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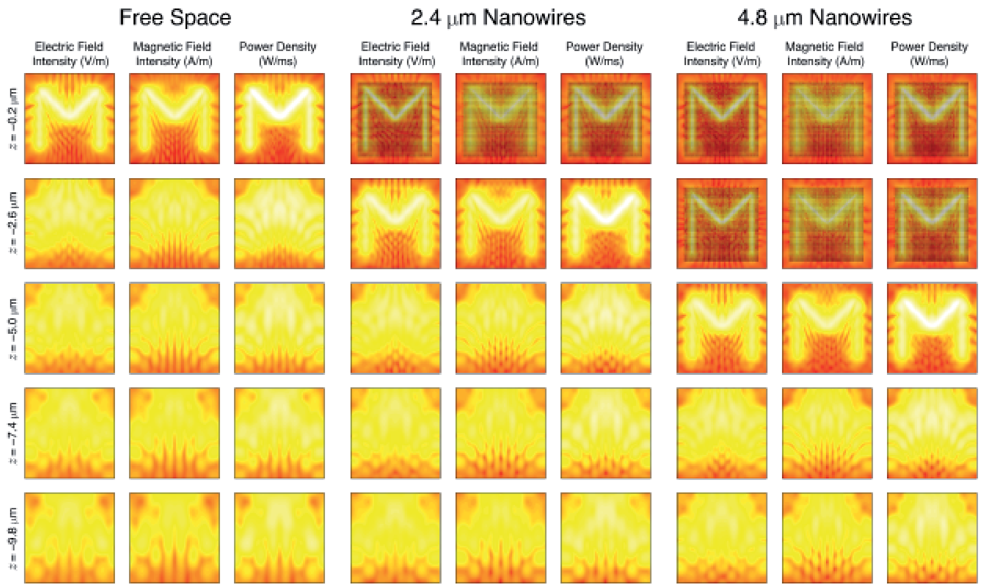

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Contents

Cover: The near-zone electric-field intensity, magnetic-field intensity, and power density along wire arrays consisting of nano-wires that were 2.4 µm and 4.8 µm in length, in comparison to free space radiation. The arrays and the free-space case were excited by an arrangement of Hertzian dipoles in the shape of an "M" operating at 250 THz. Each row of plots shows the values in a plane at the indicated distance from the plane of the array. The arrays transmit the shape of the pattern significantly further than do the dipoles by themselves. See the Solution Box column by Barışcan Karaosmanoğlu and Özgür Ergül.

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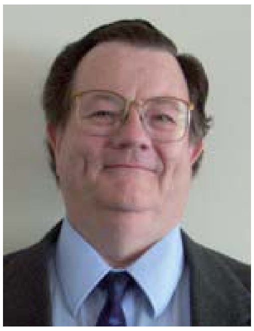

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URSI 2017 GASS Submission Deadline: January 30, 2017

The deadline for submission of Extended Abstracts or Summary Papers for the XXXIInd URSI General Assembly and Scientific Symposium (GASS), to be held August 19-26, 2017, in Montréal, Québec, Canada, is **January 30, 2017**. This is also the deadline for submitting entries to the Student Paper Competition, and for requesting Young Scientist support. The Web site at www.URSI2017.org is now accepting submissions. This is going to be a wonderful meeting in an outstanding location. You should submit your paper(s) *now!*

The Radio Science Bulletin on IEEE Xplore!

Starting in 2017, all material published in the *Radio Science Bulletin* will be abstracted, indexed, and appear on IEEE Xplore as open-access material (available without a subscription). This will include all future issues, as well as all previous issues back to the September 2002 issue. This will provide much wider exposure for material published in the *Bulletin*. The *Radio Science Bulletin* will continue to publish papers without page charges or an author processing fee.

The journal *Radio Science*, published by the American Geophysical Union, is also now available on IEEE Xplore (by subscription or access fee). This includes previous issues back to 1966.

Our Papers

The high-frequency (HF, 3 MHz to 30 MHz) band has played an important role in communications for a very long time, and continues to do so today. Because the wavelengths are so large, practical HF antennas are almost always electrically small. Such antennas are often difficult to match over wide bandwidths. Furthermore, the external background noise in the HF band is high. These factors combine to make the optimization of the receiving properties of electrically small HF antennas challenging. In his paper, Steven Best discusses the properties of such antennas, and presents formulas that can be used to optimize these receiving properties. Several important results are derived as part of this. It is shown that optimizing the small HF antenna's receiving performance is directly related to optimizing the antenna's impedance match and radiation efficiency, independently of the specific design of the antenna. It is shown that because impedance matching of such an antenna for receiving and transmitting differ, optimizing for noise figure is often more important than impedance matching. Design examples for electrically small dipole, loop, and multi-turn loop antennas are given. The paper is written in such a manner that anyone with a basic understanding of antennas should find it both interesting and useful. The concepts are potentially useful for electrically small antennas regardless of frequency.

The leap second is a topic that has recently resulted in some discussion in radio science and other areas. Issues associated with the leap second can have significant implications for systems as diverse as global navigation, financial transactions, and the operation of the Internet. In his invited paper, Judah Levine provides an excellent overview of the basic issues associated with the leap second, and discusses some of the approaches being considered to address those issues. The paper begins with a review of the definitions of time, time interval, and frequency. The problem with apparent solar time is explained. Mean solar time is introduced, and its limitations are explored. The cesium second, and its impact on time measurement and specification, are described. The adoption of Coordinate Universal Time (UTC), the two major problems associated with it, and the use of the leap second to try to address those problems, are described. The paper concludes with a summary of some of the proposals currently being considered to address the issues associated with the leap second. I think you will find this a fascinating and very readable discussion of the leap second and the issues surrounding it.

Our Other Contributions

In the Early Career Representative's Column, Stefan Wijnholds brings us the second in a two-part series of columns dealing with academic publishing. The contribution in this issue, by Stefan Wijnholds, Ross Stone, and Phil Wilkinson, deals with ethical issues in academic publishing. This includes issues affecting authors, reviewers, and editors. I urge you to read this: I think you will find it useful.

In his Ethically Speaking column, Randy Haupt and his daughter, Amy Shockley, discuss the Golden Rule and the Platinum Rule. Which is the more appropriate to use, and in what situation, are interesting questions.

Özgür Ergül's Solution Box has a new solution – but a better solution is sought. Barışcan Karaosmanoğlu and Özgür Ergül describe the use of large arrays of metallic nano-wires as transmission lines to carry electromagnetic patterns along distances long with respect to the wavelength. In this case, the wires were 2.4 μm and 4.8 μm long, and the excitation frequency was 250 THz. The arrays were very large in terms of wavelengths and numbers of elements. Using the electric-field integral equation and solving the discretized problem using the Multi-Level Fast Multipole Algorithm resulted in solutions, but required a relatively long computational time. The solutions obtained are interesting, but a more efficient solution method is sought.

James Lin's Telecommunications Health and Safety column takes a critical look at the five-year, US$25 million US-government-led project that has recently reported occurrences of two types of rare cancers in laboratory rats exposed to radio-frequency (RF) radiation used for wireless mobile-phone operations. He examines various aspects of the background, organization, proposal process, funding, reporting of results, and individuals involved in the project. Interesting questions are raised.

In her Women in Radio Science column, Asta Pellinen-Wannberg brings us the story of the career of Margaret Campbell-Brown, told in her own words. She began doing radar studies of meteors, and now combines work on radar fluxes of meteor showers with optical observations of meteors. She shares some important lessons for women considering or active in careers in radio science.

This issue contains a large number of reports on conferences for which URSI has provided either technical or financial sponsorship. These reports are a good way to share in the highlights of conferences you weren't able to attend. There are also calls for papers for several important new conferences.

As is traditional for the *Radio Science Bulletin*, this December issue contains a directory of those who are members of the various Commissions and committees that make up URSI at the international level.

A New Year

This issue will reach you near the start of the new year. My very best wishes for a most happy, healthy, safe, and prosperous New Year. Now, go submit a paper to the XXXIInd URSI General Assembly and Scientific Symposium (GASS) before the January 30, 2017 deadline!

Ross

Announcement of URSI Individual Membership

The URSI Board of Officers is pleased to announce the establishment of Individual Fellowship (FURSI), Membership (MURSI), and Individual Associate Membership (AMURSI). By joining URSI, Individual Associate Members, Members, and Fellows secure recognition with their peers, are better connected to URSI Headquarters, and are better connected to their National Committees. Each can then better provide support to the other. Other benefits include discounted registration fees at URSI conferences (beginning with the 2018 URSI AT-RASC) and at some conferences cosponsored by URSI (beginning with some conferences run by IEEE AP-S), a certificate of membership, and e-mail notification of the availability of the electronic edition of the URSI *Radio Science Bulletin*.

Fellowship is by invitation only. Associate and Membership are by application through the URSI Web site at www.ursi.org, where details of the scheme and criteria for membership can also be found. Those interested are urged to visit the Web site and apply.

Paul Cannon
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Please note that the URSI Secretariat

has moved to a new address

since15 March 2016:

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URSI 2017 GASS

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

Union Radio Scientifique Internationale

August 19-26, 2017 Montréal, Québec, Canada

Announcement and Call for Papers

The XXXIInd General Assembly and Scientific Symposium (GASS) of the International Union of Radio Science (Union Radio Scientifique Internationale: URSI) will be in Montréal. The XXXIInd 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.gass2017.org**

Submission Information

All papers should be submitted electronically via the link provided on the GASS Web site: http://www.gass2017.org. Please consult the symposium Web site for the latest instructions, templates, and sample formats. Accepted papers that are presented at the GASS may be submitted for posting to IEEE Xplore if the author chooses.

Important Deadlines: Paper submission: January 30, 2017
Acceptance Notification: March 20, 2017

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 paper submissions for the GASS, please contact the URSI Secretariat: gass@ursi.org
For all questions related to registration and attendance at the GASS, please see the GASS2017 Web site:

www.gass2017.org

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 (2017) 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, including 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 Web site used for the submission of abstracts/papers via **http://www.gass2017.org**. The deadline for paper submission for the URSI GASS2017 in Montréal is **30 January 2017**.

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 1 May 2017 on the URSI Web site.

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 and the GASS 2017 Web site at http://www.gass2017.org.

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

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Optimizing the Receiving Properties of Electrically Small HF Antennas

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Abstract

Because of the large operating wavelength, receiving antennas in the high-frequency (HF: 3 MHz to 30 MHz) operating band are often electrically small. It is well known that electrically small antennas generally exhibit low radiation efficiency, and are difficult to match over wide bandwidths. In the HF band, external background noise is high, and receiving systems are ideally designed to ensure that the system remains externally noise limited. In this paper, we discuss the properties of the general, electrically small, receiving antenna. We present formulas that can be used to determine, characterize, and compare the performance of the general, electrically small, receiving antenna. We demonstrate that optimization of the small HF antenna's receiving-performance parameters, such as its receiving sensitivity and noise figure, are directly a function of optimizing the antenna's impedance match and radiation efficiency, independently of whether a dipole, monopole, or loop-like design is utilized. We demonstrate that impedance matching for the receiving antenna is often a secondary consideration. We illustrate differences in an antenna's matching-network transfer function for the receiving mode versus the transmitting mode. We present formulas and design guidelines for optimizing the receiving system's noise figure and signal-to-noise ratio performance. Finally, we present design examples for an electrically small dipole, loop, and multi-turn loop.

1. Introduction

The HF band has been in use almost since the beginning of radio communication. For many decades, HF has been used in long-range military communications, amateur radio, and long-range over-the-horizon radar (OTHR) [1-3]. More recently, HF is being used in applications such as radio-frequency identification (RFID), and higher-data-rate communications, such as HF multiple-input multiple-output (MIMO) [4, 5]. While these applications use both transmitting and receiving antennas, this paper presents a discussion on optimizing the performance properties of the general, electrically small, HF receiving antenna.

We begin with a discussion of the properties of the general receiving antenna from the equivalent-circuit perspective. Formulas are presented for the open-circuit voltage at the receiving antenna's feed-point terminal. These formulas are subsequently used to derive expressions for the receiving sensitivity of the general antenna.

Section 2 of the paper presents a background discussion on the basic properties of the electrically small dipole and multi-turn loop, which are commonly used as receiving antennas in the HF band. Design formulas for characterizing the small antenna's radiation resistance, loss resistance, and therefore the radiation efficiency are presented. In Section 3 of the paper, we derive several expressions for the receiving sensitivity of the small multi-turn loop, as well as for the general receiving antenna. We show that the receiving sensitivity of the electrically small antenna can be expressed in terms of any of the electromagnetic (EM) wave's constituent parameters: power density, electric field, magnetic field, electric-flux density, or magnetic-flux density, independently of whether the antenna is a dipole or loop-like design.

In Section 4 of the paper, we discuss impedance-matching considerations for the receiving antenna. We illustrate that impedance matching is a secondary consideration, as a matching network designed from the transmitting perspective may not improve the antenna's performance for receiving. In Section 5 of the paper, we discuss external noise, noise figure, and signal-to-noise ratio (*SNR*) for a typical receiving system. We present formulas and design guidelines that aid in optimizing system performance from a signal-to-noise ratio perspective. Finally, we present design examples for electrically small dipole and loop antennas, comparing their performance in a typical receiving system.

We note that in the derivations and formulas that follow in this paper, we have assumed that the values of

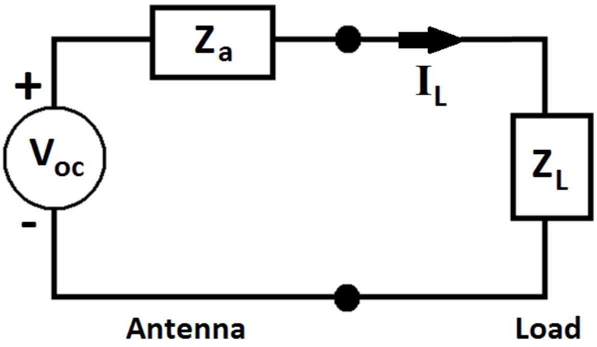

Figure 1. A depiction of the equivalent circuit of the general receiving antenna.

voltage (V), current (I) and field strength (E and H) are peak values, rather than rms values. As a result, power and power-density formulas are written in the form of $1/2|I|^2 R$ and $1/2|E|^2/120\pi$, rather than $|I|^2 R$ and $|E|^2/120\pi$, respectively.

2. The General Receiving Antenna

In recent years, there have been many papers in the literature that focused on specific designs of electrically small antennas in general, as well as specifically on HF antennas (e.g., [6-9]). HF-antenna papers have generally presented the performance properties of a specific antenna design, but they have often not considered the optimization of the HF antenna's performance within its operating environment, nor do they usually consider how the antenna properties affect the performance of the overall HF system. It is well understood that HF antennas operate in complex and noisy EM environments, and that the HF antenna's performance is established by the antenna's design, as well as by the interactions with the platform on which it is installed (vehicle, ship, aircraft, etc.), which often becomes the dominant radiator. Furthermore, to accurately characterize the HF antenna's performance, the details of the RF grounding system and antenna interactions with the Earth ground must also be considered. These issues are often beyond the scope of an antenna-design paper, because they are difficult to characterize, and they are dependent on the specific details of the antenna's installation.

When optimizing the performance properties of transmitting antennas – particularly those that are electrically small – antenna engineers primarily focus on impedance matching, matched impedance bandwidth, and radiation efficiency. With electrically small antennas, the directivity pattern and polarization properties are oftentimes secondary considerations. With the general receiving antenna, the impedance match and radiation efficiency also ultimately determine how well the antenna's performance is optimized. However, there are some subtleties to consider that are unique to the receiving antenna. These include the fact that impedance-matching considerations are different for the receiving antenna, and that the receiving system's performance is ultimately established by the signal-to-noise ratio at the detection point in the receiver.

In this section of the paper, we briefly review the electromagnetic and circuit perspectives of the receiving properties of the general antenna. We discuss the most general equivalent circuit of the receiving antenna and the determination of received power as functions of the incident EM wave properties: power density, P_d ($\mathrm{W/m^2}$); electric-field strength, E ($\mathrm{V/m}$); and magnetic-field strength, H ($\mathrm{A/m}$).

The power received by the general antenna, P_r, is given by [10, 11]

$$P_r = P_d \, \tau \, \eta_r \frac{\lambda^2 D}{4\pi}, \tag{1}$$

where λ is the operating wavelength, η_r is the antenna's radiation efficiency, D is the antenna's directivity in the direction of the incident EM wave, and τ is the receiving antenna's mismatch loss. τ is given by

$$\tau = \frac{4R_a R_L}{|Z_a + Z_L|^2}, \tag{2}$$

where Z_a is the antenna's impedance, Z_L is the load impedance connected at the antenna's feed point, R_a is the antenna's resistance (including both the radiation, R_r and loss, R_l, resistances), and R_L is the load resistance.

To determine received power using circuit theory, we begin with the Thevenin equivalent circuit for the general receiving antenna shown in Figure 1. For the purposes of determining received power, this equivalent circuit is valid for all antennas. The important consideration is the correct determination of the Thevenin circuit's open-circuit voltage.

For an antenna operating in frequency regions near its series resonance (resonance), where the radiation and loss resistances are in series, the open-circuit voltage is given by [11]

$$|V_{oc}| = \frac{|E|\lambda}{\pi}\sqrt{\frac{R_r D}{120}} = \frac{|E|\lambda}{\pi}\sqrt{\frac{\eta_r R_a D}{120}}. \tag{3}$$

For an antenna operating in frequency regions near its parallel resonance (anti-resonance), where the radiation and loss resistances are in parallel, the open-circuit voltage is given by [11]

$$|V_{oc}| = \frac{|E|\lambda}{\pi}\sqrt{\frac{\eta_r{}^2 R_r D}{120}} = \frac{|E|\lambda}{\pi}\sqrt{\frac{\eta_r R_a D}{120}} . \qquad (4)$$

When expressed in terms of the antenna's total feed-point resistance rather than the radiation resistance, both formulas are identical. For electrically small antennas, where expressions for the antenna's radiation resistance can be derived and where the directivity approaches a value of approximately 1.5, Equations (3) and (4) can be further simplified and written in terms of the antenna's physical dimensions. Additionally, we note that while Equations (3) and (4) are written in terms of the incident electric-field strength, they can also be written in terms of the incident power density, magnetic-field strength, electric-flux density, or magnetic-flux density, using the well-known relationships among these quantities. This will be discussed in greater detail in subsequent sections.

From Figure 1, the antenna's received power can be found from

$$P_r = \frac{1}{2}|I_L|^2 R_L , \qquad (5)$$

where I_L is given by

$$I_L = \frac{V_{oc}}{Z_a + Z_L} . \qquad (6)$$

We note that Equations (5) and (1) yield identical results.

3. The Electrically Small Dipole and Loop

The most fundamental antenna elements that can be used as HF receiving antennas are the electrically small straight-wire dipole and circular loop, shown in Figure 2. The straight-wire dipole has an overall conductor length *l*, and the circular loop has a conductor length (circumference) *C*, and an area *A*. We note that the monopole antenna is commonly used as an HF receiving antenna, as well. We do not explicitly discuss the performance of the monopole, since its behavior is similar to that of the dipole.

The dipole and loop are electrically small for values of ka less than 0.5 [12], where *k* is the free-space wavenumber, $2\pi/\lambda$, and a is the radius of a sphere circumscribing the maximum dimension of the antenna. As the value of ka decreases, the radiation resistances of the dipole and the loop approach zero, and are given by [10]

$$R_{rd} \approx 20\pi^2 \left(\frac{l}{\lambda}\right)^2 , \qquad (7)$$

and

$$R_{rl} \approx 320\pi^4 N^2 \left(\frac{A}{\lambda^2}\right)^2 , \qquad (8)$$

respectively. *N* is the number of turns in the loop. We note that Equation (8) is valid for electrically small loops of any geometry.

A comparison of Equations (7) and (8) reveals several important facts about the relative performance of electrically small dipoles and loops. The dipole's radiation resistance diminishes as $1/\lambda^2$, whereas the loop's radiation resistance diminishes as $1/\lambda^4$. For this reason, a loop antenna having the same conductor length as a dipole will be substantially less efficient than the dipole. However, that does not preclude the use of the loop as an effective receiving antenna, since, as seen in Equation (8), the radiation resistance, and therefore its efficiency, can be increased by increasing the number of turns. When adding turns, the loop's loss resistance increases by *N*, whereas its radiation resistance increases by N^2. The radiation resistance and efficiency of the small loop can be further increased by winding the loop's turns on a ferrite core. When the loop's turns are wound on a ferrite core, the loop's radiation resistance becomes [10]

$$R_{rl} \approx 320\pi^4 \mu_{cr}{}^2 N^2 \left(\frac{A}{\lambda^2}\right)^2 . \qquad (9)$$

μ_{cr} is the effective relative permeability of the core, given by

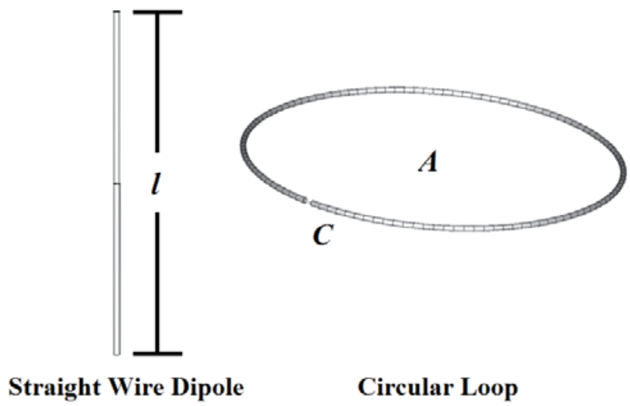

Figure 2. Depictions of the straight-wire dipole having an overall length, *l*, and the circular loop having a conductor length, *C*, and area, *A*.

$$\mu_{cr} = \frac{\mu_{fr}}{1 + D_m \left(\mu_{fr} - 1 \right)}, \qquad (10)$$

where μ_{fr} is the relative permeability of the unbounded ferrite, and D_m is the demagnetization factor, which is related to the core's geometry. The value of μ_{fr} is generally taken to be the relative permeability of the ferrite material provided by the manufacturer. The value of D_m varies with the core's geometry. For a cylindrical core with length, $2l$, greater than its radius, a, D_m can be approximated by the value of D_m of an ellipsoid, given by [10]

$$D_m = \left(\frac{a}{l} \right)^2 \left[\ln\left(\frac{2l}{a} \right) - 1 \right], \quad l \gg a. \qquad (11)$$

Another advantage of the electrically small receiving loop is that the magnitude of its reactance is generally much smaller than that of the dipole. The electrically small dipole typically has a high value of capacitive reactance, making it relatively difficult to tune, because this generally would require a large series variable inductor. The loop antenna typically has a low inductive reactance, which makes tuning relatively easy with a variable series capacitor. Oftentimes, small multi-turn, ferrite-core loops are used as simple receiving antennas for the reasons discussed above. Their performance properties will be discussed in more detail in a subsequent section.

The radiation resistances of the electrically small loop and dipole often approach zero, and are therefore a small component of their total feed-point resistance. To determine the antenna's total resistance and radiation efficiency, it is necessary to determine its loss resistance. This can often be estimated by the conductor's length and its dc resistance per unit length.

The loss resistance of an electrically small dipole having a conductor diameter, d, is approximated by [13, 14]

$$R_{le} \approx \frac{l\rho}{3\pi d\delta} \approx \frac{l}{3\pi d}\sqrt{\frac{kc\mu_0\rho}{2}}, \qquad (12)$$

where ρ is the resistivity of the wire, and μ_0 is the permeability of free space. In Equation (12), the skin depth, δ, in the conductor is assumed to be somewhat less than $d/2$. For δ somewhat greater than $d/2$, the loss resistance of the electrically small dipole can be approximated as

$$R_{le} \approx \frac{2l\rho}{\pi d^2}. \qquad (13)$$

To obtain the approximation of loss resistance in Equation (12), we assume that the current has a triangular dependence over the length of the conductor, and that the current density decays exponentially from its value at the surface of the conductor.

The loss resistance of the electrically small, multi-turn circular loop of radius r can be approximated as

$$R_{lm} \approx \frac{2Nr\rho}{d\delta} \approx \frac{2Nr}{d}\sqrt{\frac{kc\mu_0\rho}{2}}. \qquad (14)$$

For an arbitrarily shaped loop of area A, Equation (14) can be written as

$$R_{lm} \approx \frac{2N}{d}\sqrt{\frac{kc\mu_0\rho A}{2\pi}}. \qquad (15)$$

For δ somewhat greater than $d/2$, the loss resistance of the small circular loop can be approximated as

$$R_{lm} \approx \frac{8N\rho}{d^2}\sqrt{\frac{A}{\pi}}. \qquad (16)$$

Here, we assume that the current does not vary around the loop, and that the current density decays exponentially from its value at the surface of the wire.

