and A. D'yachenko, Kharkov, Ukraine

- "Microwave Response, Complex Conductivity and Effect of Order Parameter Symmetry in Fe-Based Superconductors," N. Cherpak, A. Barannik, Y.-S. He, R. Prozorov, and M. Tanatar, Kharkov, Ukraine.

After the sessions, all the participants were invited to enjoy the concert provided by Ukrainian folk instruments Ensemble "CimBanDo & Co" of the Department of Folk Instruments of the Kharkov State Academy of Culture. They were winners of awards at Ukrainian and international competitions (Figure 7).

Figure 7. Concert for the MSMW'13 participants present the teachers ensemble "CimBanDo & Co" of the Department of folk instruments of the Kharkov State Academy of Culture

Figure 8. Dr. Mikhail V. Balaban, member of Organizing Committee, is awarding the EuMA Young Scientist Third Prize to Sergey Ponomarenko

That evening, the symposium banquet was held at the university restaurant. This was a lovely event, accompanied with live music, dancing, and informal speeches. However, the dominant tone was the joy of meeting old friends and colleagues, and making new friends.

June 27

Two parallel sessions of regular papers that day went along the following topics:
Session E: "Microwave and mm-Wave Engineering"
Session F: "Radio Astronomy and Study of the Earth Environment"

In session E, the following invited paper was presented:

- "A Low-Phase-Noise GaAs FET/BJT Voltage-Controlled Oscillator for Microwave Applications," V. Ulansky and S. Ben Suleiman, Kyev, Ukraine

On the third day, the plenary session was as follows:

- "Resonant Cherenkov Type Radiation in Dispersive Metamaterials," P. Melezhik, A. Poyedinchuk, N. Yashina, and G. Granet, Kharkov, Ukraine
- "Atomic Functions and Generalized Thue Morse Sequence in Digital Signal and Image Processing," W. Hilberg, V. Kravchenko, O. Kravchenko, and Y. Konovalov, Moscow, Russia

The closing ceremony of MSMW2013 took place in the Sinelnikov Room of KhNU at 15:30. At first, the winners of the Young Scientist Paper Contest were awarded with the EuMA-MSMW prizes and certificates (Figure 8). This year, the European Microwave Association established a 1000 Euro fund to be awarded to the winners of the Young Scientist Paper Contest. This was divided into six prizes: one first prize, two second prizes, and three third prizes. The international awards jury consisted of five members: N. T. Cherpak, Kharkov, Ukraine; T. Idehara, Fukui, Japan; J. Niemeyer, Braunschweig, Germany; S. Lucyszyn, London, UK; Y. He, Beijing, China; and M. Balaban, Kharkov, Ukraine.

The First Prize was awarded to Aleksey A. Girich, "Transmission and Reflection of Electromagnetic Waves from Ferrite-Semiconductor Periodic Multilayered Structures," IRE NASU, Kharkov, Ukraine. Two Second Prizes were awarded to Mikhail A. Odit, "Tunable Metamaterial Structures for Controlling THz Radiation," St. Petersburg Electrotechnical University, St. Petersburg, Russia; and

Ivan A. Smirnov, "Spectroscopy of the Ground, First and Second Excited Torsional States of Acetaldehyde from 0.05 to 1.6 THz," IRA NASU, Kharkov, Ukraine. Three Third Prizes were awarded to Sergey Romanenko, "Microdosimetry and Physiological Effects of Millimeter Wave Irradiation in Isolated Neural Ganglion Preparation," California Institute of Technology, Huntington Medical Research Institutes Pasadena, USA; Irina. A. Protsenko, "Accurate Permittivity Characterization of Liquids by Means of WGM Resonator with Microfluidic," IRE NASU, Kharkov, Ukraine; and Viktor A. Sydoruk, "Advanced Microwave Near-Field Technique for Investigation of Material Properties," Forschungszentrum Jülich, Jülich, Germany. The certificates of the EuMA-MSMW prizes, signed by Prof. Dr.-Ing Wolfgang Heinrich, President of the European Microwave Association, and Prof. Vladimir M. Yakovenko, MSMW 2013 Chair, were handed to the winners.

The final closing address was given by Prof. Vladimir M. Yakovenko. He announced that the next symposium, MSMW 2016, will again be held in Kharkov in June, 2016. He thanked the participants and organizers for creating an unprecedented forum for scientific discussions, and expressed hope that the MSMW symposia series will be continued. He also expressed gratitude to the international institutions, such as the IEEE, URSI, and EuMA, which rendered valuable and timely support.

The Young Scientist Prize from the Ukrainian Physical Society for the best paper presentation was awarded to Mikhail V. Balaban, "Electromagnetic Wave Scattering by a Graphene-Sandwiched Thin Dielectric Disk Analyzed Using the Generalized Boundary Conditions," IRE NASU, Kharkov, Ukraine.

June 28

In order to relax after four days of intensive work, and to strengthen the links originated at the symposium, an outdoor activity was organized for participants. Nice weather and the hospitality of the hosts helped finish the symposium agenda.

Prof. Vladimir M. Yakovenko
MSMW 2013 Chair
Dr. Alexey Kostenko
MSMW 2013 Organizer
E-mail: msmw13@ire.kharkov.ua

URSI CONFERENCE CALENDAR

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

October 2013

Microwave Signatures 2013 - Specialist Symposium on Microwave Remote Sensing of the Earth, Oceans, and Atmosphere
Espoo (Helsinki), Finland, 28-31 October 2013
Contact: Contact: Prof. Martti Hallikainen, Aalto University, School of Electrical Engineering, Department of Radio Science and Engineering, E-mail: info.frs2013@ursi.fi, http://frs2013.ursi.fi/

OCOSS 2013 - Ocean and Coastal Observation Sensors and Observing Systems, Numerical Models and Information Systems
Nice, France, 28-31 October 2013
Contact: Ms. M. Dechambre, LATMOS, Quartier des Garennes, 11, Bd des Garennes, F-78280 Guyancourt, France, E-mail: monique.dechambre@latmos.ipsl.fr, http://2013.ocoss.org/

November 2013

First COSPAR Symposium - Planetary Systems of our Sun and other Stars, and the Future of Space Astronomy
Bangkok, Thailand, 11-15 November 2013
Contact:Geo-Informatics and Space Technology Development Agency, Ratthaprasasanabhakti Bdg 6th and 7th Floor, Chaeng Wattana Road, Lak Si, Bangkok 10210, THAILAND, E-mail:cospar2013@gistda.or.th, http://www.cospar2013.gistda.or.th

December 2013

4th International Colloquium on Scientific and Fundamental Aspects of the Galileo Programme
Prague, Czech Republic, 4-6 December 2013
Contact: ESA Conference Bureau, PO Box 299, NL-2200 AG Noordwijk, Netherlands, Fax: +31 (0) 71 565 6558, E-mail: esa.conference.bureau@esa.int, http://www.congrexprojects.com/2013-events/13c15/introduction

ICMAP 2013 - International Conference on Microwaves and Photonics
Dhanbad, India, 13-15 December 2013
Contact: http://icmap2013.org, http://icmap2013.org/

January 2014

RCRS 2014 – Regional Conference in Radio Science
Pune, India, 2-5 January 2014
Contact: Prof. Akshay Malhotra, Deputy Director, SIT, Pune, Symbiosis Institute of Technology (SIT), Symbiosis International University, Tel : +91 20 39116300, 6404 / 6407, e-mail: rcrs2014@sitpune.edu.in, http://www.sitpune.edu.in/abstract_submission_form.php

URSI National Radio Science Meeting
Boulder, Colorado, USA, 8-11 January 2014
Contact: Prof. Steven C. Reising, Director of Microwave Systems Laboratory, Colorado State University, 1373 Campus Delivery, Fort Collins, CO 80523-1373, USA, Fax: +1-970-491-2249, Email: steven.reising@colostate.edu, http://www.nrsmboulder.org/

VERSIM-6 - Sixth VERSIM Workshop
Dunedin, New Zealand, 20-23 January 2014
Contact: Prof. Craig J. Rodger, Department of Physics, University of Otago, PO Box 56, Dunedin 9016, NEW

ZEALAND, Fax: +64 3 479 0964, E-mail: crodger@physics.otago.ac.nz, http://www.physics.otago.ac.nz/versim/VERSIM_workshop_Dunedin_2014.html