The final points we make in this section are with regard to the general EM receiving behavior of the electrically small dipole and loop. The electrically small dipole is often referred to as an electric-dipole, because it exhibits the fundamental-mode radiation pattern of a simple dipole from low frequencies ($ka \ll 0.5$) through its first natural resonance. The loop antenna is often referred to as a magnetic-dipole, because it is assumed to exhibit the fundamental-mode radiation pattern of a magnetic-dipole. At very small values of ka, ($ka \ll 0.5$), the loop will exhibit the radiation pattern of a magnetic-dipole. As ka starts to approach values above 0.1, the null in the direction of the loop's axis degrades, and the magnetic-dipole pattern will no longer hold.

Another and perhaps more significant point relates to the responses of the dipole and loop to incident electromagnetic fields. The dipole is often presumed to sense or detect the electric field, and the loop is often presumed to sense or detect the magnetic field. In the case of an incident far-field EM wave, the dipole and loop both respond to the electric and magnetic fields. Performance properties, such as received power, open-circuit voltage, receiving sensitivity, etc., can be written in terms of the electric field, magnetic field, electric-flux density, and magnetic-flux density for both the dipole and loop. This will be illustrated in subsequent sections.

4. Receiving Sensitivity

One of the common parameters used to characterize the effectiveness of a receiving antenna is its receiving sensitivity. This is defined as the minimum strength of the incident EM wave that results in a received power equal to the thermal noise in 1 Hz of bandwidth, $k_b T_0$, where k_b is Boltzmann's constant, and T_0 is typically taken as the Nyquist temperature, 290K [15].

For the general receiving antenna, the sensitivity is oftentimes derived using the circuit diagram of Figure 1, the received power of Equation (5), and the appropriate choice of field quantity. We note that sensitivity can be defined in terms of the incident power density, electric-field, magnetic-field, electric-flux density, or magnetic-flux density for both the electrically small dipole and loop.

A common approach with the multi-turn, electrically small, air-core loop is to begin with the following expression for the open-circuit voltage [10]:

$$V_{oc} = j2\pi fNAB \,, \tag{17}$$

where f is the operating frequency and B is the incident magnetic-flux density (Tesla). In Equation (17), we assume that the magnetic-field lines are normal to the loop axis (the incident EM wave is co-polarized with the loop).

Assuming that the multi-turn loop is conjugate matched to the receiving system ($X_L = -X_a$ and $R_L = R_a$), the power delivered to the receiving system is given by $1/2\left|I_L\right|^2 R_a$, where $\left|I_L\right| = \left|V_{OC}\right| / (2R_a)$. Setting the received power equal to $k_b T_0$ and substituting Equation (17) for V_{OC}, the receiving sensitivity, S (in units of $\mathrm{T}/\mathrm{Hz}^{1/2}$) can be expressed as

$$S_B = \frac{\sqrt{2R_a k_b T_0}}{\pi fNA} \,, \tag{18}$$

where R_a, the antenna's resistance, is the sum of the radiation and loss resistances. For many electrically small loop antennas, R_a can simply be approximated by the loss resistance. We note that for the ferrite-core loop, the open-circuit voltage becomes $V_{oc} = j2\pi f \mu_{cr} NAB$, and μ_{cr} is added to the denominator of Equation (18) to determine its sensitivity. The sensitivity of the ferrite-core loop improves in direct proportion to the effective core permeability, μ_{cr}.

To express the sensitivity of the air-core loop in terms of the EM wave's other field quantities, we simply express the open-circuit voltage in terms of the appropriate field quantity. The commonly used expression for the open-circuit voltage of the electrically small, multi-turn, air-core loop is given in Equation (17) as a function of magnetic-flux density. Given the constituent relationships $B = \mu H$, $\left|E/H\right| = 120\pi$, and $P_d = 1/2\left|E\right|^2 / 120\pi$, we can write the open-circuit voltage, and therefore the receiving sensitivity, in terms of E, H, and P_d. Substituting Equation (8) into Equation (3) and assuming an electrically small antenna directivity of 1.5, we can express the open-circuit voltage of the multi-turn, air-core loop in terms of the electric field and magnetic field as

$$\left|V_{oc}\right| = kNAE \tag{19}$$

and

$$\left|V_{oc}\right| = k120\pi NAH \,, \tag{20}$$

respectively. We note that Equations (19) and (20) will yield the same result as Equation (17) for the magnitude of the open-circuit voltage.

Following the method used to arrive at Equation (18), the sensitivity of the multi-turn, air-core loop can be expressed (in units of $(\mathrm{V/m})/\mathrm{Hz}^{1/2}$) as

$$S_E = \frac{\sqrt{8R_a k_b T_0}}{kNA} \,. \tag{21}$$

The receiving sensitivities as expressed in Equations (18) and (21) provide some insight into how the physical properties of the multi-turn, air-core loop improves with an increase in the number of turns and the loop area. Increasing the number of turns and increasing the loop area improves sensitivity. We note that the results of Equations (18) and (21) differ by the relationships of the constituent parameters of the incident EM wave.

While these expressions are valuable in understanding the design of the small multi-turn loop, they do not provide insight into how the sensitivity of the electrically small loop compares to other electrically small antennas, such as a dipole or a monopole. Furthermore, these expressions were derived assuming the receiving system was conjugate matched to the loop's impedance. Knowing that mismatch and ohmic loss degrade a receiving antenna's sensitivity, we desire a formula for receiving sensitivity expressed in terms of mismatch and ohmic loss that is valid for the general, electrically small receiving antenna.

We start by deriving the sensitivity, S_E, using the form of Equation (3) containing the total feed-point resistance, R_a. This yields a received sensitivity (in units of $(\mathrm{V/m})/\mathrm{Hz}^{1/2}$), valid for the general receiving antenna, expressed as

$$S_E = k\sqrt{\frac{240 k_b T_0}{\eta_r D}}. \tag{22}$$

While Equation (22) is valid for the general, electrically small receiving antenna, we note that Equation (21) will only be valid for the multi-turn loop provided that $D = 1.5$, and Equation (8) is an accurate approximation of the radiation resistance of the loop. For the general electrically small antenna, where $D = 1.5$, Equation (22) becomes

$$S_E = k\sqrt{\frac{160 k_b T_0}{\eta_r}}. \tag{23}$$

Given the relationship among received power and mismatch and ohmic loss, Equation (23) can be modified to include mismatch loss as follows:

$$S_E = k\sqrt{\frac{160 k_b T_0}{\tau \eta_r}}. \tag{24}$$

A similar derivation holds for expressing the receiving sensitivity of the general electrically small antenna in units of $(\mathrm{A/m})/\mathrm{Hz}^{1/2}$. In this case, the sensitivity is expressed as

$$S_H = k\sqrt{\frac{k_b T_0}{90\pi^2 \tau \eta_r}}. \tag{25}$$

An alternate approach to deriving an expression for receiving sensitivity for any antenna is to begin with Equation (1), which is an expression of received power in terms of mismatch loss, radiation efficiency, and directivity. Setting the received power to $k_b T_0$, the general antennas' receiving sensitivity (in units of $\left(\mathrm{W/m^2}\right)/\mathrm{Hz}^{1/2}$) is expressed as

$$S_P = \frac{4\pi k_b T_0}{\lambda^2 \tau \eta_r D}. \tag{26}$$

There are two significant points regarding the general receiving antenna discussed in this section. The first is the fact that all receiving antennas respond to both the incident electric and magnetic fields. The dipole does not respond only to the electric field and the loop does not respond only to the magnetic field. As a result, performance characteristics, such as received power, open-circuit voltage, and receiving sensitivity, can be expressed in terms of any of the EM wave's properties. Finally, the most important point is the recognition that the absolute and relative performance of any electrically small antenna are simply determined by its mismatch loss and radiation efficiency. Optimizing the receiving performance of any antenna is a function of optimizing the antenna's impedance match and radiation efficiency. This will be illustrated and discussed in more detail in the following sections.

Figure 3. A depiction of the 15-turn air-core loop modeled in *NEC*. The loop had a diameter of 5.08 cm and an overall length of 1 cm.

5. The Multi-Turn Air-core Loop

To validate the discussion and results of the previous sections, we consider the multi-turn air-core loop. Specifically, we consider the electrically small, 15-turn loop shown in Figure 3. The loop had a diameter of 5.08 cm (2 in), an overall length of 1 cm (2.54 cm), and was wound using a copper conductor having a diameter of 0.5 mm (0.02 in). The performance of this antennas was modeled

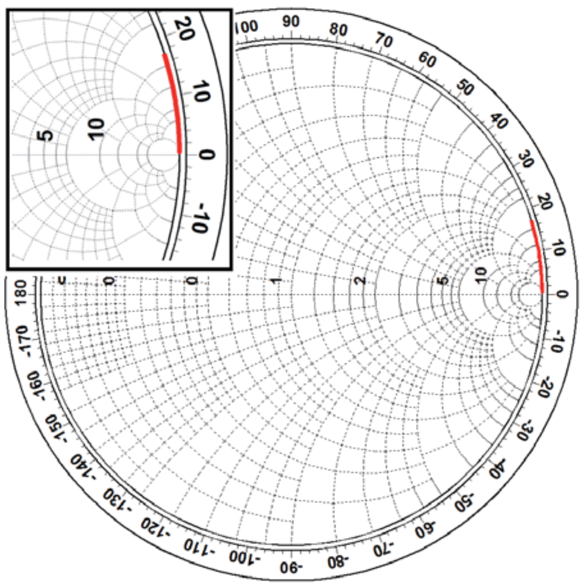

Figure 4. The feed-point impedance of the 15-turn loop antenna. The frequency range was 3 MHz to 30 MHz.

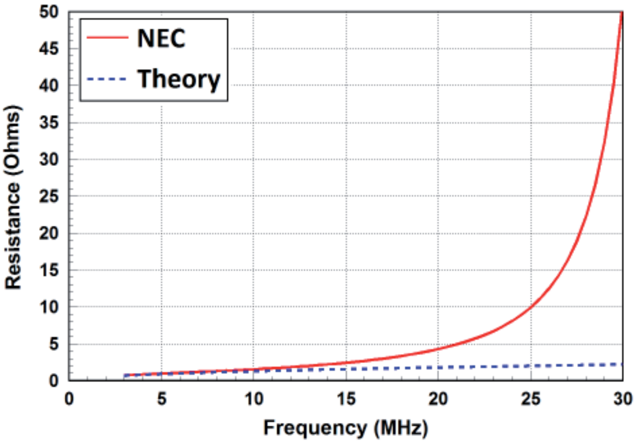

Figure 5. The feed-point resistance of the 15-turn loop antenna.

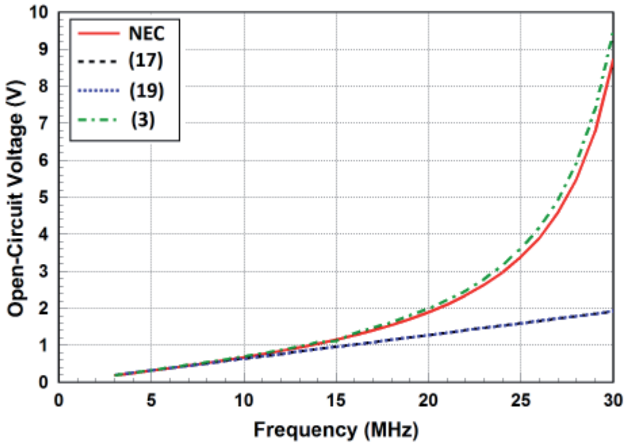

Figure 6. The open-circuit voltage at the feed point of the 15-turn loop antenna.

using the *Numerical Electromagnetics Code* (*NEC*) [16], and the results were compared to the theory presented in the previous sections.

The modeled impedance of the air-core loop is presented in Figure 4. As expected, the total resistance (radiation plus loss) was small, and the reactance varied with frequency as a function of the loop's inductance. The frequency range was 3 MHz to 30 MHz. One of the significant points to note from the Smith chart was the fact that with the 15-turn loop, the upper operating frequency closely approached the loop's first natural resonance. This was an anti-resonance, where the resistance was very large and the radiation and loss resistances were in parallel, rather than being in series. The change in inductance with increasing turns within a loop antenna, which causes the antenna to approach anti-resonance, is even more enhanced when the loop is wound on a ferrite core. For the multi-turn loop, operating near the anti-resonant frequency has a significant impact on the validity of the electrically small approximations for radiation resistance, loss resistance, open-circuit voltage, and sensitivity. These approximations become invalid with an electrically small loop operating near anti-resonance.

The simulated and theoretical resistances and open-circuit voltages are presented in Figures 5 and 6, respectively. The theoretical resistance was calculated from the sum of the radiation-loss resistances using Equations (8) and (15). At low frequencies, where the loop was electrically small, and well away from anti-resonance, theory and simulation were in excellent agreement. We note that at these frequencies, the conductor-loss resistance dominated. Near the anti-resonant frequency, the theoretical approximations were invalid even though the loop was electrically small.

In Figure 6, we saw similar results for the theoretical open-circuit voltage when the antenna was operated near anti-resonance. While Equation (17) was a commonly used expression for the open-circuit voltage of the multi-turn loop, it was not valid in frequency regions where the radiation resistance of the loop could no longer be approximated by Equations (8) or (9). This can be a significant issue with ferrite-core loops, which have a greater tendency to approach anti-resonance than the air-core loop. The invalidity of Equations (8), (9) and (17) also renders the associated, derived calculations for sensitivity invalid.

We note that Equation (3) provided an excellent approximation of the multi-turn, air-core loop's open-circuit voltage, since it is valid for all receiving antennas provided the antenna's performance properties are well known or characterized. Additionally, sensitivity calculations using Equation (26) remain valid for all receiving antennas. The discrepancy in Figure 6 between Equation (3) and *NEC* at the higher frequencies was a result of degradation in the loop's polarization purity, and the fact that the directivity may have deviated from the assumed value of 1.5.

6. Receiving Impedance Matching

When designing HF transmitting antennas, the exercise of impedance matching is critically important. The antenna's voltage standing-wave ratio (*VSWR*) must be minimized to ensure that the HF transmitter is operating at optimal efficiency, and delivering maximum output power to the transmitting system. An increase in *VSWR* will generally cause the transmitter to reduce its output power, or shut off, so as to protect the internal circuits. HF transmitters generally do not operate well into *VSWRs* much greater than 3:1 or 4:1. When utilizing electrically small antennas, some form of impedance-matching network is generally required to ensure that the *VSWR* requirements are satisfied.

When operating over large frequency bandwidths, the minimization of *VSWR* is oftentimes traded against losses within the matching network or within the antenna's structure (e.g., resistively loading the antenna). The matching-network transfer function (S_{21}) is the product or sum of the mismatch loss and the ohmic losses within

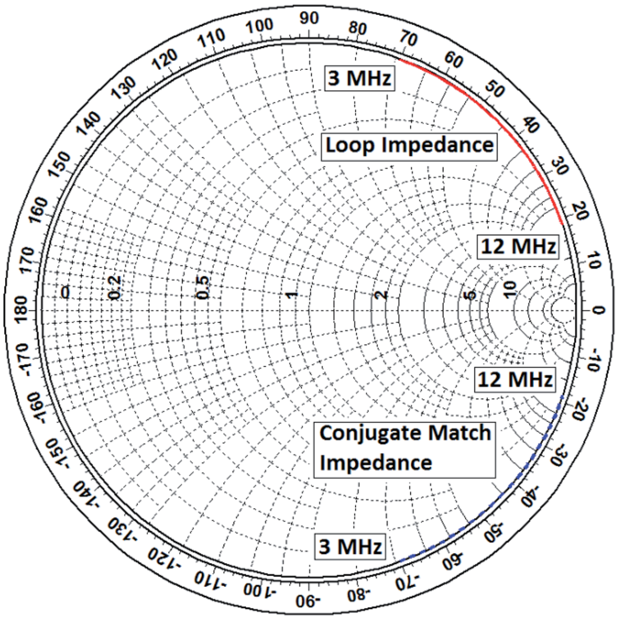

Figure 7. The feed-point impedance of a 1 m diameter circular loop and its conjugate impedance, from 3 MHz to 12 MHz.

the matching-network components. Given a low matched *VSWR*, the frequency response of the S_{21} transfer function is dominated by the network losses. We note that it is theoretically impossible to efficiently impedance match an electrically small antenna over the entire HF band.

For the receiving antenna, the decision to implement an impedance match may be different. Oftentimes, engineers assume that the antenna's *VSWR* equally attenuates signal and external noise, so it does not degrade the receiving system's signal-to-noise ratio. This is true provided the system remains externally noise limited, but this is not always the case. The next section will discuss external noise, *SNR*, and antenna noise figure in more detail. For the remainder of this section, we will defer issues related to the receiving system's *SNR* performance.

We considered the example of a 1-m (39.37 in) diameter circular loop having a conductor diameter equal to 2.63 mm (0.104 in). The feed-point impedance of the loop and its conjugate impedance (3 MHz to 12 MHz), calculated using Equations (8), (15), and a loop inductance value of 3.89 μH, are presented in Figure 7. These results were consistent with impedance calculations using *NEC*.

In order to ideally match ($\tau = 1$) the 1-m-diameter loop to a receiving system, the load impedance at its feed point had to be the conjugate of its feed-point impedance. From Figure 7, we saw that the impedance of the loop traversed the Smith chart clockwise, whereas its conjugate impedance traversed the Smith chart counterclockwise. It is well known that all passive impedances presented on the Smith chart must traverse it in the clockwise direction, thus indicating that implementation of a low-loss, broadband impedance match for the 1-m loop was not possible. This

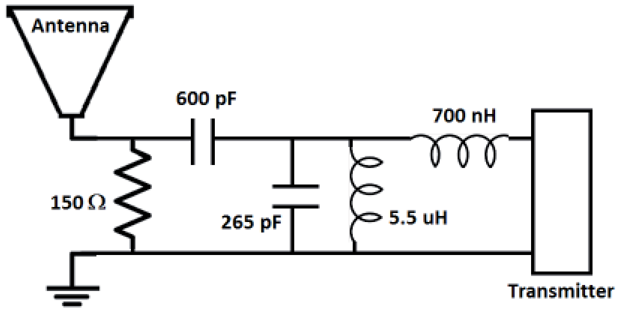

Figure 8. A depiction of the impedance network used to match the impedance of the 1 m diameter loop to a 50 ohm transmitter over the frequency range of 3 MHz to 12 MHz.

fact was consistent with the Chu limit for the quality factor of electrically small antennas and its relationship to matched-impedance bandwidth [17]. A broadband impedance match would require a lossy matching network.

To demonstrate several significant issues associated with impedance matching the receiving antenna, we started from the perspective of the transmitting antenna, where we required the *VSWR* looking from the transmitter into the matching network to be minimized. A lossy matching-network configuration that achieved a broadband match for the 1-m loop is presented in Figure 8. We assumed Q values of 800 and 60 for the capacitors and inductors, respectively. The corresponding input *VSWR* is presented in Figure 9. We saw that the 1-m loop was well matched with a *VSWR* less than 2:1 over the 3 MHz to 12 MHz frequency range.

To illustrate the differences between the matching-network characteristics when used in the transmitting mode versus the receiving mode, we first examined the network transfer function in the transmitting mode. The transfer

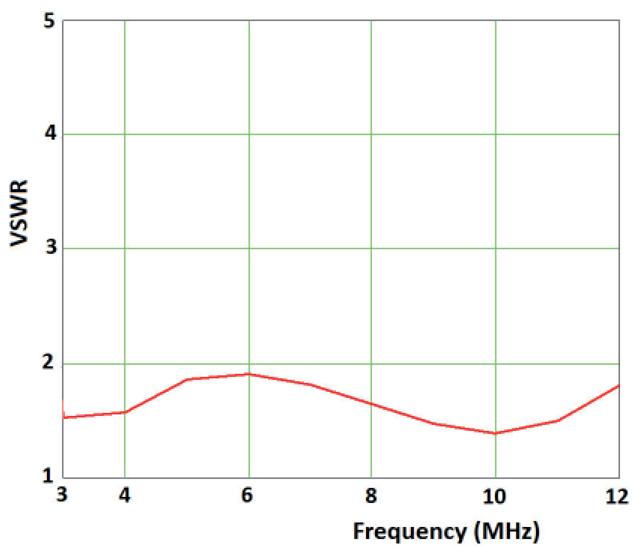

Figure 9. The *VSWR* at the input to the impedance matching depicted in Figure 8.

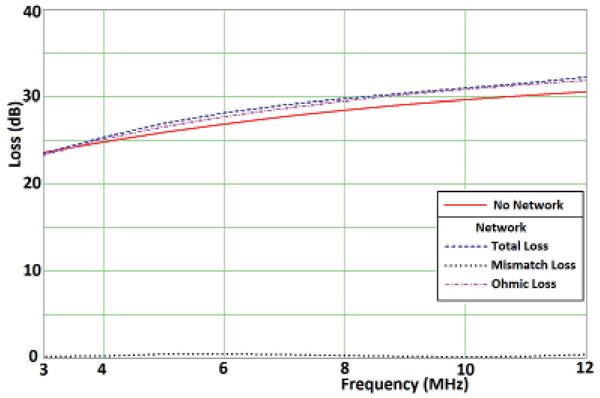

Figure 10. The transmitting mode network losses for the impedance-matching network depicted in Figure 8.

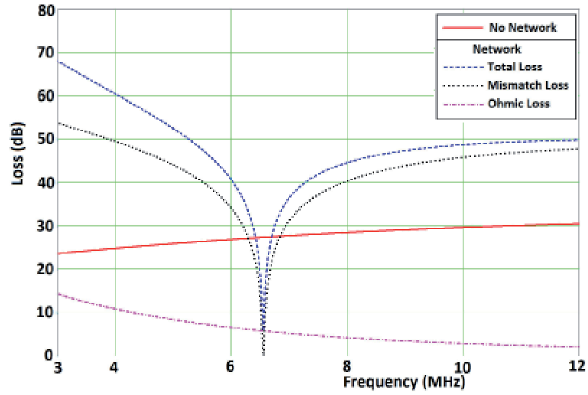

Figure 12. The receiving-mode network losses for an impedance-matching network designed to implement a conjugate match at 6.6 MHz.

function – the network's total power loss between the transmitter and the antenna – is comprised of mismatch loss and ohmic losses. The network losses for the transmitting mode are presented in Figure 10. From Figure 10, we saw that the matching-network transfer function was dominated by the ohmic losses in the network components. Furthermore, while the antenna system was well matched to the transmitter, which delivered most of its power to the network input, the actual power delivered to the antenna was not substantially different than if the antenna was fed without the matching network. In fact, over most of the 3 MHz to 12 MHz frequency range, the total network loss was higher than the total loss with no network.

Next, we examined the matching network's transfer function in the receiving mode, where the antenna was delivering power to a 50-ohm receiver in place of the transmitter. The network losses for the receiving mode are presented in Figure 11. It was interesting to note that while the total network loss was the same as in the transmitting mode (maintaining reciprocity), the network losses were dominated by mismatch loss rather than ohmic losses. In this case, the network losses on receiving were minimal, and may have had little impact on the system's noise performance. In the receiving mode, the load impedance presented to the antenna was close to 50 ohms over the entire operating band, indicating that a receiving-mode matching

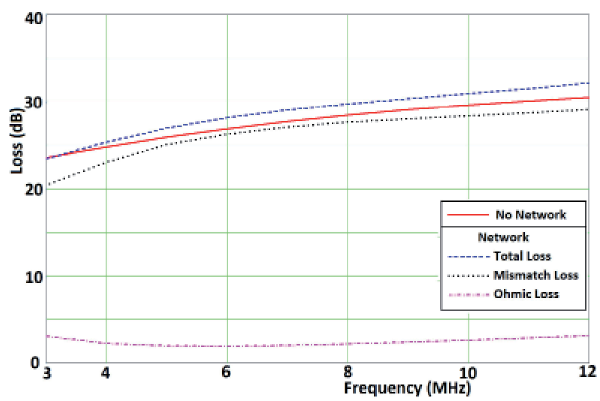

Figure 11. The receiving-mode network losses for the impedance-matching network depicted in Figure 8.

network was of little value in the receiving system. In fact, the receive-mode transfer function (total loss) was higher than if the antenna was directly connected to the 50 ohm receiver. In many instances, particularly for broadband operation, receiving antennas do not necessarily require a matching network.

The next issue we considered is the implication of trying to optimize the receiving-mode impedance match at a single frequency by implementing a conjugate matched load at the antenna's feed point. For this exercise, a matching network was designed to implement a conjugate match at approximately 6.6 MHz. The corresponding network losses for the receiving mode are presented in Figure 12. While we were able to implement a near-perfect match and transfer function at 6.6 MHz, it came at the expense of very poor performance over the remainder of the frequency range. This was consistent with the fact that electrically small antennas have a very high quality factor, and cannot be impedance matched over a very wide operating bandwidth without significant loss.

In the design of the electrically small receiving antenna, it is extremely challenging to minimize the mismatch loss factor, τ, over a reasonable operating bandwidth. Oftentimes, the optimal solution is to simply forgo a matching network. Generally, the best design approach for the receiving system is to characterize the mismatch loss factor as a function of varying resistive load values, and to design to a load resistance that provides minimum mismatch loss over the desired operating band. This will oftentimes require an low-noise amplifier (low-noise amplifier) design or an impedance transformer to transform the 50 ohm receiver impedance to the desired load resistance value.

7. Ground Effects

The nature of HF systems is such that the HF antenna operates over the Earth ground plane, which has a significant impact on the antenna's overall efficiency and radiation pattern. When operating over Earth ground, the overall efficiency of the antenna is diminished as a result of some portion of the delivered power being dissipated in the Earth. A portion of this ground-dissipated power propagates as a ground wave, sometimes over considerable distances. Here, we define the ground-loss efficiency, η_g, a factor that can be added to Equations (1) and (26) to account for the corresponding reduction in received power and the degradation of antenna sensitivity. Equations (1) and (26) become

$$P_r = P_d \tau \eta_r \eta_g \frac{\lambda^2 D}{4\pi} \tag{27}$$

and

$$S_P = \frac{4\pi k_b T_0}{\lambda^2 \tau \eta_r \eta_g D}, \tag{28}$$

respectively.

The determination of the ground-loss efficiency for the general antenna is not trivial. It varies as a function of frequency, ground properties (dielectric constant, ε_r, and conductivity, σ), antenna type (e.g., dipole versus loop), height above ground, and the antenna's orientation relative to the ground. Furthermore, the electrically small antenna's total feed-point resistance may not provide much if any insight into the level of ground loss, as it is often dominated by the copper loss resistance, and therefore does differ significantly over ground relative to the free-space value.

From an engineering design perspective, one of the most reliable methods for estimating ground loss is to use a Method-of-Moments simulation code, such as *NEC*. As examples of typical ground-loss values, we used *NEC* to simulate the efficiency of a dipole and circular loop over ground. Given the variables discussed above, a comprehensive study of ground loss is beyond the scope of this paper.

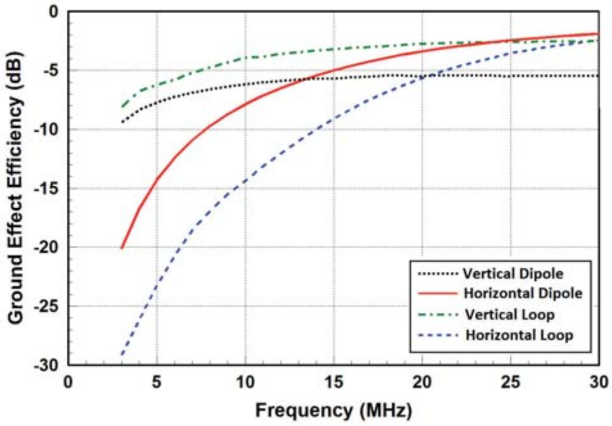

Figure 13. The ground loss efficiencies of the small dipole and loop as functions of frequency and orientation relative to ground.

Here, we considered a 2 m (78.74 in) straight-wire dipole, having a conductor diameter of 5 mm (0.197 in), and a 1 m (39.37 in) diameter loop having a conductor diameter of 5 mm. The antennas were located at a height of 2 m, and were oriented both vertically and horizontally. The ground parameters were taken as average or medium soil with $\varepsilon_r = 13$ and $\sigma = 0.005$ S/m. The ground-effect efficiency for different configurations is presented in Figure 13.

From Figure 13, we saw that ground losses were more severe at low frequencies, and varied considerably as a function of the antenna's orientation relative to ground. Generally, the closer the antenna is to ground, the more severe the ground loss. In optimizing the placement of the electrically small receiving antenna, it is recommended that the antenna be located as high above ground as reasonably possible. Decisions regarding placement and orientation of the receiving antenna must consider the desired polarization and pattern shape, which dramatically vary relative to the well-known free-space patterns of the small loop and dipole. The ground parameters also have a significant effect on ground loss and, if possible, should be accurately estimated or determined to understand their impact on antenna performance.

Another point to note is that the ground-loss effect can be mitigated to some extent with an increase in the antenna's radiation resistance. However, that does not mean to imply that antennas with higher radiation resistance always have

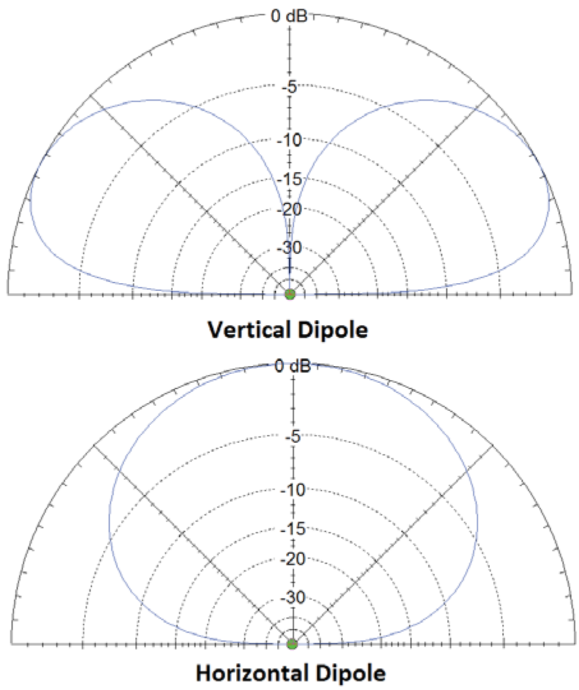

Figure 14. The radiation patterns of the vertical and horizontal 2 m dipole at 7.2 MHz. The antennas were at a height of 2 m above average soil.

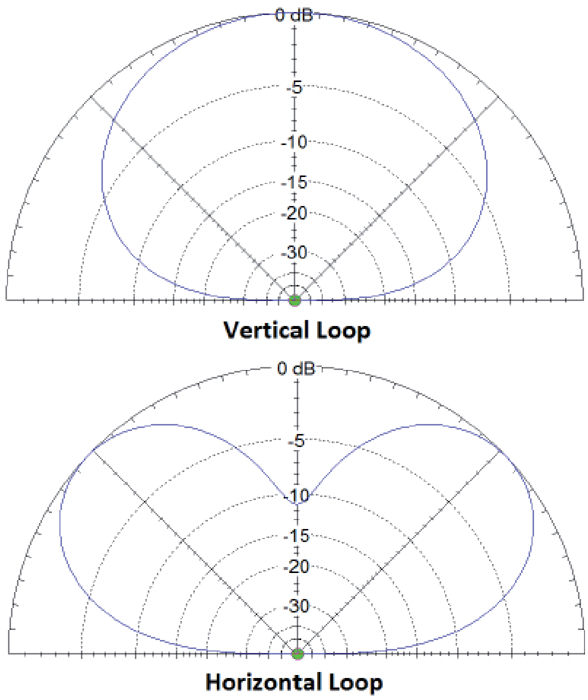

Figure 15. The radiation patterns of the vertical and horizontal 1 m diameter loops at 7.2 MHz. The antennas were at a height of 2 m above average soil.

better ground-loss performance. For example, the 2-m dipole had a much higher radiation resistance than the 1-m loop, but the vertical loop exhibited less ground loss than the vertical dipole. Generally, for the same antenna type (dipole-like or loop-like antennas), an increase in radiation resistance does offer ground-loss improvement. For example, a multi-turn loop with more turns will generally exhibit less ground loss than a similar sized loop with fewer turns.

The other significant effect of the ground is the impact on the small antenna's radiation pattern. To illustrate the significant effect of the ground on the antenna's radiation pattern, we again considered the 2-meter dipole and 1-meter diameter loop. Radiation patterns (elevation sweeps) for the vertical and horizontal dipole and loop are presented in Figures 14 and 15, respectively. The antennas were at heights of 2 m over average soil. The operating frequency was 7.2 MHz.

The radiation patterns of the simple elements over the lossy Earth ground were as expected. The horizontal dipole and vertical loop had the peak of their main beam directed overhead. Both were predominantly omnidirectional. Both responded to (receive) E-theta polarization in one elevation cut and to E-phi polarization in the orthogonal elevation cut. The inherent, bidirectional nulls of the vertical loop appeared at the lower elevations angles, but were not remarkable given that the lossy ground attenuated the far-field pattern at the lower angle. However, the elevation beamwidths were notably different in orthogonal elevation cuts.

The vertical dipole and horizontal loop exhibited omnidirectional radiation patterns with the expected nulls overhead. The vertical dipole responded to predominantly E-theta polarized signals, whereas the horizontal loop responded to predominantly E-phi polarized signals. We emphasize that both the dipole and loop responded to the EM wave, both its electric and magnetic fields. Notwithstanding near-field EM coupling, the idea that the dipole is uniquely an electric-field sensor and that the loop is uniquely a magnetic-field sensor is incorrect.

The radiation patterns at lower frequencies were much like those at 7.2 MHz. The patterns at higher frequencies changed as functions of the electrical size of the antenna and the differences in the electrical height above ground.

Determining the realized gain of the electrically small antenna requires knowledge of the antenna's mismatch loss, radiation efficiency, and ground loss. As expected, many electrically small antennas have very low gain, as will be discussed in subsequent sections.

8. External Noise, Noise Figure, and *SNR*

Prior to our discussion on external noise and signal-to-noise ratio in the HF receiving system, we emphasize that a detailed study of external noise properties, ionospheric propagation, and the propagation of the HF ordinary and extraordinary modes is beyond the scope of this paper. Here, we provide a general discussion on how the antenna's properties impact the *SNR* performance of the general receiving system, as well as methods for determining the system's noise figure and *SNR*.

In any receiving system, one must ensure that there is sufficient *SNR* at the detection point in the receiver in order to establish a successful link between the transmitter and the receiver. The required system *SNR* is a function of the system's waveform, modulation scheme, channel bandwidth, etc. Ultimately, the achieved *SNR* is limited by the noise floor of the receiver.

In low-frequency systems, such as HF, noise contributions to the receiving system are dominated by external background noise, which includes galactic noise, atmospheric noise, lightening, and man-made noise (e.g.,

Table 1. The coefficients for the calculation of the external noise figure.

Environment	*c*	*d*
Business	76.8	27.7
Interstate highway	73	27.7
Residential	72.5	27.7
Park and university campus	69.3	27.7
Rural	67.2	27.7
Quiet rural	53.6	28.6
Galactic noise	52	23

other radios, electrical equipment, motors, power supply noise, improper grounding, etc.). Ideally, we desire the HF system to be externally noise limited, that is, we do not want the internal noise contribution from the receiving system to be significant relative to the noise received or introduced by the antenna.

External noise is often difficult to predict, and varies significantly with the location of the receiving system and near-by manmade noise sources. External noise is generally not isotropic, nor is it necessarily predominant in one polarization. In the HF band, manmade noise often dominates the external noise levels. Noise predictions are often based on models of "typical" noise environments such as "*city*," "*residential*," "*rural*," and "*quiet-rural*," where the external noise figure, F_{am}, is given by [18, 19]

$$F_{am} = c - d\log\left(f\right), \tag{29}$$

where *f* is the frequency in MHz, and the coefficients *c* and *d* are given in Table 1. The external noise figure, F_{am} from Equation (29) is expressed in units of dB. We note that external noise-level predictions based on Equation (29) can put external noise levels at 20 dB to 60 dB higher than thermal noise ($k_b T_0$). The equivalent external "sky-temperature" based on the external noise figure is given by

$$T_E = \left(F_{am} - 1\right)T_0 \approx F_{am}T_0, \tag{30}$$

where F_{am} in Equation (30) is not expressed in dB. While the exact method for determining the external noise temperature seen by the antenna is to integrate the external noise sources over the antenna's directivity pattern, Equation (30) is generally taken as the external noise temperature in HF receiving systems. The external noise power seen by the antenna is then given by

$$N_e = k_b T_E B, \tag{31}$$

where *B* is the channel noise bandwidth in Hz. We note that the value of T_E is significantly higher than the Earth's ground temperature, and the noise contribution from the Earth's ground is therefore typically ignored.

In the design of HF receiving systems, the effects of the antenna's *VSWR* are often ignored, since the associated mismatch loss attenuates both external noise and the desired signal. However, if the external noise is sufficiently attenuated by the antenna's mismatch loss, it may approach the receiving system's noise floor and at some point, the receiving system will become internally noise limited. That said, we note that an internally noise-limited system does not preclude signal detection.

The receiving antenna will attenuate external signal and noise by the combined factors of mismatch loss, radiation efficiency, and ground loss. Furthermore, the antenna will introduce its own thermal-noise contribution, which is only attenuated by the antenna's mismatch loss. The total noise contribution to the receiving system from the antenna is given by [20]

$$N_{et} = k_b\left[\tau\eta_r\eta_g T_E + \tau\left(1-\eta_r\right)T_p\right]B, \tag{32}$$

where T_p is the physical temperature of the antenna, often assumed to be equal to T_0. The equivalent noise temperature for the antenna is simply given by

$$T_A = \tau\eta_r\eta_g T_E + \tau\left(1-\eta_r\right)T_p. \tag{33}$$

To ensure that the receiving system is externally noise limited, the antenna's noise temperature must be greater than the receiving system's noise temperature, T_R as defined at the antenna's feed point. From an antenna performance-optimization perspective, it is obvious that the design objectives are to minimize mismatch loss, maximize radiation efficiency, and minimize ground loss. This is entirely consistent with the antenna's receiving sensitivity as defined in Equation (28).

To better quantify and compare the antenna's receiving performance, we consider a simple receiving system as depicted in Figure 16. Figure 16 illustrates a receiving system where a balanced antenna (dipole or loop) requires a balun; a bandpass filter (BPF) is placed before the low-noise amplifier (LNA); and a coaxial cable is used to connect the low-noise amplifier to the receiver. The bandpass filter is placed before the low-noise amplifier so as to preclude external signals outside of the HF band from entering the low-noise amplifier and being amplified. This helps mitigate low-noise-amplifier saturation, and prevents possibly high levels of out-of-band noise from entering the receiver. We place the low-noise amplifier as close to the antenna's feed point as possible to optimize *SNR* performance.

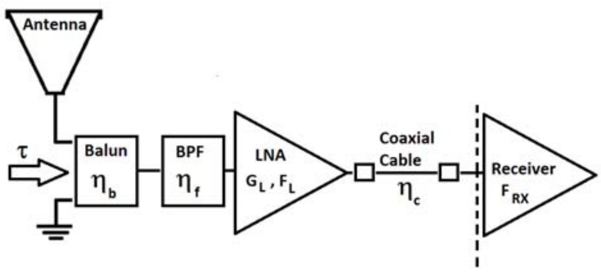

Figure 16. A depiction of a simple HF receiving system comprised of a balun, bandpass filter, low-noise amplifier, and coaxial cable.

The terms η_b, η_f, and η_c are the efficiencies of the balun, bandpass filter, and coaxial cable, respectively. The terms G_L and F_L are the gain and noise figure of the low-noise amplifier, and F_{RX} is the receiver's noise figure. In optimizing the receiving antenna, there are a number of ways to characterize its performance. We typically characterize the receiving antenna's noise figure relative to a lossless, matched antenna; however, this may not provide direct insight into whether-or-not the actual receiving system will meet the *SNR* requirements. Unfortunately, determination of the system *SNR* requires a detailed link analysis with knowledge of the incident signal power density and external noise levels.

Calculation of the antenna's noise figure relative to the lossless matched antenna can be done assuming both are connected to a receiving system having a noise temperature, T_R, defined at the antenna's feed point. To determine the actual performance of the receiving system, we need to ultimately determine the actual *SNR* at the detection point in the receiver as a function of the received signal, external noise, the antenna's performance properties, and the receiving system's noise figure, T_R.

Given the calculated external noise power in Equation (31), it is necessary to define the corresponding external signal power available to the general receiving antenna, S_i. This is given by the maximum power the general antenna is capable of receiving:

$$S_i = P_d \frac{\lambda^2 D}{4\pi} . \quad (34)$$

The general receiving antenna's noise figure can be found from SNR_i / SNR_0, where SNR_i is the ratio S_i / N_e and SNR_0 is the actual *SNR* established in the receiving system. The *SNR* established in the system, SNR_0, is given by [20]

$$SNR_0 = \frac{\tau \eta_r \eta_g S_i}{k_b \left[\tau \eta_r \eta_g T_E + \tau (1 - \eta_r) T_p + T_R \right] B} \quad (35)$$

$$= \frac{\tau \eta_r \eta_g S_i}{k_b (T_A + T_R) B} .$$

The numerator of Equation (35) is the received power delivered to the receiving system at the antenna's feed point, and the denominator is the total noise in the receiving system including the attenuated external noise, the noise contribution from the antenna's ohmic losses, and the internal noise contribution from the receiving system, where all are defined at the antenna's feed point. The noise figure of the general receiving antenna relative to that of a lossless matched antenna connected to the same receiving system, F_{ar}, is then given by [20]

$$F_{ar} = \frac{T_A + T_R}{\tau \eta_r \eta_g (T_E + T_R)} . \quad (36)$$

Equation (36) can be used to characterize the noise-figure performance of any receiving antenna relative to an ideal, lossless, matched antenna. Equation (35) can be used to determine the actual *SNR* in the receiving system. The receiving system's noise temperature, T_R, is found by cascading all of the system's internal noise contributions and referencing them to the antenna's feed point. For the simple receiving system shown in Figure 16, T_R is given by

$$T_R = \frac{(F_{RX} - 1) T_0}{\eta_c G_L \eta_f \eta_b} + \frac{(1 - \eta_c) T_p}{\eta_c G_L \eta_f \eta_b} + \frac{(F_L - 1) T_0}{\eta_f \eta_b}$$

$$+ \frac{(1 - \eta_f) T_p}{\eta_f \eta_b} + \frac{(1 - \eta_b) T_p}{\eta_b} . \quad (37)$$

In cascading the internal noise to the antenna feed point, we assumed that all of the components were matched at the input and output. Any high *VSWRs* would have to be taken into consideration in the noise temperature and *SNR* analysis of a real system. Finally, we note that the receiving sensitivity expressions developed in the previous sections are not valid for comparing the relative performance of the electrically small antenna in terms of realized system *SNR*.

9. Optimization Examples: The Dipole, Circular Loop, and the Multi-Turn Loop

In this section, we consider the optimization of the performance properties of the general, electrically small HF receiving antenna. Specifically, we consider the straight-wire dipole, the circular loop, and the multi-turn loop. The relative performance of the different antenna designs is based on the antenna's noise figure relative to the lossless, matched antenna as defined in Equation (36).

Optimization of the electrically small receiving antenna is primarily a function of its radiation efficiency and the impedance match to the receiving system, the first component of which is often a low-noise amplifier. Oftentimes, the impedance match to the low-noise amplifier is critical in optimizing *SNR* performance, particularly over wide-bandwidth operation.

Electrically small dipoles have high radiation efficiency, provided they are constructed using reasonable conductor diameters. For example, at 3 MHz, the radiation efficiency of a 50 cm (19.685 in) dipole, constructed using 10 AWG copper wire ($d = 2.588\ \text{mm} = 0.1019\ \text{in}$), is approximately 35%. A 2 m (78.74 in) dipole has a radiation efficiency of approximately 68%. The challenge with the electrically small dipole is that that its capacitive reactance is very high, making it difficult to impedance match, particularly to low impedance values such as 50 ohms. This can be an issue if one intends to use a 50-ohm low-noise amplifier in the receiving system.

The loop antenna differs significantly from the dipole in that it has a substantially lower radiation efficiency for the same conductor length. For example, a 50 cm (19.685 in) circumference circular loop (~ 16 cm or 6.3 in diameter), constructed with 10-guage copper wire, has a radiation efficiency of approximately $4 \times 10^{-4}\%$. The 1 m (39.37 in) diameter loop ($C \approx 3.14\ \text{m} \approx 123.6\ \text{in}$) has a radiation efficiency of approximately 11%. The advantage of the single-turn loop antenna is that it has a relatively low inductance reactance, which may provide a better match to a 50 ohm low-noise amplifier. The other advantage of the loop is that multiple turns and a ferrite core can be added to substantially increase its radiation efficiency. However, ferrite-core loops generally have small diameters (small areas), making dipole-like radiation efficiencies difficult to achieve. The other issue to consider with the multi-turn air- and ferrite-core loop is that their impedances tend to approach anti-resonance at higher frequencies, which may make optimization of the impedance match to a low-noise amplifier difficult, particularly over wide impedance bandwidths. We note that the small loop can be used as a receiving antenna near anti-resonance and its performance, like all antennas, is a function of mismatch loss, radiation efficiency, and ground loss.

In selecting the antenna design and orientation of the HF receiving antenna, one may also consider the propagation mode (ground wave, near-vertical-incidence, NVIS, single-hop, or multiple-hop) and the associated frequency range. These topics are beyond the scope of this paper and the examples presented in this section. Here, we consider the vertical and horizontal dipole and loop, and compare their performance properties over the HF band.

With any electrically small antenna, its overall performance properties are optimized by making the antenna as large as reasonably possible. This aids in optimizing both the impedance match and the radiation efficiency. Here, we considered a 2 m (78.74 in) dipole, a 1 m (39.37 in) circular loop, and a multi-turn loop, with the objective of optimizing their noise-figure performance. The antennas were assumed to be at a height of 2 m over average soil. Given a fixed antenna size, the radiation efficiency was optimized by using as large a conductor diameter as was reasonably possible. Here, we chose to use 10 AWG copper wire. The mismatch loss was optimized by implementing a receiving-system impedance that minimized the calculated value of τ over the HF operating band. Generally, the best optimization process is to calculate τ for a variety of real load impedances ($X_L = 0$), and to implement the load resistance that provides the minimum average τ over the operating band. Implementing arbitrary values of load resistance may be difficult, given the necessity of working with 50 ohm systems. One approach is to use an impedance transformer and/or low-noise amplifier that transforms the system's 50 ohm impedance to close to the desired load resistance. Impedance transformers are typically available, or can be designed in a wide range of transformation ratios (e.g., 2:1, 3:1, 4:1, 8:1, 16:1, 32:1, etc.). Finally, we caution against attempting to tune and match the antenna at a single frequency, as this often significantly degrades performance at other frequencies.

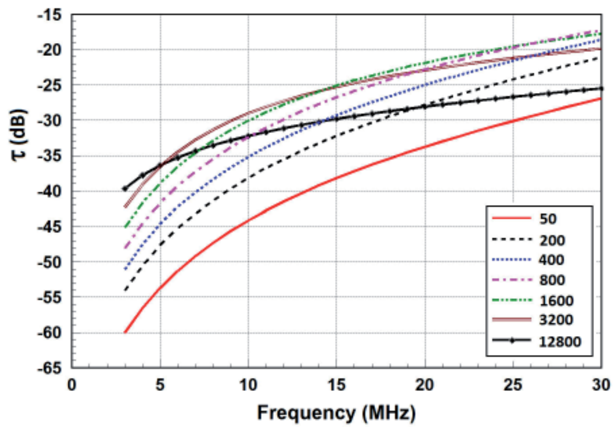

Figure 17. The values of τ in dB for the 2 m dipole as a function of load resistance.