April 2014

RADIO 2014 - Radio and Antenna Days of the Indian Ocean 2014
Flic-en-Flac, Mauritius, 7-10 April 2014
Contact: Conference Secretariat RADIO 2012, University of Mauritius, Réduit, Mauritius, Fax: +230 4656928, E-mail: radio@uom.ac.mu, http://sites.uom.ac.mu/radio2012/

May 2014

EMC'2014 - 2014 International Symposium on Electromagnetic Compatibility
Tokyo, Japan, 13-26 May 2014
Contact: E-mail: emc14-contact@mail.ieice.org, http://www.ieice.org/~emc14/

June 2014

EUSAR 2014 – 10th European Conference on Synthetic Aperture Radar
Berlin, Germany, 2-6 June 2014
Contact: Mr. Jens Fischer (DLR), EUSAR 2014 Executive, Oberpfaffenhofen, 82234 Wessling, Germany, Fax: +49 8153-28-1449, E-mail: eusar2014@dlr.de, http://conference.vde.com/eusar/2014

August 2014

COSPAR 2014 ("COSMOS")
40th Scientific Assembly of the Committee on Space Research (COSPAR) and Associated Events
Moscow, Russia, 2-10 August 2014
Contact: COSPAR Secretariat, c/o CNES, 2 place Maurice Quentin, 75039 Paris Cedex 01, France, Tel: +33 1 44 76 75 10, Fax: +33 1 44 76 74 37, cospar@cosparhq.cnes.fr, http://www.cospar-assembly.org/

ICEAA 2014 - International Conference on Electromagnetics in Advanced Applications
Palm Beach, Aruba, 3-9 August 2014
Contact: Prof. P.L.E. Uslenghi, Dept. of ECE (MC 154), University of Illinois at Chicago, 851 So. Morgan St., Chicago, IL 60607-7053, USA, E-mail: uslenghi@uic.edu, http://www.iceaa.net/

URSI GASS 2014 - XXXIst General Assembly and Scientific Symposium of the International Union of Radio Science
Beijing, China CIE, 16-23 August 2014
Contact: URSI Secretariat, Sint-Pietersnieuwstraat 4, B-9000 Ghent, Belgium, E-mail: info@ursi.org, http://www.chinaursigass.com and http://www.ursi.org

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/

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

Deadline Extended to November 4, 2013

EuCAP 2014

8TH EUROPEAN CONFERENCE ON ANTENNAS AND PROPAGATION

6-11 APRIL 2014
THE WORLD FORUM,
THE HAGUE, THE NETHERLANDS

WELCOME

The BENELUX Antenna & Propagation Community welcomes EuCAP 2014 to The Hague, situated on the North Sea Coast, close to Amsterdam Schiphol Airport.

EuCAP 2014 is the 8th European Conference on Antennas & Propagation organised by the European Association on Antennas and Propagation (EurAAP) since 2006. The previous successful editions took place in Nice, Edinburgh, Berlin, Barcelona, Rome, Prague and Gothenburg. The average attendance is around 1000 delegates.

EuCAP is supported by the top level Associations in Antennas and Propagation, thus fostering true collaboration at European and global levels. AMTA will support the organisation of the Exhibition, provide special AMTA sessions, and cooperate in the application tracks.

SCOPE OF THE CONFERENCE

To provide a forum on the major challenges faced by the Antenna, Propagation and Measurement communities with the aim of fostering exchange of ideas between experts in their respective fields. Contributions from European and non-European industries, organisations, universities and institutions are solicited. This conference will provide an overview of the current state-of-the-art in the field, highlighting the latest developments and innovations required for future applications.

FORMAT OF THE CONFERENCE

The conference combines the following formats:

- Plenary sessions with invited keynote speakers
- Oral sessions (both convened and regular)
- Posters (presented in the same central area as the exhibition)
- Short Courses & Workshops
- Exhibition

Organised by

EurAAP

Supporting Associations

U.R.S.I. · IEEE · IET The Institution of Engineering and Technology · AMTA · APS

Important Deadlines

- **Submission of Abstracts**

Deadline Extended to November 4, 2013

- **Submission of Final Papers**
  17 January 2014

ABSTRACT SUBMISSION

AAuthors are kindly invited to submit their abstract by 13 October 2013. The on-line submission form is available via the conference website.