For the 2 m dipole, we used *NEC* simulations to calculate τ as a function of varying load resistance, with the results presented in Figure 17. The optimum value of load resistance was between 1600 ohms and 3200 ohms. At

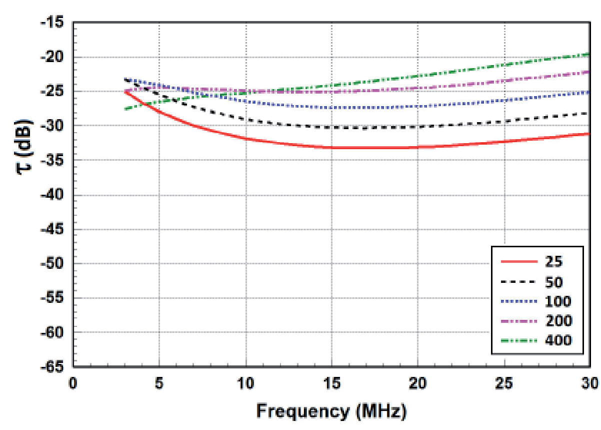

Figure 18. The values of τ in dB for the 1 m loop as a function of load resistance.

values of load resistance above 12800 ohms, the mismatch loss began to worsen over the entire band. A load resistance of 1600 ohms (32:1 transformer) improved the mismatch loss by approximately 15 dB at 3 MHz, and 10 dB at 30 MHz.

We next considered the 1 m loop, and again used *NEC* to calculate the value of τ as a function of load resistance, with the results presented in Figure 18. The optimum value of load resistance was approximately 200 ohms. At higher values of load resistance, the mismatch loss began to degrade at the lower frequencies. While the 1 m loop was less efficient than the 2 m dipole, we noted that its mismatch loss was substantially better over most of the HF band. We noted that the results in Figures 17 and 18 held for both the vertical and horizontal orientations, as the impedance did not significantly change with the change in orientation.

Using *NEC*, we simulated the value of radiation efficiency and ground loss for the dipole and loop, and calculated their noise figures. We assumed a receiving system (Figure 16) with a balun transformer having 0.25 dB loss; a bandpass filter with 0.25 dB loss; a low-noise amplifier with a gain of 30 dB and a noise figure of 1.5 dB; a coaxial cable with 2 dB loss; and a receiver with a 5 dB noise figure. The resulting value of T_R was 170.924K. The dipole and loop noise figures are presented in Figure 19. We calculated the external background noise using Equation (29), assuming "*galactic*" noise levels. We assumed a load resistance of 1600 ohms for the dipole and 200 ohms for the loop. From Figure 19, we saw that the dipole antenna had better noise-figure performance than the loop, and that the vertical orientations exhibited better noise figures than the horizontal orientations. We also noted that the noise figure improved with increasing levels of external noise. The external "*galactic*" noise level chosen here predicted the most conservative or pessimistic antenna performance.

In and of itself, the noise figure of the antenna does not provide a precise indication as to whether or not the HF receiving system is internally or externally noise limited. The

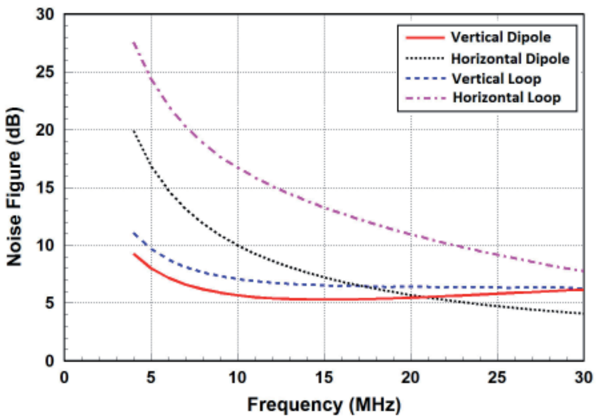

Figure 19. The noise figures of the 2 m dipole and 1 m loop located 2 m over average soil. The external noise level was assumed to be "*galactic*."

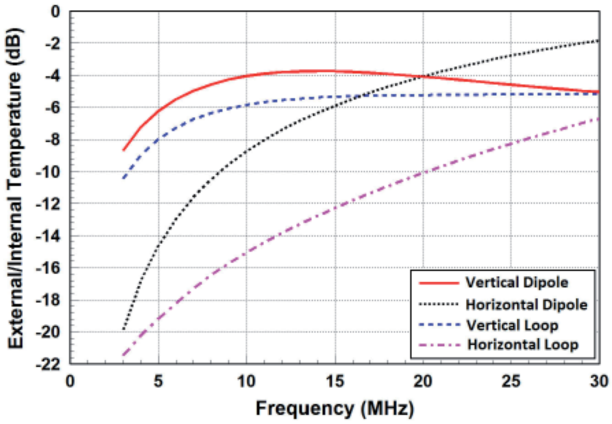

Figure 20. The ratio of external background noise temperature to the receiving system's internal noise temperature for the 2 m dipole and 1 m loop located 2 m over average soil. The external noise level was assumed to be "*galactic*."

system will be externally noise limited when the antenna's noise temperature, T_A, is greater than the receiving system's noise temperature, T_R. The ratios of T_A/T_R for the 2 m (78.74 in) dipole and the 1 m (39.37 in) loop are presented in Figure 20. From Figure 20, we saw that these antenna designs were not externally noise limited: rather, they were internally noise limited. We emphasize that the assumed external background noise level was "*galactic*," and note that with an increase in external background noise level, the receiving system tends to become externally noise limited. However, determining whether a link can be established between the transmitting and receiving system requires a link-budget analysis to determine the actual *SNR* in the receiver.

The next example was the optimization of an electrically small multi-turn loop. The design objective with the small multi-turn loop was to minimize the overall size of the receiving antenna, and to achieve reasonable values of radiation efficiency and mismatch loss. Here, we used the 1 m (39.37 in) loop as a reference design.

Considering the 1 m loop in free space, the radiation efficiency at 3 MHz was calculated to be −29.66 dB using *NEC* and −29.57 dB using theory. We choose a small loop diameter of 7.63 cm (3.00 in) so as to make the use of a ferrite core reasonable. With this loop diameter, over 2000 turns were required when using an air core to achieve the same efficiency as the 1 m loop. When using a ferrite core with $\mu_{fr} = 100$ and a cylindrical length of 20 cm (7.84 in), approximately 25 turns were required to achieve the same

Table 2. The radiation-efficiency calculations for the 22-turn loop at 3 MHz (values are in dB).

Loop Configuration	Theory	*NEC*	*FEKO*
Air-Core	–49.24	–49.15	–49.31
Ferrite-Core	–29.62	N/A	–29.9

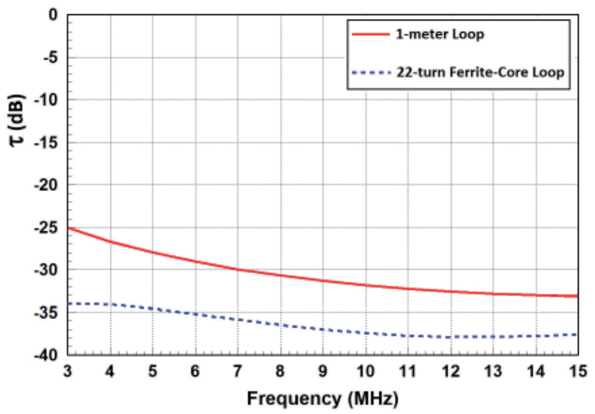

Figure 21. The values of τ for the 1 m air-core loop and the 22-turn ferrite-core loop.

efficiency as the 1 m loop. To validate these estimates and the noise-figure calculations that followed, we compared theory and simulation using *NEC* and *FEKO* [21] to model 22-turn air-core and ferrite-core loops. We determine their radiation efficiencies at 3 MHz. The numerical results are presented in Table 2.

Using the impedance-matching optimization procedure previously discussed, we found that a load impedance of 3200 ohms provided an optimum value of mismatch loss for the ferrite-core loop. We noted that the 22-turn ferrite-core loop exhibited an anti-resonance at approximately 9 MHz, which had minimal impact on the optimized mismatch loss. The mismatch loss and noise figure of the 22-turn ferrite-core loop over a frequency range of 3 MHz to 15 MHz is compared to that of the 1 m air-core loop in Figures 21 and 22, respectively.

We saw from Figure 21 that the mismatch loss between the two antenna designs varied from approximately 10 dB at 3 MHz to 5 dB at 15 MHz. This difference in mismatch loss accordingly impacted the difference in noise figure. In addition to the differences in mismatch loss, the noise figures also differed due to differences in their ohmic and ground losses as a function of frequency. We saw that the

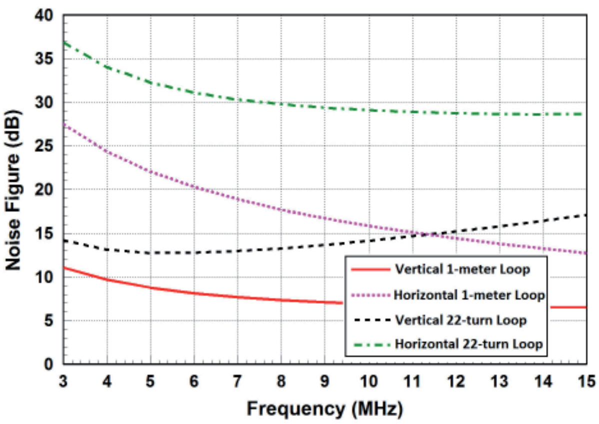

Figure 22. A comparison of the noise figures of the 1 m air-core loop and the 22 turn ferrite-core loop.

small ferrite-core loop, designed to match the free-space efficiency of the 1 m loop, did not perform as well as the 1 m loop operating over Earth ground.

10. Summary

In the design of electrically small antennas, there is always some amount of performance tradeoff in terms of mismatch loss and radiation efficiency. Ultimately, optimizing the design of the electrically small receiving antenna is a function of maximizing the antenna size as much as is reasonably possible, optimizing the load impedance seen by the antenna, improving the radiation efficiency as much as possible, and minimizing the internal losses in the receiving system. To fully characterize the absolute or relative performance of the receiving antenna, one can use the formulas for receiving sensitivity, noise figure, and compare the ratio of antenna noise temperature to the receiving system's noise temperature.

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Coordinated Universal Time and the Leap Second

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Abstract

I will discuss the considerations that were important in the design of the current version of Coordinated Universal Time. The design includes the addition of additional "leap" seconds to keep Coordinated Universal time within ±0.9 s of the UT1 time scale, which is a proxy for the position of the Earth in space. I will describe the advantages and problems associated with the leap-second system, and a number of changes that have been proposed to the realization of the time scale.

1. Introduction

Coordinated Universal Time, generally abbreviated as UTC, is the basis for civil time and frequency in almost all countries. There have been a number of different definitions of the relationship between UTC and International Atomic Time (TAI), but I will discuss only the current realization of UTC, which dates from 1972.

The single UTC time scale is used to realize the definitions of three related quantities: time, time interval, and frequency. It is difficult to design a time scale that can satisfy the requirements of the different applications that depend on these three quantities, and this difficulty is the root of current discussions to change the realization of UTC. In order to appreciate this difficulty, I will present a short historical discussion of the older definitions of time and frequency, because the current definition is an extension of the older definitions of time and time interval.

2. Definitions of Time, Time Interval, and Frequency

The times of events in antiquity were derived from astronomical observations of the positions of the sun, the moon, or a star. The day was defined by local sunrise or sunset, the month by the observation of a new moon, and the year by the spring equinox or by the first observation of a particular star just before sunrise.

Even in antiquity, it was known that the different time scales were not commensurate: that there are not an integral number of solar days in a lunar month or in a solar year. Each society devised a method for dealing with this problem, and the resulting calendars were often quite complex. I will not discuss this complexity, because it is not important for the current definition of UTC, which is based on the length of the second and considers only integer multiples and fractions of this base quantity. For example, a UTC day is exactly 86 400 (24 × 60 × 60) UTC seconds long.

A time interval is the elapsed time between two consecutive "standard" astronomical events. A clock is simply a device that acts as an interpolator. It facilitates the measurement of time intervals between the standard astronomical events.

All clocks comprise two systems: a device that generates periodic events or "ticks," and a method for counting the ticks to display the elapsed time interval since an origin that is unique to each time scale. When time and time interval were astronomically defined, the interval between the ticks of a clock – or, equivalently the frequency of the tick generator – had to be adjusted so that the time interval displayed by the clock agreed with the astronomical definition. Frequency was therefore a derived quantity that was implicitly defined by astronomical observations. It could not be independently defined. That situation was acceptable until the start of the 20th century, because there were few, if any, applications that depended on frequency and not on time.

3. The Problem with Apparent Solar Time

The interaction between the orbital motion of the Earth with respect to the sun and the spin of the Earth about its axis increases the length of the apparent solar day (the interval between two consecutive solar noons, for example) by an average of about four minutes (approximately $24 \times 60/365.25$) relative to the time it takes the spin of the Earth to make a complete 360° revolution with respect to the distant fixed stars, which is called the sidereal day. The elliptical shape of the orbit of the Earth adds an annual variation to this effect. (Kepler's second law, which is really a statement of conservation of angular momentum, requires that the orbital angular speed is greatest when the Earth is closest to the sun, and decreases as the sun-Earth distance increases.) Since frequency and time interval are derived quantities, this annual variation is pushed into them, as well.

4. Mean Solar Time

The annual variation in the length of the apparent solar day was known in antiquity, but it became more serious when applications that depended on frequency but not on time or time interval were developed. The frequencies assigned to radio stations in the early years of the 20th century are an example of the problem. Artifact frequency standards, initially based on precision inductors and capacitors, and later on quartz crystals, were developed to address the requirement for a standard frequency reference. They had inadequate long-term stability, and required periodic recalibration by astronomical observations. The annual variation in apparent solar time resulted in an unacceptable variation in the calibration of the frequency of these reference devices.

The first solution was to define mean solar time: a time scale based on the motion of a fictitious sun, moving along the equator at a constant speed that matched the average apparent motion of the real sun moving along the ecliptic. (It is common in astronomy to think of the Earth as stationary, with the sun in orbit around it.) The difference between the apparent and mean suns is the "equation of time," a periodic function that has an amplitude of approximately 16 minutes. In addition to the variation resulting from conservation of angular momentum, the equation of time has a contribution produced by the periodic difference between the position of the real sun, which moves along the ecliptic, and the fictitious sun, which moves along the equator. This contribution is caused by the tilt of the axis of the Earth with respect to the plane of the apparent annual motion of the sun.

A contemporary realization of mean solar time is Greenwich Mean Time, which is defined in principle as mean solar time as observed on the Greenwich meridian. (In current practice, mean solar time is derived from sidereal time: the apparent motion of the Earth with respect to distant stars.)

5. Limitations of Mean Solar Time

There are some practical difficulties in constructing a clock that realizes mean solar time. There is no astronomical observation that directly realizes mean solar time, so that it is difficult to calibrate a clock without extensive observations. The two possibilities are combining sidereal time with the orbital motion of the Earth, or combining apparent solar time with the equation of time. The length of the sidereal day could be measured with an accuracy of a few milliseconds by observing the times of meridian transit of a bright star at a number of observatories. The observations at each observatory define the time scale UT0. These data are affected by polar motion: the precession and nutation of the axis of rotation of the Earth. The data from the different observatories could be combined to separate the effects of polar motion from the rotation rate of the Earth. This analysis yields the UT1 time scale, which is a proxy for the angle of the Earth in space corrected for polar motion. Contemporary determinations of UT1 and mean solar time are based on very-long-baseline interferometry (VLBI) observations of signals from very distant radio sources.

However, there are more serious problems. In the 1920s, it became apparent that the length of the UT1 day was not a constant as measured by the best pendulum clocks of that era. The length of the UT1 day had an annual variation that could be modeled and removed to produce a time scale called UT2. However, UT2 had a secular variation due to the irregular slow down in the angular velocity of the Earth about its axis of rotation. As I previously discussed, the secular variation in UT2 was pushed into time interval and frequency.

There were a number of changes in the astronomical definition that attempted to preserve time derived from astronomy as the fundamental unit, but none of them was completely successful. For example, one attempt to define the second was to use the length of the year 1900. Since the length of the year 1900 was not an observable for practical metrology, the practical standards of time, time interval, and frequency had to be based on some method of extrapolating the definition and realizing it in some contemporary observation or physical device. The extrapolated reference device became the *de facto* standard quantity, since there was no effective way of linking this reference back to the fundamental definition. (This result was not unique to time or time interval. The length of the meter was defined in principle in terms of a portion of the circumference of the Earth, but the length in practice was determined by the artifact standard that was constructed from the fundamental definition. The fundamental definition was irrelevant from the perspective of practical metrology.) However, a more fundamental change was already on the horizon.

6. Frequency and Quantum Mechanics

The considerations that I have discussed above were fundamentally changed by quantum mechanics. The frequency associated with a transition between quantum states was proportional to the energy difference between them. This energy difference could be calculated by combining the principles of quantum mechanics with the properties of atomic particles, such as the masses and charges of electrons and protons, the speed of light, and other similar quantities. The point was that frequency was a fundamental parameter from the quantum-mechanical perspective, and the frequency associated with an atomic transition was a fundamental invariant property of nature. The natural extension of this idea was to make frequency the fundamental unit, and have both time and time interval be derived quantities.

7. The Cesium Second

Although the quantum-mechanical principles that I discussed in the previous section are true for any atom in principle, various engineering considerations favored the use of a hyperfine transition in the ground state of cesium as the definition of frequency. (These considerations are less important today, and it is likely that a different atomic transition will be chosen as the definition of frequency in the foreseeable future. This change is unlikely to have a significant impact on the realizations of the standards of time and frequency.)

In order to make the transition between a system based on astronomical time as the fundamental definition to one based on the cesium frequency, Essen and Perry, at the National Physical Laboratory in the UK, and Markowitz, at the US Naval Observatory in Washington, USA, measured the frequency of the cesium transition in astronomical time units. After several years of observations ending in 1958, they concluded that the length of the second should be defined as 9 192 631 770 cycles of the cesium hyperfine transition in the ground state. This value was accepted as the definition of the length of the second in 1965. The intention was to minimize any discontinuity in the length of the second.

The length of the cesium second implicitly defined the length of the cesium day as 86 400 cesium seconds. The minute and the hour were implicitly defined in the same way as exact integer multiples of the cesium second. The lunar month and the solar year were now derived quantities that had to be measured in units of the cesium second.

From the start, it was clear that the value adopted for the length of the cesium second resulted in the length of the day that was too small relative to astronomical observations. The fractional frequency difference was about 3×10^{-8}, which produced a time dispersion of about 1 s/year. The source of the discrepancy was that the value used for the length of the UT1 day was based on relatively old observations, and the rotation rate of the Earth had slowed down by the time of the comparison experiments in the 1950s.

A somewhat larger value for the number of cycles in a cesium second would have solved the immediate problem. However, the irregularities in the rotation rate of the Earth combined with the secular increase in the length of the astronomical day guaranteed that no choice for the number of cesium cycles in a second could permanently remove the discrepancy, which would have secular and irregular variations no matter what value was chosen. The choice of frequency as the fundamental parameter was consistent with quantum mechanics and with the assumption that the frequencies of atomic transitions, which are calculable in principle in terms of the fundamental constants of nature, should be invariant. However, it did nothing to remove the variability in the astronomical time and time intervals. These quantities now had the secular and deterministic variations that were previously associated with frequency when time was the fundamental parameter.

8. The Conflict Between Time and Frequency

The definition of the length of the second in terms of the transition frequency in cesium, and the increasing availability of commercial cesium standards in the 1960s, divided the user community into three distinct groups:

Group 1 was the scientific community, which regarded frequency as a fundamental parameter derived from atomic properties by the use of quantum-mechanical principles. This group considered frequency (or wavelength) as conceptually equivalent to the other fundamental constants, such as the charge and mass of the electron and proton and similar parameters. Any difference between a time scale derived from the cesium frequency and a time scale related to astronomy could be handled by defining an offset parameter that would be published as needed and administratively applied. The offset could not be predicted algorithmically because of the irregular variation in the rotation rate of the Earth.

Group 2 was the astronomical community, which regarded time as a proxy for the angular position of the Earth in space. Although the offset between astronomical time and atomic time could be tabulated and administratively applied, there were applications that were designed with the premise that the offset would be a small quantity, so that the official UTC time scale could be used as a proxy for the orientation of the Earth in space without additional parameters or corrections.

Group 3 was the engineering community, which required a stable and easily constructed artifact frequency standard that could be used for accurate and relatively rapid calibrations. There was nothing wrong with a standard that was derived from the properties of atoms and the values of other fundamental constants, but that was a secondary consideration. In addition to its variability, astronomical time scales did not provide an easily accessible frequency standard that could be used for routine calibrations.

Based on current observations (in 2016), the difference between the length of the day defined astronomically and the length of a day defined by cesium seconds would diverge at a rate of somewhat less than one second per year, or on the order of one minute per century. This difference would not be observable in everyday timekeeping for a long time, since it was much smaller than the width of a time zone, or the offset in apparent solar time introduced by a change to daylight-saving time. Some extrapolations predicted a more rapid divergence, perhaps as large as several minutes per year.

9. The 1972 Solution

In 1972, the standards community attempted to design a time scale that would satisfy all of the previous conditions. The result was the current version of UTC.

1. The frequency of UTC would be the same as the frequency of International Atomic Time (TAI), a time scale that was designed to realize the SI second on the rotating geoid as closely as possible. The length of the International Atomic Time second was defined based on the hyperfine transition frequency in the ground state of cesium as realized on the rotating geoid. The length of the UTC second was fixed at the previously accepted value of 9 192 631 770 cycles of the cesium transition. UTC time signals and data could thus be used as a source of the standard reference frequency and the standard reference time interval almost all of the time (except for intervals that crossed a leap second, as I will discuss in the next section). The UTC time scale would be disseminated by timing laboratories and national metrology institutes based on a local realization of the cesium second.

2. The Bureau International de l'Heure was initially charged with monitoring the difference between atomic time and UT1, a time scale based on the rotation of the Earth. The job was transferred to the International Earth Rotation and Reference Service (IERS) in 1988, at the same time as the tasks of computing International Atomic Time and UTC were passed to the International Bureau of Weights and Measures (BIPM). Since the length of the cesium second was too short to begin with, and since the discrepancy was expected to increase with time, the length of the day determined by counting cesium seconds would be too short. When the discrepancy approached 0.9 s, a leap second would be added to UTC so that the discrepancy would not exceed 0.9 s. The effect of the leap second would be to allow UT1 to catch up to cesium-based UTC. The leap second would be added after the last second of the last minute of the last day of a month. In other words, the leap second would be added following 23:59:59 UTC. The months of June and December were preferred, and all of the leap seconds to date have been added at the end of one of these months.

3. The name of the leap second would be 23:59:60, and the following second would be 00:00:00 of the next day. In a month when a leap second was scheduled, the last minute of the last day of the month would thus have 61 seconds.

From the astronomical perspective, the leap second was not really an extra second. It was inserted to correct for the fact that all of the previous seconds since the last leap second were somewhat too short, and the leap second should not count in the integer number of seconds that have elapsed between any two epochs. From the astronomical perspective, the leap second would not have been needed if all of the previous seconds had had the correct length. In other words, the leap second would not have been necessary if civil time were based on UT1. (In this sense, it is analogous to the leap day, which is inserted to correct for the fact that a 365-day year is also somewhat too short relative to the solar year. As with the leap second, the leap day is not used in many applications that compute time intervals.)

Although the use of cesium seconds between leap-second events would result in a short-term discrepancy between the UTC time scale and the angular position of the Earth, there would be no long-term divergence between these two quantities. The difference between the two time scales, which was called dUT1, would be transmitted with a resolution of 0.1 s by radio time services. This resolution was considered adequate for most astronomical applications that required higher accuracy in the angular position of the Earth in space than was provided by the uncorrected cesium time scale, which could have an offset from UT1 that could be as large as ±0.9 s. It was implicitly assumed that applications that required a resolution greater than 0.1 s in dUT1 would already be administratively inserting the value of this parameter.

10. The Problems

The definition of UTC had two fundamental problems. These were recognized in 1972, but were not regarded as very serious at that time. Both of them are now much more serious, which is one of the reasons why a change to the definition of UTC is being considered.

10.1 Problem 1

Unlike the astronomical perspective, which regarded cesium seconds as fundamentally too short, the engineering and scientific communities saw them as having the correct duration. From this perspective, the leap second was an extra second that introduced a step in time intervals or frequencies measured across a leap second that was not consistent with the evolution of a real time process. Measurements of velocity or of time of flight would be affected if the measurement interval included a leap second. Radio navigation systems, such as GPS, therefore defined a private time scale that did not include leap seconds beyond those that were already defined when that scale was initialized.

The decision to include the leap seconds in the initial value of the GPS system time increases the confusion. There had been 19 leap seconds added to UTC when the GPS time scale was initialized in 1980, so GPS system time was equal to UTC at that instant, but was 19 seconds behind TAI. The GPS system time does not include subsequent leap seconds, so that there are now two time scales: UTC, and GPS system time, which differ by a different number of seconds from TAI.

Galileo, the European global navigation satellite system, defined its own system time. When the system time was initialized in 1999, it was set to 13 seconds ahead of UTC at that instant. There had been 32 leap seconds added to UTC at that time, so that Galileo system time was 19 seconds ($-32+13$) behind TAI. GPS and Galileo systems times thus had the same integer second.

Beidou, the Chinese navigation system, also defined its own system time. It was set to UTC on January 1, 2006. It therefore included the 33 leap seconds that had been inserted into UTC at that instant, but would not include any future leap seconds. It therefore would have a constant integer-second offset with respect to the Galileo and GPS system times, and an increasing integer-second offset with respect to UTC as additional leap seconds were added to UTC after January, 2006.

There are a number of other satellite navigation systems, and almost all of them have similar definitions and offsets. For example, the origin epoch for IRNSS, the Indian Satellite Navigation system, is August 22, 1999. At that instant, the INRSS system time was 00:00:00 22 August 1999; the corresponding UTC time was 21 August 1999 23:59:47. IRNSS system time was thus set 13 seconds ahead of UTC, so that it has the same integer second as GPS and Galileo. (There is no fixed relationship between the seconds fractions of the various system times.)

Finally, Glonass, the Russian navigation system, currently uses the UTC time scale as system time.

The orbital speed of all of the navigation satellites is about 4 km/s, so that a time step of 1 s can introduce a significant offset in the determination of position or time of flight. The proliferation of private time scales is undesirable in principle, and is a potential source of errors and confusion in practice. The global navigation satellite systems transmit the difference between UTC and satellite system time, but there have been many examples of receivers not processing this information correctly. These errors reappear with disturbing frequency each time a new receiver is developed.

10.2 Problem 2

The official name of the leap second was 23:59:60, but almost all clocks cannot represent that time. This is especially true for all digital systems, which keep time as the number of seconds since some origin time. These systems convert this count to the more conventional year-month-day hour-minute-second format when the value is output. This system has no provision for identifying the extra leap second. The usual implementation in these systems is therefore to effectively stop the clock for 1 s and transmit a time corresponding to 23:59:59 twice: once when that time arrives, and the second time during the leap second.

Assigning the same time tag to two consecutive seconds introduces an ambiguity in determining the time-order of events, since 23:59:59.2 during the second second actually occurred after 23:59:59.5 during the first second. To further complicate this issue, the leap second is defined with respect to UTC (and not local time), so that it occurs in the morning of the following day in Asia and Australia, and late in the afternoon in California and Hawaii. This is potentially disruptive for commercial and financial applications that use UTC to apply time tags to transactions.

Unfortunately, some implementations of digital time systems insert the extra leap second by transmitting the time equivalent to 00:00:00 of the next day twice. This has the same long-term behavior as the official version, but it puts the leap second in the wrong day, and has a time error of 1 s with respect to UTC during the leap-second insertion.

A more serious issue is the "leap smear" method, which amortizes the additional leap second over some longer time interval by adjusting the effective frequency of the clock oscillator to account for the extra second. This has the obvious advantage that the time is monotonic and time stamps cannot violate causality. However, it has an error both in time and in frequency with respect to the definition of UTC over the interval of the smear. In addition, the parameters of the "smear" are not defined in any standard, so that there is no assurance that different implementations of the method will agree among themselves on the time during the adjustment period. These considerations may not be important for a casual user of the time services, but they may be very important for users who are required to use time stamps that are traceable to national and international standards. This is especially the case for commercial and financial transactions in Europe, which are currently required to maintain a sub-second time accuracy that is traceable to national time standards. It is likely that these sub-second accuracy requirements will be implemented in the United States as well in the foreseeable future.

The Network Time protocol is often used in a hierarchical client-server model, where many systems act as clients to systems closer to a standard time reference and simultaneously act as servers to other systems. In general, most clients are configured to query multiple servers to facilitate error detection. The leap-smear technique can be troublesome in this configuration, especially if a client system queries some servers that realize the smear technique and some that don't. The two queries will return time stamps that differ by a time of order 0.5 s; a discrepancy of this magnitude will be treated as an error by the client, but it is not clear which of the two time stamps will be accepted.

Finally, there are some computer systems that simply ignore leap seconds altogether. These systems will have a 1 s error from the instant that a leap second is inserted until the system is resynchronized after the insertion. This is a problem in principle, but is much less serious in practice because the clocks in these systems are not intended to be accurate at the level of a few seconds anyway, so that the additional offset due to the leap second does not make a significant difference. The only concern with this implementation is that users should understand the design assumptions and not rely on the system time for time stamps that are accurate at the level of 1 s.

The Internet time servers operated by NIST receive approximately 140 000 requests per second for time in standard network formats. The Network Time Protocol (NTP) has a provision for announcing a future leap second, but has no provision for identifying the leap second when it occurs. The protocol therefore transmits a binary time equivalent to 23:59:59 a second time during the leap second, as I discussed above. During a leap-second event, the NIST time servers will receive approximately 280 000 requests with a binary time equivalent to 23:59:59, and the users will have no simple way of knowing which of these is the actual time and which is the leap second.

NIST operates a single time server that transmits UT1 time in the standard Network Time Protocol format. The accuracy of this service is limited by the stability and reciprocity of the network time delay between the user and the time server in Colorado. This is typically on the order of a few milliseconds. This accuracy is significantly higher than the 0.1 s accuracy of radio transmissions of the dUT1 parameter.

11. The Future

The rate of increase in the length of the day is irregular, so that its short-term behavior cannot be modeled. However, there is every expectation that the length of the day will continue to increase, so that leap seconds are likely to be required more frequently in the foreseeable future. This will exacerbate the difficulties of applying them, and may increase the pressure to change the current definition of UTC. A number of changes have been discussed for the last 15+ years, but none of them has been implemented as of now (December, 2016). The proposals can be divided into two broad categories: (1) proposals that maintain a connection between UT1 and UTC, and (2) proposals that do not.

The simplest version in the first category is to do nothing: to simply continue the system as it is currently implemented. Other proposals in this category increase the limit on the dUT1 parameter so that leap seconds are required less often. However, multiple leap seconds could be needed in this solution. One version of this proposal is to add leap seconds on February 29 every four years. The insertion date would be fixed, but the number of leap seconds would vary. A similar solution would use leap minutes instead of leap seconds. Leap minutes would probably be needed only once or twice per century if the current slowdown rate continues unchanged. It is not clear that increasing the interval between leap-second events and increasing the number of leap seconds at each event is an improvement over the current system. It certainly exacerbates the problems associated with stopping the clock during the leap-second(s) event. The magnitude of the dUT1 parameter would exceed 1 s, which would break many of the radio time services that transmit this parameter.

The simplest version of the proposals in the second category is simply to stop adding leap seconds to UTC but to make no other changes. The difference between UT1 and UTC would increase, and users who needed UT1 time would have to administratively add the value of dUT1. Time services that transmitted UT1 time, similar to the existing NIST Internet time server, might be developed, although this would be another source of confusion. The format of many time transmissions would have to be modified to accommodate values of dUT1 that would exceed 1 s. The formats of the messages from the NIST radio stations WWV and WWVB would have this problem. The integer-second time offsets between UTC and the various time scales of the global navigation systems would remain but would not get any larger.

A related proposal would be to stop adding leap seconds, and rename the resulting time scale to something other than UTC. This would emphasize the fact that the implementation of the time scale had changed. (There is a precedent for not doing this. The fundamental definition of the meter has been changed several times without renaming the quantity, and there has been no change in the name when the realization of the volt was changed.)

The most extreme version of proposals in this category would be to use International Atomic Time (TAI) instead of UTC. This would require a large time step to remove all of the leap seconds that have been inserted into UTC since 1972. The time offsets of the various global navigation system time scales with respect to TAI would presumably remain. A change in the name of the legal time scale to anything other than UTC would have a significant impact on the legal definition of time in many countries.

There has been some discussion that there is (or should be) a difference between the metrological definition of UTC as a realization of the SI second on the rotating geoid, and the details of the format used to transmit the UTC time and the dUT1 offset in radio signals. The metrological definition would presumably be the province of the standards community in general and the International Bureau of Weights and Measures (BIPM) in particular, while the transmission format would be the province of the International Telecommunications Union (ITU) and the World Radio Conference. These discussions are in the very early stages. This question will probably be discussed at the next meeting of the BIPM Consultative Committee for Time and Frequency (CCTF), which will meet next year (June 2017). The World Radio Conference (WRC-15) of the International Telecommunications Union decided to postpone a final decision to the next full meeting in 2023, and it is almost certain that the current leap second system will remain in place at least until then.

12. Summary

The process of adding leap seconds to UTC is designed to maintain a close link between UTC and UT1, a time scale related to the rotation of the Earth. The leap-second process introduces difficulties for applications that use UTC for frequency or time interval, and for applications that must apply time tags to events that happen during a leap second. There is no simple solution that can satisfy all of these requirements. Whatever solution is finally adopted is going to introduce some level of difficulty for some class of applications. Where you stand on this question is largely determined by where you sit.

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In Memoriam: Xueqin Huang

Xueqin Huang peacefully passed away in the presence of his family in Lowell, Massachusetts, on October 15, 2016. He was known throughout the international research community for his fundamental research in the exploration of the ionosphere.

Xueqin Huang was born in Hunan Province in China (CIE) in 1939. He graduated from the Physics Department of Wuhan University in 1963. He then joined the Chinese Research Institute of Radiowave Propagation (CRIRP) in Xinxiang, and in 1977 he became the Director of the Ionosphere Laboratory at CRIRP. Starting in 1979, he spent two years as a Visiting Scholar at the University of Massachusetts Lowell. After his return to China, he became the Director General of CRIRP in 1986. He was appointed Professor in 1987. In 1990, Prof. Huang rejoined the University of Massachusetts Lower Center for Atmospheric Research (UMLCAR) as a Research Professor. After his retirement from the University in 2012, he continued his research activities as a senior scientist with the Lowell Digisonde International (LDI) company.

Prof. Huang was one of the earliest experts in China in the 1970s to participate in the ITU/CCIR activities in Geneva, serving as the Chinese (CIE) National Representative on the ITU/CCIR Study Group 6 for Ionospheric Propagation. In the 1980s, he carried out feasibility studies for the incoherent scattering measurement of the Chinese Kunming Radar. As a classically trained physicist and mathematician, he became extremely successful in interpreting radio measurements of the Earth's ionosphere and plasmasphere in terms of the structure and dynamics of the magneto-plasma medium. At UMLCAR, he developed the first successful algorithm for the automatic scaling of topside ionograms recorded on the Alouette and ISIS satellites, and the subsequent inversion to electron-density profiles. He then applied the same ideas to the real-time processing of ground-based ionogram data in the Digisonde, leading to the development of the Real-Time Ionogram Scaler with True height inversion algorithm, ARTIST. Today ARTIST is deployed in all Digisondes operating around the globe, and the scaled data are assimilated in real time in the International Reference Ionosphere (IRI) electron-density model. More recently, Prof. Huang was successful in deriving an empirical plasmasphere electron-density model, using data from the Radio Plasma Imager (RPI) instrument on NASA's IMAGE satellite, and inverting the measured plasmagrams into the electron-density profiles along magnetic field lines. In a groundbreaking publication in 2012, Xueqin Huang was able to show that electromagnetic waves in an unbounded cold magneto-plasma have parallel phase and group velocities when the propagating energy is represented by spherical waves, rather than by plane waves.

The international ionospheric research community has lost one of their best. He is survived by his wife, Mengjuan Zhao, and his two sons, Yong Huang and Xin Huang.

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In Memoriam: Staffan Ström

Sadly, Staffan Ström quietly passed away on August 28, 2016, and made the scientific community a lot emptier. His commitment to science, understanding, and pin-sharp insight in all his scientific endeavors will be missed by all his many friends, nationally and internationally. Staffan is survived by his wife, Charlotta, and their two daughters, two brothers, and a sister.

Staffan Ström was born on September 14, 1934, in Göteborg, Sweden. In 1959, he completed his undergraduate studies at the School of Electrical Engineering at Chalmers, Göteborg. In 1967, he presented his PhD dissertation in Mathematical Physics at the Institute of Theoretical Physics at the same university.

After his PhD, Staffan spent two years, 1969-1971, at the University of Texas at Austin as a visiting research associate. This was an excellent opportunity for Staffan to develop his knowledge in group theory under the direction of Prof. Sudarshan: a skill that later paid off well.

Returning to Göteborg, Staffan moved to another research field. Together with his supervisor, Prof. Nils Svartholm, Staffan realized that there was a need for more applied research at the institute. The new group, created in the early 1970s with Staffan as the obvious leader, was called Applied Mathematical Physics, encompassing applied mathematics in elastodynamics, electrodynamics, and acoustics. The timing for the creation of this group was well founded. An excited group of graduate students was eager to pursue studies under Staffan's supervision, and the group quickly became internationally well reputed.

In 1984, Staffan was appointed the Chair of Electromagnetic Theory at the Royal Institute of Technology (KTH) in Stockholm. This was the well-known chair that Prof. Erik Hallén had held a decade earlier. Staffan and his family, together with a small group of students from the old group in Göteborg, moved to Stockholm. Staffan stayed at KTH until he retired in 1999. During those 25 years, he built a world-leading group in electromagnetic theory, and supervised many graduate students. After retirement, he was active for many years. In particular, he was the coordinator and leader of a large research project in antenna applications during 2000-2004.

The scientific work by Staffan can be divided into three parts:

1.Work concerning the representations of space-time transformation groups.

2. Work concerning the null-field approach to scattering and wave propagation of time-harmonic elastodynamic, electromagnetic, and acoustic waves.

3.Work concerning wave-splitting, imbedding, and Green's function methods in direct and indirect scattering in the time domain.

The work in group theory dealt with different aspects of the unitary irreducible representations of several space-time transformation groups, such as the Lorentz, Poincaré, de Sitter, and Euclidean groups. Both Lie algebra and Lie group methods were investigated. The Poincaré group is the fundamental space-time transformation group of special relativity, and the quantum and classical theories of electromagnetism are Poincaré covariant. The Poincaré – and often, the more restricted Euclidean – invariance and covariance are of direct relevance for applications in classical electromagnetism. Staffan published several journal and book contributions on group theory, but he also wrote a comprehensive and pedagogical book on group theory, later used as course material at the Institute of Theoretical Physics.

The transition matrix (T-matrix) of a scatterer completely characterizes the scattering properties of an obstacle. In the 1960s and early 1970s, Peter C. Waterman presented an elegant formulation of the scattering problem, and an algorithm for finding the transition matrix of a single homogeneous or PEC scatterer. Specifically, Waterman made extensive use of the extinction part of the integral representation of the solution, and repeated use of decompositions of the free-space Green's function. The formulation is valid up into (and sometimes beyond) the resonance region. In the early 1970s, Staffan soon realized that Waterman's work could be extended to more complex scattering geometries. With a background in group theory, Staffan recognized that the Waterman method could be generalized to several scatterers by utilizing the translation properties of the spherical vector waves. These efforts resulted in a large and well-cited collection of journal papers and book chapters. In particular, Staffan contributed with several chapters on scattering theory in the *Handbook on Acoustic, Electromagnetic and Elastic Wave Scattering* edited by V. V. Varadan, A. Lakhtakia, and V. K. Varadan.

Several fundamental mathematical questions concerning Waterman's method (nowadays, usually called the null-field approach) are still open, such as questions of convergence and the stability of the method. An essential question is whether a certain complete system of expansion functions forms a basis, or better still, a Riesz basis, for the relevant L^2 spaces. Staffan was interested in such questions, and collaborated with several mathematicians to solve these mathematical problems in classical wave scattering.

The theoretical foundations of the direct scattering problem are well understood. Various methods have been developed, and the pertinent scattering characteristics of a scattering problem can be solved numerically. In contrast to the direct scattering problem, the inverse scattering problem lacks this knowledge and understanding, and the problem suffers several salient ill-posed steps. For several years, Staffan worked on imbedding algorithms to solve and understand the ill-posedness of the inverse scattering problem. He worked first in one spatial dimension, in particular, transmission along a nonuniform *LCRG* line for which all of *L*, *C*, *R*, and *G* depend on the length coordinate along the line. Later, together with his graduate students and Prof. Vaughan Weston, he worked in three spatial dimensions. Out of Staffan's many results, he showed that the inverse problem in which the reflection kernel is taken as the given input data is well-posed in the time-domain setting, i.e., the deconvolution is the only ill-posed step. His scientific accomplishments in this field were collected in the book, *Time Domain Wave-Splitting and Inverse Problems*, coauthored with Sailing He and Vaughan Weston.

Out of Staffan's wide scientific production, his 1973 *Physical Review D* paper on scattering by several scatterers is the paper that has obtained the most attention. Staffan realized early that translation of spherical waves could be used to solve scattering by many objects, and he was one of the first to quantify the multiple-scattering contributions within the framework of Waterman's null-field approach. Staffan's background in group theory was instrumental in solving this problem. He also extended Waterman's null-field approach to handle layered objects of increasing complexity. In 2002, Staffan became an IEEE Fellow for his contributions to the null-field approach to multiple-scattering problems.

Staffan made several important contributions to the URSI community during almost three decades, and he encouraged his students early in their careers to participate in URSI activities and conferences. This engagement in URSI – both nationally and internationally – was extended when Staffan was appointed the Chair in Stockholm. In particular, his engagement with the Swedish National Committee (SNRV) – one of the national committees under the auspices of the Royal Swedish Academy of Sciences (KVA) – increased, and this commitment had a major impact on the development of radio science in Sweden. Under his chairmanship (1994-2005), SNRV became an active network for mutual cooperation, crucial for a nation like Sweden, which wanted to remain in the forefront of radio science and telecommunication applications. Moreover, Staffan also strengthened the Nordic collaborations in the field, especially with our Finnish radio scientists. Staffan became an honorary member of the SNRV after his retirement.

Internationally, Staffan played an important role in URSI. He organized the Electromagnetic Field Symposium in Stockholm in 1989. During 1999-2002, he was the Chair of Commission B (Fields and Waves), with special responsibilities to organize the Electromagnetic Field Symposium 2001 in Victoria, Canada. As Chair, he was also in charge of the activities in the Commission B program at the URSI GA in Maastricht 2002.

Staffan had a remarkable talent for making his graduate students feel happy, important, and inspired in their endeavors towards the PhD. His friendly, diplomatic, and modest personality also made our many visiting scientists feel recognized and appreciated. The atmosphere in the group was easy going, relaxed, and full of humor, and it was always a pleasure to go to work with Staffan as a leader.

Staffan was a passionate sailor, and he owned several yachts through the years. When the weather and time permitted, he spent his leisure time in the archipelagos of Göteborg and Stockholm, and further out on the Baltic Sea. Staffan also shared a love for art and music with his wife, Charlotta.

With the death of Staffan, Sweden lost a great leader and scientist, and we who have been fortunate to interact with Staffan mourn him. Fortunately, his scientific work remains, and it will inspire future generations of radio scientists.

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Call for Papers for a Special Issue on "Wireless Power Transmission: From Short-Distance Near-Field Implantable Devices to Solar Power Satellite Systems"

Submission deadline: September 15, 2017

The URSI *Radio Science Bulletin* (*RSB*) is soliciting papers for this special issue, tentatively scheduled for publication in December 2017 (depending on the number of papers accepted for publication, two issues may be involved).

Current research, development, and implementation activities in wireless power transmission (WPT) techniques and systems span the range from short-distance, near-field implantable devices, to very-long-range applications such as solar-power satellites (SPS). RF, ultrasonic, microwave (MW), laser, and hybrid transmission mechanisms are employed. WPT activities concern numerous experts in radio science and often involve diverse multidisciplinary subjects. The purpose of the special issue is to provide an overview of ongoing WPT R&D activities worldwide, and to examine future perspectives. Members of most URSI Commissions should therefore consider contributing to this special issue.

Topics of interest for the *RSB* special issue include but are not limited to the following:

- Near-field (induction, radiation) power transfer
- Coils, resonators, and antennas for short-distance WPT
- Applications of short-distances WPT systems
- Medically implanted ,biological devices and electronic tags for WPT
- Energy harvesting for wireless sensor networks
- Near-field and far-field WPT propagation as a function of frequency
- High-frequency power transmitters, antennas, and devices for WPT
- High-efficiency rectifying circuits and devices for WPT systems
- Rectennas and rectenna arrays
- MW transmission and control of beamforming for WPT systems
- Terrestrial WPT long-distance systems
- Atmospheric and weather effects as a function of WPT frequency
- SPS and space/aeronautic applications
- WPT standardization, regulations, and biological-hazard effects
- Co-location of radio communications, radar, and WPT systems
- RFI mitigation techniques for WPT systems
- Design of long-distance WPT systems

Potential authors are invited to submit draft papers in PDF format to one of the Guest Editors below. The submission deadline is **September 15, 2017**. Preliminary acceptance notification is planned by October 15, 2017. Final manuscripts are due by November 15, 2017.

Guest editors for the WPT special issue:

Prof. Nuno Borges Carvalho (e-mail: nbcarvalho@ua.pt) from the University of Aveiro Portugal,which is leading the European COST1301 on WPT

Prof. Moti Haridim (e-mail: mharidim@hit.ac.il), Vice President of Holon Institute of Technology (HIT) Israel and member of COST 1301

Prof. Jacob Gavan (e-mail: jacobg@sce.ac.il), head of the Communication Engineering section at the SCE College of Engineering in Ashdod, Israel, and former Dean of the Faculty of Engineering of HIT.

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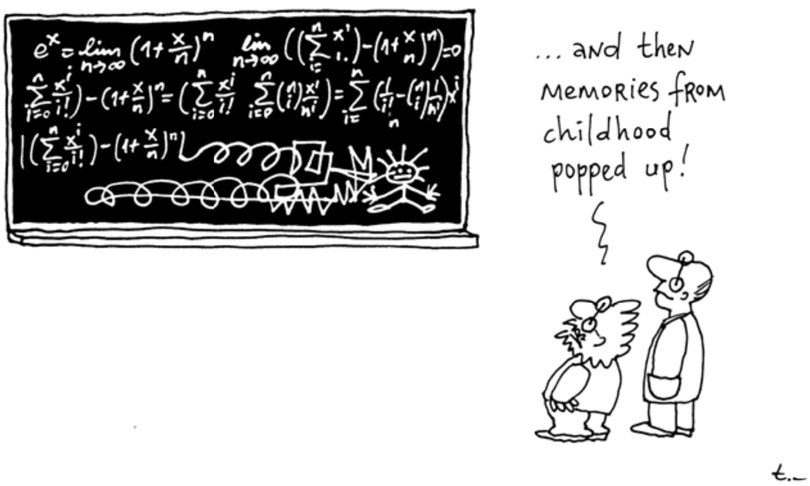

Call for Papers

The 7th IEEE International Symposium on Microwave, Antenna, Propagation, and EMC Technologies (MAPE 2017)

October 28-30, 2017 Xi'an China

The Symposium will take place in celebration of the information-era milestone. The aim of the Symposium is to provide a multidisciplinary forum for the corresponding engineers and scientists. The topics of the symposium will cover all of the interesting theory and techniques of microwaves, antennas, propagation, and EMC.

The symposium is sponsored by the IEEE Beijing Section and Beijing Jiaotong University. You are cordially invited to summit papers to this important event in engineering and science, and to meet colleagues from around the world in 2017 in China, where there are more potential challenges and opportunities for electronic and electrical engineering, science, and technology.