APPLICATION TRACKS

EuCAP 2014 will feature a session track focussing on applications. This will increase interaction between academia and industry. During abstract submission, authors will be invited to allocate their contributions to one or more applications, enabling the formation of application tracks in the final program. Contributions not targeting a particular application will be allocated to regular sessions all along the week.

SHORT COURSES & WORKSHOPS

In the spirit of the previous EuCAP editions, EuCAP 2014 will also provide a series of short courses and workshops. Those interested are invited to submit a firm proposal for a Course before August 20th, 2013.

EXHIBITION & SPONSORSHIP

EuCAP 2014 will provide ample opportunities for exhibitors and sponsors. Contact the conference service provider for further information and floor plans.

Contact

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ICEAA - IEEE APWC

August 3-9, 2014 **Palm Beach, Aruba**

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ICEAA 2014
International Conference on Electromagnetics in Advanced Applications

IEEE APWC 2014
IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications

The sixteenth edition of the International Conference on Electromagnetics in Advanced Applications (ICEAA 2014) is supported by the Politecnico di Torino, by the University of Illinois at Chicago, by the Istituto Superiore Mario Boella and by the Torino Wireless Foundation, with the principal cosponsorship of the IEEE Antennas and Propagation Society and the technical cosponsorship of the International Union of Radio Science (URSI). It is coupled to the fourth edition of the IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications (IEEE APWC 2014). The two conferences consist of invited and contributed papers, and share a common organization, registration fee, submission site, workshops and short courses, and social events. The proceedings of both conferences will be published on IEEE Xplore.

Suggested Topics for ICEAA

Adaptive antennas
Complex media
Electromagnetic applications to biomedicine
Electromagnetic applications to nanotechnology
Electromagnetic education
Electromagnetic measurements
Electromagnetic modeling of devices and circuits
Electromagnetic packaging
Electromagnetic properties of materials
Electromagnetic theory
EMC/EMI/EMP
Finite methods
Frequency selective surfaces
Integral equation and hybrid methods
Intentional EMI
Inverse scattering and remote sensing
Metamaterials
Optoelectronics and photonics
Phased and adaptive arrays
Plasma and plasma-wave interactions
Printed and conformal antennas
Radar cross section and asymptotic techniques
Radar imaging
Radio astronomy (including SKA)
Random and nonlinear electromagnetics
Reflector antennas
Technologies for mm and sub-mm waves

Suggested Topics for APWC

Active antennas
Antennas and arrays for security systems
Channel modeling
Channel sounding techniques for MIMO systems
Cognitive radio
Communication satellite antennas
DOA estimation
EMC in communication systems
Emergency communication technologies
Indoor and urban propagation
Low-profile wideband antennas
MIMO systems
3.5G and 4G mobile networks
Multi-band and UWB antennas
OFDM and multi-carrier systems
Propagation over rough terrain
Propagation through forested areas
Radio astronomy (including SKA)
RFID technologies
Signal processing antennas and arrays
Small mobile device antennas
Smart antennas and arrays
Space-time coding
Vehicular antennas
Wireless mesh networks
Wireless security
Wireless sensor networks

ICEAA - IEEE APWC 2014
PALM BEACH, ARUBA 3-9 August 2014

Information for Authors

Authors must submit a full-page abstract electronically by March 7, 2014. Authors of accepted contributions must submit the full paper, executed copyright form and registration electronically by June 6, 2014. Instructions are found on the website. Each registered author may present no more than two papers. All papers must be presented by one of the authors.

Deadlines

Abstract submission	March 7, 2014
Notification of acceptance	April 11, 2014
Full paper and presenter registration	June 6, 2014

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Information for authors

Content

The *Radio Science Bulletin* is published four times per year by the Radio Science Press on behalf of URSI, the International Union of Radio Science. The content of the *Bulletin* falls into three categories: peer-reviewed scientific papers, correspondence items (short technical notes, letters to the editor, reports on meetings, and reviews), and general and administrative information issued by the URSI Secretariat. Scientific papers may be invited (such as papers in the *Reviews of Radio Science* series, from the Commissions of URSI) or contributed. Papers may include original contributions, but should preferably also be of a sufficiently tutorial or review nature to be of interest to a wide range of radio scientists. The *Radio Science Bulletin* is indexed and abstracted by INSPEC.

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