Scope: Contributions describing original research, surveys, and applications in these and other areas are solicited:

1. **Electromagnetic Field and Microwave Technologies**
   - Electromagnetic Theory
   - Metamaterials
   - Complex Media and Artificial Media
   - Computational Electromagnetics
   - Optimization Methods in EM Design
   - Passive and Active Circuits
   - Power Amplifiers, Linearization, and Active Components
   - MMICs and Microwave Circuits
   - Microwave and Millimeter-Wave ICs
   - Millimeter-Wave and Sub-Millimeter-Wave Components, Circuits and Systems
   - Waveguide Structures
2. **Antennas and Propagation**
   - Microstrip Antennas
   - Array Antennas, Phased Arrays, and Feeding Circuits
   - Adaptive and Smart Antennas
   - Ultra-Wideband, Broadband, and Multi-Band Antennas
   - Reconfigurable Antennas and Arrays
   - MEMS/Nanotechnology for antennas
   - RFID
   - Millimeter- and Optical-Wave Propagation
   - Earth-Space and Terrestrial Propagation
   - Ionospheric Propagation
   - Propagation and Channel Characterization
3. **Signal Processing, Coding, or Waveforms**
   - Error Control Coding
   - Blind Signal Processing Technology
   - Bandwidth-Efficient Modulation
   - Orthogonal FDM
   - Space-Time Codes
   - Analog-to-Digital Conversion
   - Signal Separation and Interference Rejection
   - Signal Processing Tools for Ad Hoc, Multi-Hop, and Sensor Networks
   - Information Fusion
4. **Electromagnetic Compatibility**
   - EMC/EMI Prediction, Visualization, and Education
   - EMC Test and Measurement
   - EMI Control Technology
   - EMC Standards
   - Lightning, ESD and EMP
   - Biological Effects and Medical Applications
   - Spectrum Management
5. **Micro-Electronic Devices, Circuits, and Systems**
   - New Materials
   - Design, Simulation, and Analysis
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   - Circuits and Sub-circuits for RF/IF/baseband
   - TV/Radio/Mobile/Satellite Chips
   - Advanced Process, Packaging, and Integration Technologies
6. **Radar and Remote Sensing**
   - Remote Sensing
   - Wireless Sensors and Ad Hoc Networks
   - SAR Polarimetry and Interferometry
   - Subsurface Sensing
   - Remote Sensing with GNSS & Integrated Systems
7. **Communication, Information, and Control Technologies**
   - 4G/LTE/5G Mobile Wireless Systems
   - Communications in High-Speed Railways
   - Train Control Systems Based on Communication
   - Driverless and Automatic Train Operation
   - Computer Simulation Techniques
   - Monitoring and Maintenance

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Solution Box

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SOLBOX-05

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1. Introduction

In this issue, a new set of problems (SOLBOX-05) is introduced. Relatively large arrays of metallic wires are considered as transmission lines to carry electromagnetic patterns along distances long with respect to wavelength. The main challenge is related to the electrical sizes of the problems, which lead to relatively large numbers of unknowns, even when surface formulations are used. In addition, it is required to compute the near-zone electromagnetic fields in the vicinity of the wires, which might be difficult to accurately achieve (e.g., with 1% maximum error). The arrays are modeled as finite (50 × 50 wires with finite lengths), while the wires are periodically arranged. On the other hand, the sample solutions that are also included in this issue do not directly use the periodicity. Hence, these solutions with an accelerated algorithm (the Multilevel Fast Multipole Algorithm) are feasible but slow. Alternative solutions of the same problems by other solvers, possibly exploiting the symmetry, are welcome.

2. Problems

2.1 Problem SOLBOX-05

(by B. Karaosmanoğlu and Ö. Ergül)

As depicted in Figure 1, two different arrays of 50 × 50 metallic wires for transmitting electromagnetic power patterns were considered. Each wire had a square cross section of 0.1 μm × 0.1 μm. The wires were regularly arranged with 0.1 μm gaps in the transverse (x and y) directions. Two different lengths for the wires were considered: 2.4 μm and 4.8 μm. The overall sizes of the first and second arrays were therefore 9.9 μm × 9.9 μm × 2.4 μm and 9.9 μm × 9.9 μm × 4.8 μm, respectively. The arrays were investigated at 250 THz in free space (the wavelength was approximately 2.4 μm), and the wires were modeled as perfectly conducting closed surfaces. For the excitations, a total of 344 Hertzian dipoles, which

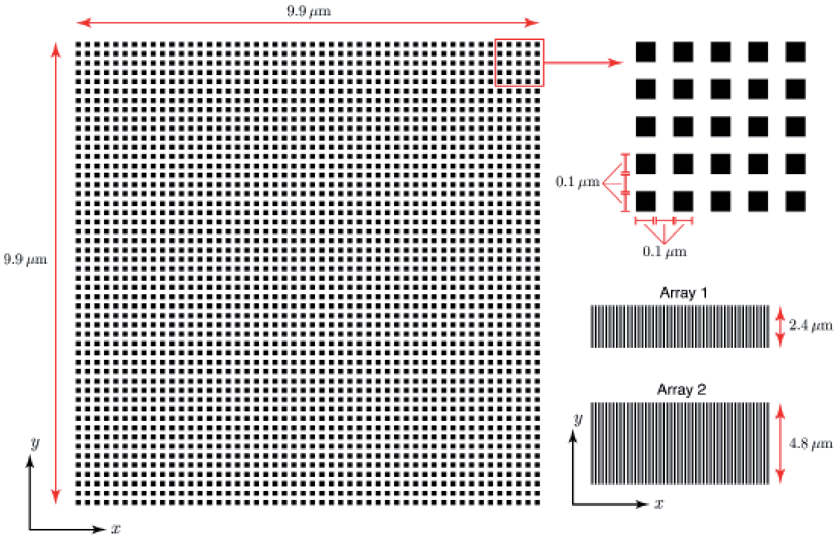

Figure 1. The geometry of the arrays involving 50 × 50 wires periodically arranged. The lengths of the wires were 2.4 μm for the first array, and 4.8 μm for the second array.

were arranged to generate an M-shaped pattern, were used. The locations of the dipoles with respect to the arrays, as well as their orientations, are described in Figure 2. The distance between the dipoles and wires was 0.2 μm. It was desired to find the electric-field intensity, the magnetic-field intensity, and the power density at different locations along the wires, especially in comparison to the free-space radiation of the dipoles.

3. Solution to Problem SOLBOX-05

3.1 Solution Summary

Solver Type (e.g., noncommercial, commercial):
Noncommercial research-based code developed at CEMMETU, Ankara, Turkey.

Solution core algorithm or method: Frequency-Domain Multilevel Fast Multipole Algorithm (MLFMA).

Programming language or environment (if applicable):
MATLAB + MEX + Parallel Toolbox

Computer properties and resources used:
Two 2.5 GHz Intel Xeon E5-2680v3 processors, using 16 cores

Total time required to produce the results shown (categories: < 1 sec, < 10 sec, < 1 min, < 10 min, < 1 hour, < 10 hours, < 1 day, < 10 days, > 10 days):
< 10 hours (smaller array) and < 10 days (larger array)

3.2 Short Description of the Numerical Solution

Problem SOLBOX-05 was solved by using an in-house implementation of the MLFMA in the frequency domain [1]. The transmission problems were formulated with the electric-field integral equation (EFIE) for accurate analysis of the thin wires. The EFIE was discretized with

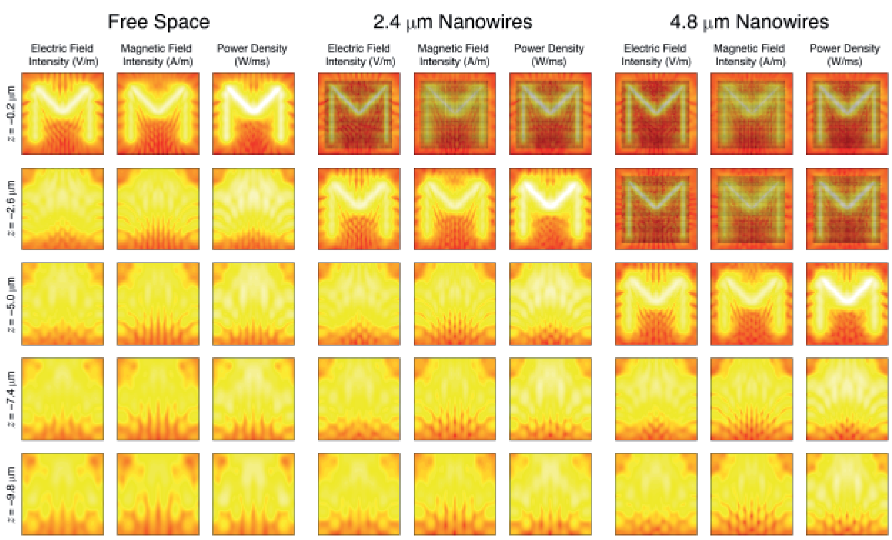

Figure 2. The Hertzian dipoles used to excite the wire arrays. The dipoles were arranged to generate an M-shaped pattern.

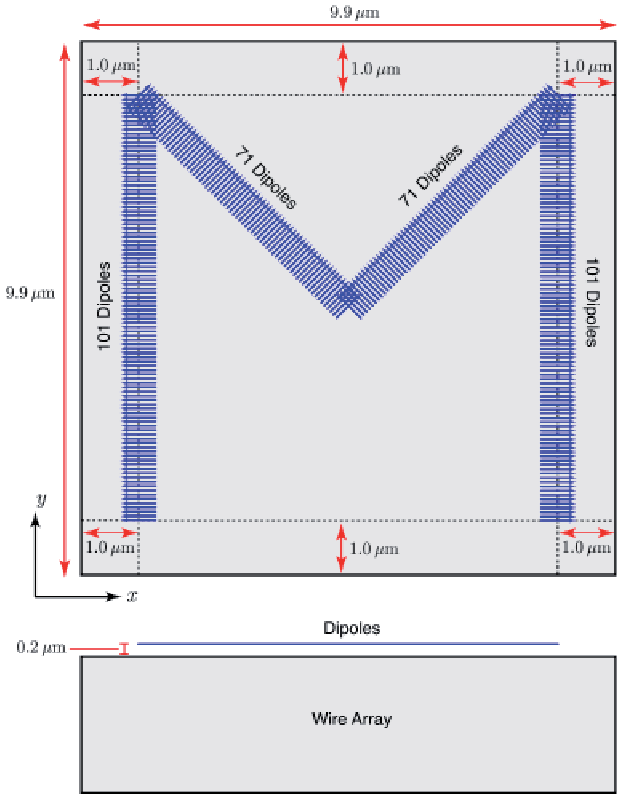

Figure 3. The near-zone electric-field intensity, magnetic-field intensity, and power density along the wire arrays, compared to the free-space radiation from Hertzian dipoles. Depending on the size of the array, the M-shaped pattern could be transmitted to long distances.

the standard Rao-Wilton-Glisson functions [2] on triangular meshes. The total numbers of triangles were 430,000 and 850,000 for the smaller and larger arrays, respectively, leading to 645,000 and 1,275,000 unknowns. The MLFMA with six levels was used on 16 cores, using the worker system of the parallel toolbox (*MATLAB*). The MLFMA was parallelized using the three-dimensional hierarchical strategy [3, 4]. All interactions were calculated with 1% maximum error. For this purpose, near-field interactions were calculated by employing singularity extraction [5] and Gaussian integration. The same integration techniques were also used when calculating the near-zone fields once the coefficients expanding the electric current were found. In the context of the MLFMA, far-field interactions were computed via aggregation-translation-disaggregation loops, using plane-wave expansion for the radiated and incoming fields. The numbers of harmonics and samples were determined via the excess-bandwidth formula [6]. Interpolations and anterpolations between the levels were carried out with the Lagrange method, using 4×4 stencils. Using the bi-conjugate gradient stabilized (BiCGStab) method without preconditioning, 1047 and 1905 iterations were required for the smaller and larger problems to achieve 0.005 residual error. These large numbers of iterations (due to the ill-conditioned matrix equations derived from the traditional EFIE and the lack of preconditioning) were the main reasons for the relatively long solutions times (11.5 hours and 48.8 hours, respectively, categorized as < 1 day and < 10 days in Section 3.1). The accuracy of the solutions was reliable, and was tested via the equivalence theorem.

3.3 Results

Figure 3 presents the near-zone electric-field intensity, magnetic-field intensity, and power density along the wires. Using the dB scale, the dynamic ranges were [10,80] (dBV/m) for the electric field, [–40,30] (dBA/m) for the magnetic field, and [–10,50] (dBW/ms) for the power. Assuming that the dipoles were located at 0.2 μm and the wires started at 0.0 μm, the field and power values were sampled on the planes at $z = -0.2$ μm, -2.6 μm, -5.0 μm, -7.4 μm, and -9.8 μm. On each plane, a total of 241 × 241 samples were used. The results showed that in free space (the first three columns of Figure 3), the pattern quickly deteriorated away from the dipoles, leading to an undecipherable pattern at -2.6 μm. By using 2.4 μm wires, it became possible to maintain the readability until -2.6 μm. It was hence observed that the wires effectively carried the pattern along their axes. Using 4.8 μm wires further increased the transmission of the pattern, leading to good resolution at -5.0 μm. It was remarkable that once the electromagnetic fields were coupled to free space at the end of the wires, the patterns quickly deteriorated.

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Golden Versus Platinium Rules

Randy L. Haupt and Amy J. Shockley

One of the lectures in our senior design course covers the Platinum Rule. Of course, I had heard of the Golden Rule before, but the Platinum Rule was new to me. I therefore found myself researching the topic in order to prepare for my next lecture. For the uninformed reader, the distinction between these two rules is:

Golden Rule: Treat others as *you* want to be treated.

Platinum Rule: Treat others as *they* want to be treated.

I assume whoever named the rule "platinum" was implying that it is superior to the Golden Rule. From my experience with airline status, credit cards, etc., "platinum" trumps "gold" status. Out of curiosity, I checked on the prices: gold was US$40.36/g and platinum was US$30.50/g. Wait a minute: that means gold is 32% more expensive than platinum. In order to solve this dilemma, I had to go to *Wikipedia* for more information. Platinum has the symbol Pt and atomic number 78 on the periodic table, compared to gold with the symbol Au and the atomic number 79. Platinum was discovered in 1735, while gold may have been discovered around 6000 B.C. My additional research concluded that gold weighs more than platinum, was discovered earlier, and has more historical relevance. Why is platinum considered superior?

Platinum rings are more expensive, but this is largely due to the purity of the materials. Platinum jewelry is typically 95% pure platinum, whereas 18k gold is only 75% gold, and 14k is merely 58.5% gold. Even though platinum and gold are precious metals, platinum is the stronger and more durable of the two. Last year, my wife lost the diamond in her engagement ring because a gold prong broke. That is why engagement rings today are typically made with platinum prongs.

The difference between the Golden and Platinum Rules is one of perspective. You know how you would like to be treated, so in applying the Golden Rule, it is easy to concoct an approach on how to treat others. However, the Platinum rule requires that you gain an understanding of the other person in order to determine how they want to be treated before developing your approach in dealing with them. In short, the Platinum Rule requires more communication and empathy.

Which approach is better? The overwhelming opinion on the Internet is that the Platinum Rule wins this battle. The logic is based on empathy, and can be summed up by saying: "Our diverse world requires that you make the effort to take into account another person's perspective and background before interacting with them." The Platinum Rule may seem superior in theory; however, problems arise with the application. Finding out what somebody wants is often tricky: hence the need for gift receipts. We also live in an increasingly narcissistic society, so the wants of the other person are not always reasonable. This reminds me of the quote from an unknown author, "Just because someone doesn't love you the way that you want them to, doesn't mean that they don't love you with everything they have." Perspective can be a problem with both rules. If you have a warped opinion of yourself or other people have a warped opinion of themselves, then these rules only provide a relative standard for interactions, and may not work well at all.

In the end, both rules provide simple guidance for interacting with others. Perhaps the best approach is the Golden Rule applied with a touch of empathy.

European School of Antennas 2017

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ANTENNA MEASUREMENTS FOR MILLIMETER AND SUBMILLIMETER WAVELENGHTS
AALTO - Espoo, May 8-12
Coordinator: A. Raisanen

INDUSTRIAL ANTENNA DESIGN
IMST- May 15- 19
Coordinators: W. Simon – D. Manteuffel

LARGE SCALE RADIO PROPAGATION
UCL, Leuven June 12-16
T Kuerner, V. Degli Esposti, C. Oestges

ANTENNA SYNTHESIS
UNINA - Naples, June 19 - 23
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ANTENNA IMAGING TECHNOLOGIES
TUDelft - Delft, June -26-30
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Coordinator: O. Breinbjerg

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METASURFACES and METATRONICS
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Coordinator: M. Salazar, D. Segovia

ANTENNA AND RECTENNAS FOR IOT APPLICATIONS
UCA, Nice, 6-10 November
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INTEGRATION of SIMULATION AND MEASUREMENTS METHODS IN ANTENNA DESIGN
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An Editorial

The NIEHS/NTP Study to Evaluate the Toxic and Carcinogenic Potentials of Mobile-Phone RF Radiation

On May 26, 2016, a US-government-led project reported occurrences of two types of rare cancers in laboratory rats exposed to radio-frequency (RF) radiation used for wireless mobile-phone operations [1].

This five-year project has been ongoing for more than 10 years, with a currently-estimated price tag of $25 million or more of US taxpayers' money (two to three times its original budget). That is huge! It is the largest health-effect study ever undertaken by the National Toxicology Program (NTP) of the National Institute of Environmental Health Sciences (NIEHS).

Observation of malignant gliomas in the brain and schwannomas of the heart from two-year (or lifelong, in most cases) RF-exposed rats represented partial findings from the project. Results reportedly were reviewed by expert peer reviewers selected by NTP and the National Institutes of Health (NIH).

The NIEHS/NTP's announcement of animal results from their large RF health-effect study is major: in 2011, the World Health Organization's International Agency for Research on Cancer (IARC) classified exposure to mobile-phone RF radiation as a possible carcinogen to humans. The classification was based on epidemiological studies reporting increased cancer risks among heavy or long-term users of cell phones.

The IARC had assessed available scientific papers, and concluded that while evidence was incomplete and limited, especially with regard to results from animal experiments, epidemiological studies reporting increased risks for gliomas (a type of malignant brain cancer) and acoustic neuromas (a non-malignant tumor of Schwann-cells-sheathed auditory nerves) among heavy or long-term users of mobile phones were sufficiently strong to support a 2B classification of possibly cancer-causing in humans for exposure to RF radiation.

The classification of possibly carcinogenic to humans is third on the IARC groupings of carcinogenic risk to humans. The highest category is Group 1, which is reserved for agents that are carcinogenic to humans. It is followed by Group 2A: probably carcinogenic to humans; 2B: possibly carcinogenic to humans; then Group 3: not classifiable as to its carcinogenicity to humans; and lastly, Group 4: probably not carcinogenic to humans.

Reactions have been swift, startling, and disconcerting. Some mainstream media opined that use of mobile phones does not lead to cancer. The NTP report was just hype, pure and simple. In contrast, the American Cancer Society, among others, considered the NTP report as signifying a paradigm shift in the understanding of RF radiation and cancer, reversing its previous position.

How can this be?

To be sure, no new or any single study can be taken in isolation. Indeed, a large database of published research already exists. However, a number of published animal cancer studies on RF exposure have been equivocal and controversial. The inconsistencies have posed uncertainty to assessments of health risks from RF exposure.

The NTP project was developed to challenge the limitations of previous animal studies on the potential of non-thermal RF exposure to cause chronic health effects such as cancer under controlled laboratory conditions. Its goal was to provide a major contribution of scientific knowledge on a very important public-health issue. Complete results from the NTP studies have been belatedly promised by the end of 2017.

According to NTP, the early offer of partial findings was prompted amid other factors by the widespread global usage of cellular mobile devices among users of all ages, as a very small increase in the incidence of cancer resulting from exposure to mobile-phone RF radiation could have broad implications for public health. There is also a high level of public and media interest regarding the safety of mobile-phone RF radiation. Early release of the results (ahead of submission to, and publication in, a scientific journal) was thus seen practically as a public-health obligation.

On that basis, some observers have decided that the findings would change the conversation, and allow people to point to much more hard evidence to say that mobile-phone RF exposure does pose a health risk. Nevertheless, a number of questions may be raised about the reported study, even though the study is the single, largest, and most comprehensive study of laboratory animals exposed to mobile-phone RF radiation.

Rhetoric aside, there are some rather puzzling issues surrounding the project.

Note that the mobile-phone RF exposure of rats and mice research project is the largest and most expensive animal health effects study ever undertaken by NTP [2]. However, it was sole-sourced through a contract to an industrial firm, with an estimated budget of $12 million for a five-year duration. (The life spans of rats and mice are about two years.) Moreover, at the time, the contractor did not appear to have any prior experience in conducting research involving biological or health effects of laboratory animals exposed to RF radiation.

However, available evidence shows that in due time, and prior to awarding the sole-sourced contract, NIEHS/NTP officially received a 30-page written proposal from a major research university presenting their interest and capability in response to NTP requirements. The submitted proposal indicated that they have a newly renovated and expanded animal facility, have in place essential features necessary to conduct GLP studies on chronic toxicity/carcinogenicity of RF radiation in large groups of rats and mice (e.g., environmentally controlled animal rooms, necropsy room, histology laboratories, quality assessment group, etc.), and expertise and staff to care for and process large numbers of animals (e.g., RF exposure and dosimetry engineers, toxicologists, pathologists, veterinarians, animal-care technicians, pro-sectors, histologists, etc.). The proposed principal investigator (PI) was a well-known leader with more than 30 years of research experience at the time, conducting multidisciplinary research in biological and health effects of RF and radiation. He had listed 150 journal publications in that field.

In addition to the PI, the team included toxicologists, chemists, engineers, exposure specialists, veterinarians, health and safety officers and quality assurance unit officers on staff (and could appoint, if additional support was needed) at the university. The physical and organizational propinquity could greatly facilitate the daily interaction and constant coordination of efforts needed among the disciplinary areas throughout the in-life portion of the studies.

Nevertheless, NIEHS/NTP decided against conducting a competitive procurement. In summary, the basis was that "the capability statement submitted does not demonstrate capability nor sufficient experience to perform the project described in the NTP statement of work on the toxic and carcinogenic potential of mobile phone RF radiation in laboratory animals." The specific rationale provided was "although the PI has many years of experience in RF radiation," there is no evidence "indicating that he has ever managed and coordinated a multidisciplinary health effects research project approaching the magnitude of that described in the NTP on studies to evaluate the chronic toxicity and carcinogenicity of mobile phone RF radiation. An RF toxicology study led by the PI and highlighted in the capability statement because it was deemed to be 'similar to the NIEHS-NTP solicitation' was conducted 25 years ago." Moreover, "it is unclear how the PI will have adequate time to devote to all of his proposed roles in this project; he is proposed at 100% effort."

The bizarre and obvious paradox aside, this judgment is beyond perplexing if one recognizes that the sole-sourced contractor did not have any prior experience in conducting research involving biological or health effects of RF radiation on laboratory animals at all. Verdicts on facilities also included, "Most important, the laboratories that were proposed to participate in this project do not have a facility that could properly house the 14 reverberation chambers" required for these studies. The university proposed to "construct the RF reverberation exposure chambers in modular units," adjacent to its Toxicology Research Laboratory, Biological Resources Laboratory and in the proposed RF exposure facility.

This was a non sequitur! It was patently clear: the unique NTP-required facility did not exist anywhere in the entire world, and they knew it. If not newly constructed, extensive remodeling would be required of any comparable existing facility to accommodate the RF reverberation exposure chambers.

Facts speak louder, as always. It appears to have taken more than a few years for the sole-sourced contractor to finish installation of the reverberation chambers in their exposure facilities: it was likely one of the principal culprits for the huge budget overrun and excessive delay in project completion from five to more than 10 years.

Moreover, NTP's reporting of occurrences of two types of cancers in RF-exposed rats (malignant gliomas in the brain and schwannomas of the heart) may have been somewhat of a challenge, or perhaps an extant dilemma. John Bucher, the associate director overseeing the NTP study, shared with North Carolina's leading newspapers (*Charlotte Observer* and *Raleigh News & Observer*, in January 2010) that he "doubts scientific research can demonstrate a link between cell phones and cancer." Bucher was quoted as saying, "I anticipate either no correlation or, if anything is seen at all, it won't be a strong signal" [3]. NIEHS and NTP are located in Durham, North Carolina.

Furthermore, Ronald Melnick spent the last decade of his career at NIEHS planning and designing the NTP cell-phone animal exposure project. Before retiring in 2009, he had sole-sourced the massive project through a contract. In a recent *Microwave News* article on the NTP mobile-phone cancer report [4], Melnick was quoted as saying, "The study had low power and was more likely to show no effect. The fact that it did makes the results more compelling." This statement begs several questions. Given the NTP contract stipulation that these studies shall be conducted in accordance with the current "Specifications for the Conduct of Studies to Evaluate the Toxic and Carcinogenic Potential of Chemical, Biological and Physical Agents in Laboratory Animals for the National Toxicology Program," does it mean that all NTP health effects studies are designed to have low statistical power, or had Melnick designed and planned for the NTP mobile-phone cancer study to have low statistical power? Worse, should anyone trust NTP's reputation on identification of chemical and other environmental carcinogens, based on such low statistical power in their experimental design? Are 90-100 animals per exposure group small in toxicology and cancer studies involving thousands of animals in total? Typically, these kinds of projects are regarded as large animal studies.

In a written response to a *New York Times* article on the NTP mobile-phone health-effects study [5], Melnick [6] stated that the author of the *Times* article was "probably unaware that the design of this study was presented at an annual meeting of the Bioelectromagnetics Society prior to the start of these studies." It should be noted that while meeting participants considered a comprehensive study of animals exposed to mobile-phone radiation as important, the vast majority of opinions expressed was that use of reverberation chambers for RF exposure was inappropriate. It is fraught with potential complications in terms of maintaining RF field uniformity, as number, mass, and movement of animals vary over time and space; uncertainties of animal housing, feeding, watering, and waste disposal; and changes in environmental conditions including mechanical factors, among others, inside the chambers. There may even be better ways to do it. Obviously, NTP paid no attention to them and proceeded anyway.

Another intriguing attribute of this NTP investigation, which took effect in 2005, as a five-year project with a budget of $12 million, was that it quickly became very guarded. Everyone involved was mum about it. NIEHS had refused to release any progress reports or project documents [7]. The lack of transparency was palpable. In contrast to scientific norms, there were no presentations of any results at any scientific meetings. At a minimum, one would expect years ago NTP to have presented and discussed such topics as design, performance, and measurement of exposure fields in the unique reverberation chambers, and dosimetric characterization of specific RF absorption rates (SAR) in exposed animals. However, none was forthcoming until the sudden announcement in May. Meanwhile, the five-year project has carried on for more than 10 years, and the $12 million sole-sourced contract has ballooned to a budget of exceeding $25 million, so far.

Is it possible that, right or wrong, NIEHS/NTP appears to have determined to do their own thing, and draw their own conclusions as to the "Studies to Evaluate the Toxic and Carcinogenic Potential of Cell Phone Radio Frequency Radiation"?

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Women in Radio Science

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Introduction from the Associate Editor

This time, I present Margaret Campbell-Brown, Associate Professor of Physics and Astronomy at the University of Western Ontario, and a member of the very successful Western Meteor Physics Group in Canada.

I met Margaret for the first at the Meteoroids 1998 Conference in Tatranská Lomnica in Slovakia, where she was presenting her work on light curves from shower meteors. She was at that time very young, just finishing her Bachelor in Science degree, but she already sounded like a mature scientist. Apparently her early childhood interests in stars contributed to her self-confidence to take the right steps heading towards an astronomer career, starting with profound math and physics studies at the university.

Margaret has had one of the straightest career paths within our field. Some of us from the "hippie-time" generation have previously described within this column that we could never imagine, during our early studies, that we would reach the positions we finally ended up in. That is, of course, a wonderful adventure, but I think it is good that young girls can also systematically plan for a scientist's career. Margaret gives here two important issues from her own experience: young female students should not think they are not smart enough, and teachers should remember to encourage enthusiastic students.

Margaret always gives very clear presentations at the conferences. She is a very successful teacher and supervisor at all levels, from undergraduates to postdocs. In addition, she has a wonderful family, with two young children, and succeeds to manage all this. Here comes her story.

Stars and Dinosaurs

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There is a joke that there are two paths by which children decide to be scientists: stars and dinosaurs. This is obviously not true for everyone, but an interest in astronomy certainly started me on my academic career in meteors.

Although the skies near Montreal are very light-polluted, I loved going outside to look at the stars. My father gave me his star chart, and my mother a pair of binoculars with which I could find the fainter stars in the background glow. I would spend hours in the backyard, hunting down the brightest deep-sky objects. Ironically, I was never very successful at meteor observing.

I decided quite early to take a lot of math and physics, since I had read that those were important things for an astronomer to learn, and I was encouraged by my science teachers. This encouragement was very important when I first met calculus, which I found daunting at first, but soon decided wasn't so very difficult. When it came time to go to university, I decided to go to a small but well-regarded school in a small town near the east coast of Canada. Mount Allison University did not have an astronomy program, but the physics program had a good reputation.

There were no female professors in the Physics Department, and just one other female student. However, classes were small (sometimes only five students in upper-year physics), and very collaborative. It was a very supportive environment, which I enjoyed immensely.

It turned out that there was one professor who did astronomy research at the school: Dr. Robert Hawkes had a small but important meteor-research program. Since the university had no graduate students in Physics, undergraduates had many research opportunities. I was fortunate to work for Bob for two summers, in which I recorded video meteor data, watched the tapes to find the meteors, and then carefully digitized and analyzed the data.

To that point, I had not been involved with radio science at all. In 1997, in my final year at Mount Allison, the Leonid meteor shower started ramping up activity in advance of the parent comet's perihelion passage two years later. I was invited to come along on an observing campaign to the Mohave Desert in California, organized by a graduate student working with Bob Hawkes' supervisor, Jim Jones, at the University of Western Ontario. Although Peter Brown was young, he had a passion for meteors and a gift for organizing international campaigns. I helped to run the video equipment, but looked in on the radar that was running at the same time.

In spite of this, I still nearly missed being involved with radio science. I was still set on being a regular astronomer (one who studies stars or galaxies), and applied and was accepted to grad school, working with a noted astronomer on star formation. Just after I'd received the acceptance, I traveled to Western to give a talk on my Leonid meteor analysis to the international group that had participated in the observing campaign. Jim Jones pulled me aside and asked if I wouldn't rather come there and do meteor science. Within the day, I had let my original supervisor know I wouldn't be coming, and submitted my application to Western.

Over the next three years, I helped to put together the Canadian Meteor Orbit Radar, which has been running continuously ever since. I did my PhD on observing biases of transverse-scatter meteor radars, which gave me an excellent practical and theoretical understanding of radar scattering from plasmas in the atmosphere. It also gave me time to get to know my fellow student, Peter Brown, better, and we were married a month after I received my PhD.

My research now is mostly on optical observations of meteors, but I keep my hand in by calculating radar fluxes of meteor showers, which involves all the fascinating complexity of scattering off the 20 km long plasma produced by interplanetary grains smaller than a millimeter. Balancing work and two young children is challenging at times, but it helps to have a spouse whose research is so close to one's own: we can cover for each other at work when there's an emergency at home.

Although many women face overt discrimination when they choose a male-dominated field, there are more subtle ways women turn away from these careers, as well. Physics and calculus are challenging in the first year or two of learning. Studies show that women are more likely to believe they are struggling because they aren't smart enough, while young men attribute their difficulties to the material itself. At this stage, it is important to encourage students to keep in mind their goal: if their enthusiasm for the goal is strong enough, it may get them through a difficult term or two. I try to keep this in mind when mentoring the students in my classes. A bit of extra encouragement may be all that is needed to keep a promising young researcher engaged until she finds her place.

Introducing the Author

Margaret Campbell-Brown is an Associate Professor of Physics and Astronomy at the University of Western Ontario. Born and raised in Montreal, she received a BSc from Mount Allison University in New Brunswick, Canada, and a PhD in Physics from the University of Western Ontario in 2002. After postdoctoral work at the European Space Agency (ESTEC) and the University of Calgary, she came back to the University of Western Ontario in 2005 as faculty. She teaches both Physics and Astronomy courses at the university, and does research with her colleagues in the Meteor Physics Group and her graduate students. The group is partly funded by the Meteoroid Environment Office at NASA Marshall, with whom they work closely.

Margaret's research interests include optical observations of meteors, particularly observing fragmentation, modeling of meteoroid ablation in the atmosphere, and meteoroid flux measurements with both optical and radar observations. Uncharacterized observing biases in both observing techniques keep her happily busy.

Early Career Representative Column

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Introduction by the Associate Editor

In the previous issue of this column (in the June 2016 *Radio Science Bulletin*), Ross Stone, Phil Wilkinson, and I described the process of academic publishing. This column is its sequel, in which we concentrate on the ethical issues involved in that process. Based on my own, still limited, experience as a reviewer for several journals, and as an Associate Editor for the journal *Radio Science*, I can already testify that the actors involved in the academic publishing process are required quite regularly to reflect on such ethical issues. I therefore hope that this column will help to make readers (again) aware of these important matters.

I am again very grateful to Ross Stone, who allowed me to use a recent column written by himself and Levent Sevgi on academic publishing in the *IEEE Antennas and Propagation Magazine* as a starting point. That column already contained a lot of useful material concerning ethical issues with which authors may be confronted, such as duplicate submission and plagiarism. We have extended the column by also reviewing ethical issues concerning reviewers and (associate) editors, such as conflicts of interest.

As this column also aims to provide room for short announcements for events that are of particular interest to young scientists, I would like to bring the Young Scientist Program and the Student Paper Competition (SPC) of the upcoming 2017 URSI General Assembly and Scientific Symposium (GASS) to the attention of the readers. The Young Scientist Program provides a number of awards to assist young scientists in attending the GASS. These young scientists must be less than 35 years of age on September 1, 2017, and should have a paper submitted and accepted for a regular session of the GASS. In the SPC, ten finalists will be chosen based on the quality, originality, and scientific merit of the submitted paper. All of them will be recognized at the banquet. The top five will present their papers in a special SPC session, where their presentations will be judged on clarity, adherence to time, accessibility to the wide audience of URSI radio scientists, and the ability to answer questions on the work. For more information about the Young Scientist Program and the SPC, please visit the URSI GASS Web site at www.ursi2017.org. I am looking forward to meeting you in Montreal!

Ethical Issues in Academic Publishing

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Abstract

In this sequel to a previous article on the academic-publishing process, we discuss the ethical issues involved in that process. The integrity of academic publications needs to be safeguarded by the actors involved, in particular the authors, reviewers, and editors. Here, we review the key responsibilities of authors, reviewers, and editors, addressing issues such as duplicate submission and publication, plagiarism, and conflicts of interest.

1. Introduction

The academic and scientific publishing process involves many actors, whose roles were described in a previous article [1]. The authors, the reviewers, and the editors involved in this process have an obligation to safeguard the integrity of the process. The purpose of this article is to review appropriate practices for authors, reviewers, and editors in the context of scientific ethics and integrity. Many of these issues fall into the category of ethical issues, but they also are issues about which the major academic publishers (including the AGU, the publisher of the URSI-supported journal *Radio Science*) have developed policies. As was the case for the previous article, this article was based on a recent article in the *IEEE Antennas and Propagation Magazine* on academic publishing [2]. However, we chose to discuss the ethical issues in a separate article to allow for space to extend the discussion to cover reviewers and editors.

The material in this article should be useful for both those who are new to academic publishing, such as students, and those who have experience publishing papers. Based on the growing number of incidents of violations of policies related to publication ethics that Editors-in-Chief (EiCs) have seen in recent years, it is apparent that many well-meaning (and experienced) authors may be unfamiliar with these policies.

The author resources for *Radio Science* provide a link to the document on *AGU Scientific Integrity and Professional Ethics (SIPE)* [3]. This article uses those AGU guidelines as a starting point. Other academic publishers, such as the IEEE, have their own policies. In the case of the IEEE, those policies are spelled out in the *IEEE PSPB Operations Manual* [4]. These policies and those of other academic publishers often have a substantial degree of overlap among their basic principles. This article has therefore been organized around the roles of the main actors.

2. The Role of the Author

2.1 Authorship: Who Is (and Is Not) An Author

The *AGU SIPE* document states that authors have an ethical obligation to

> include as coauthors only those persons who have made significant scientific contributions to the work, and determine order of authorship in a manner appropriate to the contribution. All coauthors share responsibility for the quality and integrity of the submitted and published manuscript.

Note that a manager, an advisor, or a funding sponsor who has not made a significant intellectual contribution to the work reported in an article would not qualify for authorship. Such authorship is referred to as *honorary authorship* or *gift authorship*. Although not explicitly spelled out in the AGU policies, it is usually also considered unethical to deny authorship to people who contributed to the work, as this denies those *ghost authors* due credit for their work. IEEE policies make it clear that omitting a qualified author is unethical.

2.2 The Responsibilities of Authors

The *AGU SIPE* document contains a section on the ethical obligations of authors and contributors of papers submitted to AGU publications. This section reviews a number of these obligations that are directly related to the publication process. We will treat duplicate submission and publication, as well as plagiarism, in separate sections.

Because all authors should have made a significant contribution to the work, any part of the article must be the responsibility of at least one author. However, the *AGU SIPE* document also states that the corresponding author should "ensure that all coauthors are fully cognizant of the steps and changes in the manuscript during the review and that all authors agree to the final version of the manuscript." This implies that all authors of a published paper should either have approved the material that is published under their name, or have had the opportunity to remove their name from the author list if they did not and if the dispute could not be settled amongst the authors before publication. As a result, all authors can be – and are – held accountable for all work submitted under their name. This is important. There have been a number of cases in which an author's name was added to an article without his or her knowledge. In some cases, this was an example of *gift authorship*, as mentioned above; in other cases, it was done in an attempt to enhance the apparent stature of the list of authors. This has led to significant trouble when there were problems with the article. There have also been cases where an advisor allowed his or her name to be put on an article without carefully reading the article. When the article was subsequently found to contain errors – or worse, plagiarism – the advisor was held equally as responsible as the others listed as authors.

When an article is revised and resubmitted, all coauthors should be asked to approve the revised version. While a coauthor has the right to remove his or her name from an article at any time, an author's name should not be removed without his or her permission. Similarly, adding an author after an article has been initially submitted should only be done in cases where an honest error or omission was made, and the person being added meets the requirements for authorship. Before publication of an article, the AGU carries out an e-mail check with each author to confirm their status.

Where an article has multiple authors, the order of the authors is at the discretion of the authors. Some authors choose to list authors in the order of the perceived importance of their contribution to the work reported. Some list authors alphabetically. Some use other criteria. However, once the order of the authors and the list of the authors has been established, it should not be changed without the permission of all of the living authors.

Those starting out in their career should give some consideration to the order in which their name is listed on publications. Some institutions give more "credit" to publications where an author's name is listed first. The validity of that is very questionable, given that at least the AGU and the IEEE (along with some other academic publishers) leave the order of listing of authors up to the authors, themselves.

Those starting out in their career should also give careful consideration to how they list their name on publications. The key point is to be consistent: you want search engines, indexers, and all of the various citation mechanisms to be able to consistently find your articles as belonging to you. As an example of what not to do, listing yourself as W. Stone, W. R. Stone, R. Stone, and W. Ross Stone on different papers would be likely to result in those papers being identified with four different authors. Since "Ross" is not an uncommon family name, even W. R. Stone and W. Ross Stone could result in confusion (even though in this case, Ross is a given name). Similar considerations apply when a name change occurs (e.g., due to a change in marital status).

Fortunately, the use of unique identifiers for authors has become more widespread. ORCID (orcid.org) is one example. Another, similar problem occurs for those whose native language is not based on the English alphabet (of course, that is the majority of the world). The issues with languages such as Chinese, Japanese, and Korean are obvious, but even the inherent importance of accents in names in such languages as German and Spanish have created problems for systems that weren't designed to recognize them. Fortunately, some publishers now have support for rendering author names in their native language in submitted papers (see, e.g., [5]).

Authors have a responsibility to report any possible conflict of interest to the Editor-in-Chief. It should be noted that these conflicts of interest may concern not only publication of the results presented in the article, but may also affect the underlying research, itself. Some publishers, such as the IEEE, expect authors to disclose such potential conflicts of interest to the readers as well, by requesting the authors to mention both financial support for the work being reported on and financial support for themselves in an article. Any potential conflict of interest should be identified and explained.

Authors have a responsibility to describe the methods and processes used in performing the work reported in an article in sufficient detail to allow someone else to duplicate the work. This can be a problem when proprietary methods or processes are involved. However, if such considerations so preclude giving an adequately detailed description of the work that it cannot be properly evaluated, then it probably cannot be published. Such issues should be raised during the review stage.

The AGU has a clear policy on data underlying publications [6]:

> ...all data necessary to understand, evaluate, replicate, and build upon the reported research must be made available and accessible whenever possible.... authors are expected to curate the above data for at least 5 years after publication and provide a transparent process to make the data available to anyone upon request.

Ideally, the authors should lodge the data with a data center. Some publishers actually give the author the option to upload supporting material along with their paper that is put into the publisher's online repository as files associated with that publication (the IEEE is one publisher that does this). This allows authors to provide multimedia content to the readers of their article, for example. It can also be used to publish the simulation code used for the simulations reported in the paper, or to publish a small data set.

2.3 Duplicate Submission and Publication

Regarding duplicate submission and publication, the *AGU SIPE* document states: "Avoid unnecessary fragmentation or redundant publication of research reports to artificially increase the number of publications." To appreciate the broad scope of this statement, it is useful to take a look at the website of the Committee on Publication Ethics (COPE, publicationethics.org), which is referred to on the AGU Web site. Duplicate submission concerns papers that have already been submitted or even have been published, but are submitted again to a different journal.

Note that the AGU explicitly refers to fragmentation. Unfortunately, this is a quite common practice in many fields. For example, many discussions on duplicate submission emerge when a conference paper presenting a new idea is extended to a full journal paper. In such cases, it is good practice to cite and summarize the original publication and explain what is the novel contribution of the new publication (indeed, this is a requirement of IEEE policy). The reviewers and editors then have to judge whether the novel contribution warrants a new publication. This can be done by a very pragmatic test: If a researcher spent the time to find both the original conference paper and the subsequent journal paper, would the researcher feel adequately rewarded by the amount of additional information in the journal paper? If so, then the journal paper probably contains sufficient new contributions to justify publication.

Another form of fragmentation is writing multiple papers presenting different views of the same data. Although this may be useful in some cases, it is often most helpful for readers to get a single, complete story about those data presented in a single piece of work. If you feel you are forced to split a paper into multiple parts due to page limits, that would be a good issue to discuss with the EiC of the journal to which you are planning to submit the material.

Duplicate submission is not permitted. *The key to totally avoiding any problem with duplicate submission is full disclosure.* If an article is submitted and some portion of it has been published in some manner, or is under submission somewhere else, then disclosure of that in the article (and to the EiC of the publication at the time of submission) removes any ethical issue for the author. It then becomes the decision of the EiC as to whether to accept the submission.

Some authors have tried submitting the same article to two or more publications at the same time, with the idea of allowing the publication that first accepted the article to publish it (this appears to be most common among students who are new to academic publishing). The plan is often to then withdraw the submissions from the other publications. This is a clear violation of the AGU guidelines and of IEEE policy. In addition, it is unfair to the reviewers and editors who have to invest a significant amount of time in the reviewing each submitted paper. If this is discovered (and the chances that this will be discovered are quite high), it usually results in immediate rejection of the paper and frustrated reviewers and editors. This is not usually helpful in getting the paper published in any of the publications involved. In the case of the IEEE, such actions are considered serious author misconduct, and repeated incidents can lead to consequences such as being barred from publishing in any IEEE publication for a period of time.

2.4 Plagiarism

The IEEE defines plagiarism as [4, Sec. 8.2.1.B.7] "the use of someone else's prior ideas, processes, results, or words without explicitly acknowledging the original author and source." Note that this isn't limited to copying someone else's words without adequate credit. It extends to the use of ideas, processes, and results. If you use someone else's work, you have to give them proper credit. If you don't, it is plagiarism.

The *AGU SIPE* document is very clear about plagiarism: "Never plagiarize the work of others or your own work. Always provide appropriate citation." Again, the documents on the COPE Web site provide lots of useful material on this subject.

Unfortunately, plagiarism has become a far-too-common problem in academic and scientific publishing. Many publications therefore use a tool such as *CrossCheck* (http://www.crossref.org/crosscheck/ index.html). *CrossCheck* compares the text of a submitted article to the *CrossCheck* database, as well as to material on the Web. The *CrossCheck* database contains millions of published articles made available by a very large number of academic and scientific publishers. *CrossCheck* returns a score indicating a cumulative percentage of overlap between the submitted article and the articles in the *CrossCheck* database, and shows the overlap with each article. If that score exceeds a threshold set by the publication doing the checking, an individual (typically, the Editor-in-Chief or an associate editor) reviews the identified overlapping material.

Some identified overlapping situations are benign. For example, it is common for totally independent articles to cite the same papers as references, and depending on its settings, *CrossCheck* may find those same cited references and flag them as overlapping material. The level of plagiarism can vary greatly, from a quotation for which the source is cited but that is not properly delineated, to un-credited copying of (almost) an entire article. The penalties for plagiarism vary accordingly, ranging from authors having to write an erratum to being permanently banned from publishing with AGU (and possibly other publishers, in very serious cases).

It is perhaps worth commenting on one practice that is certainly not intended as plagiarism, but can end up being interpreted as plagiarism. If English is not the first language of an author, writing a scientific paper in English can be difficult. There have been instances in which authors have "written" papers by taking sentences that say what the authors needed to say from papers that have been published, and putting them together to create a new paper (sometimes changing a few words, as needed). Given the ability to search for phrases on the Web and the cut-and-paste capabilities of browsers and word-processing software, this actually is not that difficult to do. Unfortunately, such a process will almost certainly guarantee a very high "overlap" score in *CrossCheck*. Is this plagiarism? In one sense, it is, although that is probably a question best left for ethicists to argue. Regardless, it is not a good practice in writing a scientific paper, because the authors are not learning how to efficiently express themselves. A much better practice is to spend time using grammar tools and the thesaurus that most word processors provide (although care has to be used with these). Many publishers' Web sites also list services that will provide English-language editing and proofing for scientific papers by skilled editors at relatively modest cost.

3. The Role of the Reviewer

3.1 Objectivity

Reviewers play a crucial role in the academic-publishing process. The AGU Web site refers to the *COPE Ethical Guidelines for Peer Reviewers* [7], and the AGU has included a summary of those guidelines in the *SIPE* document. Although authors may disagree with the outcome of the reviewing process, there should be no disagreement with the fairness of that process. This requires reviewers to be objective.

In the rest of this article, the term "(associate) editor" will often be used. This is meant to refer to an Editor-in-Chief or an Associate Editor, as well as to the other editors who are given other titles by different publications. The term refers to anyone who has editorial responsibility within the publication.

The *COPE Ethical Guidelines for Peer Reviewers* provide a number of requirements that should ensure the objectivity of the reviews. Reviewers should "only agree to review manuscripts for which they have the subject expertise required to carry out a proper assessment." Reviewers should not agree to review a manuscript the subject matter of which lies (largely) outside their area of expertise. Because many journals require their reviewers to judge this based purely on the abstract of the manuscript, it may only become apparent during the review that the manuscript falls outside the reviewer's area of expertise. In such cases, the reviewer should report this to the (associate) editor handling the manuscript. If reviewers decide to perform a review of a manuscript that falls partly outside their area of expertise, they should clearly indicate which parts of the paper they could not properly judge due to lack of expertise. This allows the (associate) editor handling the manuscript to search for another reviewer to cover those parts of the manuscript or judge those parts personally.

According to the *COPE Ethical Guidelines for Peer Reviewers*, reviewers should "declare all potential conflicting interests, seeking advice from the journal if they are unsure whether something constitutes a relevant interest." The AGU is happy to assist in this. Typical conflicts of interests include working at the same institution, or on the same project, or having recently had a mentor-mentee relationship.

In a single-blind review process, the identity of the authors is known to the reviewers, but the identity of the reviewers is not known to the authors unless the reviewers opt for disclosure. An assessment of potential conflicts of interests can be made at the time one is invited to review an article with a single-blind review process. In a double-blind review process, the identities of both authors and reviewers are not disclosed. In the case of a double-blind review process, potential conflicts of interest may only become apparent during the review. As before, the appropriate action for the reviewer is to contact the (associate) editor handling the manuscript to report that the reviewer has a suspicion of a conflict of interest. Finally, one should always be aware of the possibility of a *perceived* conflict of interest. In some cases, such a perception can be considered as equally undesirable as an actual conflict of interest.

According to the *COPE Ethical Guidelines for Peer Reviewers*, reviewers should "not allow their reviews to be influenced by the origin of a manuscript, by the nationality, religious or political beliefs, gender or other characteristics of the authors, or by commercial considerations." In other words, reviews should be unbiased, and should focus on the content of the paper. Providing an unbiased review is more difficult than one may think due to unconscious biases. One piece of evidence for the presence of such unconscious biases was provided by Snodgrass [8], who made a comparison between the results of single-blind and double-blind review processes. The evidence presented in [8] and references therein indicated that double-blind reviewing removed several potential biases from the process, including biases related to gender and related to prominence or publishing history in the field. The IEEE Antennas and Propagation Society's annual Student Paper Contest has used double-blind reviewing since 2009, and the data from the experience with that contest support similar conclusions [2].

3.2 Confidentiality

Because manuscripts are written to present new ideas for which the authors would like to receive due credit, all actors involved in the publishing process should treat the manuscript confidentially. They should not disclose its contents, or even the fact that a manuscript from a certain research group is under review, as this could put the author(s) at risk of being "scooped" by another author. The *COPE Ethical Guidelines for Peer Reviewers* therefore state that "peer reviewers should respect the confidentiality of peer review and not reveal any details of a manuscript or its review during or after the peer-review process, beyond those that are released by the journal."

This confidentiality also concerns the personal research activities of the reviewer, and those of the reviewer's research group and institution. In other words, the reviewer should "not use information obtained during the peer-review process for their own or any other person's or organization's advantage, or to disadvantage or discredit others" (*COPE Ethical Guidelines for Peer Reviewers*).

3.3 Timeliness and Politeness

There is significant pressure on many authors to get their work published in a timely manner. One example of such pressure is a situation where the extension of an author's appointment depends on timely publication. Most publications therefore strive to reduce the time between submission and publication to a reasonable and predictable period. This requires reviewers to provide their reviews in a timely manner.

To ensure this, the (associate) editor handling the manuscript typically asks the reviewers to provide a review within a certain timeframe. If the reviewer cannot complete the review within the indicated timeframe, the reviewer should indicate this to the (associate) editor. This will allow the (associate) editor to decide whether an extension can be given for the review, or whether another reviewer, who can do the review in time, needs to be sought. Although the timeframe proposed by the (associate) editor may initially seem reasonable, unforeseen circumstances during the review period may cause delays in completing the review. The reviewer should report such delays to the (associate) editor as soon as possible, and preferably provide an indication of the date by which the review can be completed.

Even if the reviewer finds that the manuscript should be rejected for publication, the review should be written in a manner respectful to the authors. In the *COPE Ethical Guidelines for Peer Reviewers*, this is formulated as follows: "peer reviewers should be objective and constructive in their reviews, refraining from being hostile or inflammatory and from making libelous and derogatory personal comments" and reviewers should "recognize that impersonation of another individual during the review process is considered serious misconduct." Similarly, should an author receive a review he or she finds unacceptable, that is not a license to heap scorn on the reviewer. All parties should also realize that cultural differences can escalate a tactless or thoughtless comment into a significant insult.

4. The Role of the (Associate) Editor

4.1 Objectivity

The Editor-in-Chief has full responsibility for the editorial processes for his or her publication. A key aspect of this responsibility is the responsibility for acceptance or rejection of manuscripts submitted to the publication. According to the *AGU SIPE* document, the editor should therefore "provide unbiased consideration to all manuscripts offered for publication, judging each on its merits without regard to personal bias, race, religion, politics, nationality, gender, seniority, or institutional affiliation of the author(s)." A personal bias may have many causes, and recognizing it requires the ability to reflect on one's own thoughts. This matter becomes even more difficult in cases in which others may perceive a bias. In case of doubt, the (associate) editor is advised to consult another (associate) editor, or to even delegate responsibility of a manuscript to another (associate) editor.

In the guidelines for editors, the *AGU SIPE* document explicitly mentions several possible causes of bias. Besides the causes mentioned in the previous paragraph, (perceived) conflicts of interests should obviously be avoided. This issue was already discussed in Section 3.1. However, an (associate) editor should not only be aware of his/her own conflicts of interests, but should also be vigilant concerning conflicts of interest between reviewers and authors.

An interesting class of papers are papers reporting results that are at variance with the dominant paradigm, or that present null results. Regarding those papers, the *AGU SIPE* document states that such papers "should be given full and equal consideration based upon the criteria of importance, originality, clarity and relevance."

The importance of having clear criteria is nicely illustrated by the example given in [2], in which the Editor-in-Chief had to handle a situation in which the reviewers (and possibly the associate editor handling the paper) disagreed on what to do with a manuscript. In such cases, the Editor-in-Chief needs to first assess whether he or she is technically competent to decide among the differing opinions. If so, he or she should read the article and make a decision. If not, the Editor-in-Chief should obtain additional input from one or more competent reviewers to resolve the issue.

Interestingly, if an Editor-in-Chief becomes directly involved in such situations, makes a decision based on specific criteria, and communicates those criteria to the author, there usually are no significant problems. Authors may disagree with the result, but if the criteria are reasonable and are clearly and objectively stated, it is hard to disagree with the fairness of the process. In contrast, problems almost always arise when an Editor-in-Chief does not become involved in such situations. When a decision is made where there obviously are conflicting criteria, such a decision is likely to appear arbitrary to the author. That is rarely interpreted as a fair process by an author. Problems also often arise when the reasons for a decision are not fully and clearly communicated to an author.

4.2 Timeliness and Confidentiality

Because timeliness of publication is important, the (associate) editor should process all manuscripts promptly, and should try to avoid unnecessary delays in all steps of the publication process. This may require the (associate) editor to remind reviewers to submit their reviews in a timely manner. If it turns out that a reviewer is not able to comply with that request, the (associate) editor has to decide how to handle that situation. Depending on circumstances, the (associate) editor may invite a new reviewer, or may make a decision based on the already-submitted reviews.

An (associate) editor also has an important role in ensuring the confidentiality of the review process. The *AGU SIPE* document therefore states that the (associate) editor should "never disclose information about a manuscript under consideration to anyone other than those from whom professional advice is sought." As (associate) editors usually handle more papers than reviewers, the guideline to not use information or ideas from papers under consideration for one's own or one's institutional interests should be respected even more carefully.

Despite the thoroughness of the academic-publishing process, it may still happen that an error is found in an already-published paper. In such cases, it is in the interest of the scientific community that such errors are corrected as quickly as possible. The (associate) editor should therefore "quickly facilitate publication of errata to correct erroneous information in a published report" (*AGU SIPE* document).

5. Conclusions

In this article, we reviewed the key responsibilities of authors, reviewers, and (associate) editors in ensuring the integrity of academic publications. Academic publications should present unbiased information, and should give due credit where appropriate. To ensure objectivity, all actors involved should be aware of the possibility of both real and perceived conflicts of interest. In addition, authors should avoid duplicate submission and publication, should avoid plagiarism, and should carefully consider the authorship of papers. Reviewers and editors should work together to ensure the confidentiality, objectivity, and timeliness of the review process. Only when all of the aforementioned who are involved in the publication process adhere to the ethical principles formulated by the AGU and other scientific organizations can readers of academic publications have confidence in the results presented therein.

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2017 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting
San Diego, CA
July 9th-15th, 2017

The 2017 IEEE AP-S Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting will be held on July 9-15, 2017, at the Manchester Grand Hyatt hotel in San Diego, CA. The symposium and meeting are cosponsored by the IEEE Antennas and Propagation Society (AP-S) and the US National Committee (USNC) of the International Union of Radio Science (URSI). The technical sessions, workshops, and short courses will be coordinated between the two organizations to provide a comprehensive and well-balanced program. This meeting is intended to provide an international forum for the exchange of information on state-of-the-art research in antennas, propagation, electromagnetic engineering, and radio science. The paper-submission deadline is **January 16, 2017**.

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www.2017apsursi.org

Paper Submission

Authors are invited to submit contributions for review and possible presentation at the symposium or meeting (the “conference”) on topics of interest to AP-S and USNC-URSI, including advancements and innovations in the fields of electromagnetics, antennas, and wave propagation. Suggested topics and general information are listed on the Web site. In addition to regularly scheduled sessions for oral and poster presentations, there will be a student paper competition, as well as special sessions, workshops, and short courses that will address timely topics and state-of-the-art advancements in these fields. AP-S submissions must be in standard IEEE two-column format, and must be two pages in length. USNC-URSI submissions may be in either a one-page, one-column format with a minimum length of 250 words, or in the IEEE two-page, two-column format with a length of two pages. In all cases, only accepted and presented submissions that are in the IEEE two-page two-column format and substantially fill the two pages will be submitted for possible inclusion in IEEE Xplore, if the author chooses submission to Xplore. All accepted and presented submissions will appear in the proceedings distributed at the conference. The presenting author will be required to register for the conference by April 7, 2017, in order for their paper to be included in the conference. A complete list of AP-S and URSI topics, as well as detailed instructions including formats and templates, are available on the conference Web site: **www.2017apsursi.org**

AP-S Student Paper Competition

Eligible entries in the Student Paper Competition must have only one student author, and that student must be the first author. Each additional coauthor must submit a signed letter indicating that his/her contribution is primarily advisory. Letters must be in PDF format and must be uploaded to the symposium’s student paper Web site in the indicated area at the time the paper is submitted. All Student Paper Competition entries will be evaluated using a double-blind review process, in addition to the normal review process used for regular submissions. Detailed instructions are available on the conference Web site. For additional information, contact Mona Jarahi (mjarrahi@ucla.edu).

Special Sessions

Requests to organize special sessions should be submitted to Kathleen Melde (melde@email.arizona.edu) no later than **October 9, 2016**. Each proposal should include the title of the special session, a brief description of the topic, an indication of whether the proposed session is for AP-S, USNC-URSI, or is joint, and justification for its designation as a special session. All proposals should be submitted in PDF format. Special sessions will be selected and finalized by the end of November 2016. At that time, additional instructions will be provided to the organizers of the special sessions chosen for inclusion in the conference. The associated papers or abstracts will be due **January 16, 2017**. A list of special sessions will be posted at the symposium Web site in December 2016.

Exhibits

Industrial, academic, and book exhibits will be open June 11-13, 2016. Exhibitor registration and additional information can be found on the conference Web site.

Short Courses/Workshops/Tutorials

Several short courses and tutorials on topics of special and current interest will be solicited by the technical program committee and organized for the conference. Individuals who wish to organize a short course or workshop should contact Ethan Wang (ywang@ee.ucla.edu) or Satish Sharma (ssharma@mail.sdsu.edu) by **November 14, 2016**.

Report on MICRORAD 2016

In April 2016, the 14th Specialist Meeting on Microwave Radiometry and Remote Sensing of the Environment (MicroRad 2016) took place in Espoo, Finland. It was hosted and sponsored by the Aalto University, which is the biggest technical university in Finland. The General Chair of the meeting was Martti Hallikainen, who organized a wonderful event in the charming location of Otaniemi. The conference venue was the historical main building of Helsinki University of Technology. This is now the center of Aalto University technology campus in Otaniemi, which is a beautiful example of architecture by the famous Finnish architect, Alvar Aalto.

MicroRad represents a unique gathering, where the microwave radiometry community has an opportunity to present new missions, research results, technological advances, and innovations in the field of passive microwave remote sensing. It is jointly sponsored by the Center for Microwave Remote Sensing (Ce.Te.M.) and the IEEE Geoscience and Remote Sensing Society (GRSS), and co-sponsored by URSI Commission F.

The symposium always attracts scientists and engineers from all over the world. It was first organized in Italy in the late 1980s. It has been planned alternatively in Italy and the US every second year until 2014. This was the first time the meeting was held outside of this alternation, in agreement with a decision of the MicroRad Permanent Steering Committee.

MicroRad 2016 lasted four days (April 11-14). 125 persons registered for and attended it, presenting both oral talks and posters. Scientists came from many nations worldwide (Europe, US, Australia, and Asia). Several sessions were organized on microwave radiometry spanning different topics: from future missions to applications of satellite data to atmosphere, land, and oceans. Interesting poster sessions were organized in the hall in front of the session room where coffee breaks took place, in order to facilitate the attending of posters.

Figure 2. One of the tables at the banquet at the Restaurant Sipuli.

The first three days were opened by an invited lecture. The first lecture was given on Monday by Simon Yueh (JPL): "SMAP Mission and Science Recovery Status." The second lecture, on Tuesday, was by Ville Kangas (ESA): "Current and Future Microwave Radiometers at ESA." The last lecture, on Wednesday, was by Jianchen Shi (RADI-CAS): "Monitoring Vegetation with Microwave Radiometers."

The meeting was also integrated with amusing social events. The opening reception (Figure 1) was held in Espoo the afternoon of Monday, after the last oral session of the day. The City of Espoo sponsored a reception on Tuesday at the Tapiola Cultural Center, close to the conference venue. Mr. Harri Tanska, Director of Espoo City Public Works, welcomed attendees at the reception. Finally, a charming dinner was held on Friday in Restaurant Sipuli (Figure 2). This is a restored red brick warehouse, located

Figure 1. Martti Hallikainen (c), with Elena Lobl (l) and Roger Lang (r).

Figure 3. (l-r) Rajat Blindish, Paolo Pampaloni, and Vinia Mattioli during the presentation of the Golden Florin Award.

Figure 4. (l-r) Paolo Pampaloni, Dara Entekhabi, Jaan Praks, and Martti Hallikainen.

next to the Uspenski Cathedral. During the banquet, Paolo Pampaloni, the Chair of the Golden Florin (Fiorino Oro) Award Committee, announced an award to Tom Jackson, who unfortunately was not able to attend the meeting and was represented by Rajat Bindlish (Figure 3). The Golden Florin is an award presented every two years to individuals who have made outstanding contributions to research in passive microwave remote sensing throughout their careers and are members of IEEE GRSS. The award is sponsored jointly by the Center for Microwave Remote Sensing (Ce. Te.M.) and the IEEE GRSS.

The local organizing committee was comprised of Martti Hallikainen (General Chair), Jaan Praks (Technical Chair), Jaakko Seppänen, Jari J. Hänninen, Sari Haapiainen-Laine, Kati Gustafsson from Aalto University, and Juha Kainulainen, from Harp Technologies Ltd. The Steering Committee was comprised of the historical members of past MicroRad meetings. Some of the members of both the local and steering committees are pictured in Figure 4.

On Friday morning, a technical tour to Aalto University was organized. It started with a visit to the remote sensing and nano-satellite facilities in the EE Building, and then proceeded to selected laboratories on campus.

In conclusion, we had a great four days of oral and poster presentations, discussions, events – and splendid weather (Figure 5)! A very-well-organized Web site was set up, where a nice gallery of photos is now available, at http://www.microrad2016.org/Photos. Proceedings papers, based on papers submitted, registered, and presented at MicroRad, are now available on IEEE Xplore. A special issue was organized in the *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* (*JSTARS*).

The MicroRad Steering Committee met on Thursday, April 12, at lunchtime to decide the future MicroRad organization. Shannon Brown, Leila Guerriero, Roger H. Lang, David M. Le Vine, Giovanni Macelloni, Frank Marzano, Simonetta Paloscia, Paolo Pampaloni, Steven C. Reising, Ed R. Westwater, and Martti Hallikainen attended the meeting. During this meeting, it was decided that the next MicroRad meeting will be organized by Dara Entekhabi at MIT in 2018.

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Figure 5. The meeting participants.

Workshop on "Metrology for Aerospace" and "URSI in Italy"

On the wings of success of the first two editions of the IEEE International Workshop on Metrology for Aerospace (MetroAeroSpace), a third edition was proposed for the purpose of strengthening the collaboration among researchers working in the field of instrumentation and measurement methods for aerospace. The third edition of MetroAeroSpace was held in Firenze, Italy, June 21-23, 2016. The cradle of the Renaissance and appreciated by millions of tourists, Firenze has been a UNESCO World Heritage Site since 1982. Museums, palaces, and churches house some of the greatest artistic treasures in the world.

As in the previous editions, the focus was kept on the state of art and practice of metrology for aerospace. In particular, the focus was on (but not limited to) new technologies for metrology-assisted production in the aerospace industry; aircraft-component measurements, sensors, and associated signal conditioning for aerospace; and calibration methods for electronic test and measurement for aerospace. The program was designed to raise the interests of a wide group of researchers, operators, and decision-makers from the metrology and aerospace fields, by presenting the most innovative solutions both from the scientific and technological point of views.

The keynote speeches were given by experts in the field of metrology for aerospace:

- Dr. William H. Prosser from the NASA Engineering and Safety Center (Langley Research Center, USA) gave a talk about "Applications of Advanced Nondestructive Measurement Techniques to Address Safety Issues of Flight on NASA Spacecraft"

- Dr. Alessandro Cozzani, from the European Space Research and Technology Centre, described the "Trends and Research on Contactless Measurements for Environmental Testing of Space Systems"

The preparation of the technical program of the Third IEEE International Workshop on Metrology for AeroSpace was particularly challenging, since 155 abstracts were received from all over the world. The final program hosted 26 oral and poster sessions, scheduled over two days. Due to the time constraints of the conference, only 129 papers were selected based upon the review activity of the program committee and additional reviewers. Authors from 23 countries attended MetroAeroSpace. All the submitted papers were peer reviewed, and those accepted were made globally accessible via IEEE Xplore.

This edition of the workshop was improved with respect to previous ones by adding a significant number of special sessions. This was done for two reasons:

- There are so many fields of application of metrology for aerospace that a single track would have been much too dispersive

- In contrast to a unified definition of research in the field of metrology for aerospace, a spontaneous aggregation of well-focused themes was promoted, with the specific aim of providing a forum of debate relevant to each prominent research field.

In more detail, the technical program included several events and activities. This edition of MetroAeroSpace included for the second time:

- "Military Metrology for AeroSpace," a session organized in cooperation with the AFCEA Chapter of Naples, which took place at the Institute of Military Aeronautical Sciences in Firenze on June 21

- Three half-day tutorials on the following subjects:

  – "Precise Time Scales and Navigation Systems," Patrizia Tavella (INRIM and Vice Chair of URSI Commission A)

  – "RADAR Role: From the Underground to the Outer Space," Alfonso Farina, LFIEEE, BoG AESS

  – "Measurement for Planetary Exploration: Mars and Exomars," Stefano Debei, Center of Studies and Activities for Space, Padua, Italy

For the first time, MetroAeroSpace included demonstration sessions, providing an interactive and tangible form of presentation quite different from the usual oral and poster sessions. Static exhibitions of two military systems were offered:

- Unmanned SHADOW 200 - RQ-7B V2 by AAI/Textron Systems (organized by the Italian Army and Rigel srl - AAI/Textron Systems)

- SARAD - Automatic Data Analysis and Recording (organized by the Italian Navy)

During MetroAeroSpace, some sessions were organized for the purpose of providing attendees with the opportunity to contact institutions and experts operating in different fields of metrology for aerospace. In particular, the following sessions and meetings were held:

- "The Italian Strong Contribution to Epochal Rosetta Mission"

- The "Opus Suite" User Group meeting

- The "URSI Italian Committee meeting"

The URSI Italian National Committee meeting was attended by some twenty researchers working in universities and research institutes. Three presentations were given after that the session chair, Roberto Sorrentino, President of the URSI Italian Member Committee, introduced URSI activities in Italy.

The first presentation was a contribution from Commission J: "The Clock-Like Nature of the Radio Pulsars," from Andrea Possenti (INAF, Osservatorio Astronomico di Cagliari, Italy). Radio pulsars are highly magnetized and rapidly rotating neutron stars. Their radio beams can be detected as radio pulses when they sweep the line of sight to the observer, at the pace of the neutron star's spinning. Since some of the underlying neutron stars are ultra-stable rotators, the pulsed emission from the associated radio pulsar behaves as the tick of a natural clock. This property can be exploited for performing a variety of experiments of fundamental physics, as well as for establishing a terrestrial time scale entirely based on cosmic sources. The contribution reviewed methodologies and perspectives in this field.

The second presentation was a contribution from Commission F: "Use of Millimeter and Optical Wavelengths for Next-Generation Aerospace Communication Systems," from Carlo Capsoni (Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano, Italy). High-throughput satellite communication systems (HTS), providing multimedia service as well as space science missions, can greatly benefit from the use of very high frequency carriers (in the millimeter or even infrared bands), in order to take advantage of the larger bandwidths made available. Aeronautical applications aimed at distributing service information among air traffic control centers and aircraft for increasing flight security as well as providing global access to passengers to the Internet during travel also share the interest in these bands. The drawback of using very short wavelengths is the definite impact of the impairments caused by the troposphere. This contribution reviewed the advantages and disadvantages of these future systems, and the strategies required to move towards the operational phase.

The third and last presentation was a contribution from Commission E: "Proficiency Testing in EMC," from Carlo Carobbi (Dipartimento di Ingegneria dell'Informazione, Università degli Studi di Firenze, Italy). Achieving electromagnetic compatibility (EMC) for modern electrical and electronic equipment is not an easy task. This is mainly due the increasing need for efficient power conversion (high-frequency switching power supply), connectivity (ubiquitous radiofrequency communication modules), and fast processing of a relatively large amount of data (high-speed digital circuits) within the same equipment. EMC is a an even more critical issue in military, avionic, and space applications, where pieces of electrical and electronic equipment are subject to high power and broadband interference, must operate in close proximity, and must share the same ground and power supply. Furthermore, in these contexts, consideration of the safety and economic consequences of a possible failure due to electromagnetic interference during a military or space mission or a regular flight is mandatory. Due to these reasons, not only EMC-compliant design but also EMC testing requires a high degree of specialization and competence, especially in high-frequency measurement techniques.

At the same time, EMC testing is going through a process of continuous improvement. Such a process involves aspects such as traceability of measurement results, calculation of measurement uncertainty, and evaluation of measurement repeatability. The competence of EMC testing laboratories is formally recognized through assessment by a third party against the requirements of the ISO IEC 17025 standard, which mandates the implementation of a systematic approach to the above-mentioned aspects. In particular, assurance of the quality of test results requires some form of verification, which has to be experimental, i.e., complementary to documentation, and representative of the testing process carried out by the EMC laboratory. This is achieved through participation in proficiency tests, as clearly pointed out in terms of a specific requirement in clause 5.9.1, item b) of ISO IEC 17025. Proficiency tests are inter-laboratory comparisons specifically designed to evaluate participants' performance against pre-established criteria.

All the participants appreciated the variety of topics and applications covered by the URSI special session in MetroAeroSpace, a distinctive feature of URSI and its organization into ten scientific Commissions.

The next, fourth edition of MetroAeroSpace will be held in Padua, Italy, on June 21-23, 2017 (http://www.metroaerospace.org/). We are sure that this edition of MetroAeroSpace will also provide attendees with a unique opportunity for spreading their research results, gathering and connecting experts in metrology for aerospace from all over the world.

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9th International Kharkiv Symposium on Physics and Engineering of Microwaves, Millimeter, and Submillimeter Waves (MSMW'2016)

The MSMW'2016 symposium took place at V. N. Karazin Kharkiv National University, Ukraine, on June 21-24, 2016 (www.msmw.org.ua). 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: O. Ya. Usikov Institute for Radiophysics and Electronics of the National Academy of Sciences of Ukraine (IRE NASU); Scientific Council of the National Academy of Sciences of Ukraine on Radio-Physics and Microwave Electronics; Institute of Radio Astronomy of the National Academy of Sciences of Ukraine (IRA NASU); V. N. Karazin Kharkiv National University (KhNU); Kharkiv National University of Radioelectronics (KhNURE); Institute of Magnetism of NAS and MES of Ukraine (IM NASU); IEEE AES/AP/ED/EMB/GRS/MTT/NPS Societies East Ukraine Joint Chapter; European Microwave Association; and the International Union of Radio Science.

Technical cosponsors were the IEEE AES/AP/ED/EMB/GRS/MTT/NPS Societies East Ukraine Joint Chapter, the IEEE Ukraine Section, the European Microwave Association (EuMA), and the International Union of Radio Science.

The working days of the symposium were from June 21 to 24. Every day, the program started with a plenary session, where several invited lectures were presented. After that, three parallel sessions with contributed papers were held. The working language of the symposium was English. All symposium days contained social events. The number of registered participants was 175, including 157 scientists from Ukraine and 18 scientists from abroad (Turkey, Japan, Poland, Italy, USA, Mexico, Russia, Belarus, and South Africa). The total number of papers presented during the symposium was 215, including 21 invited talks.

The MSMW'2016 Proceedings were prepared in CD-ROM format. The program of the symposium program contained papers submitted by world-known experts in microwaves and shorter-wavelength science and technology.

The organizers thank the IEEE AES/AP/ED/EMB/GRS/MTT/NPS Societies East Ukraine Joint Chapter and the European Microwave Association (EuMA) for contributing to the symposium. The European Microwave Association provided a special grant for awards to the young scientists for the best presentations during the symposium.

June 21

The symposium started on June 21, 2016, with the opening ceremony (Figure 1). It began with the welcoming speech of Prof. Petr N. Melezhik, the MSMW'2016 Chair, Director of IRE NASU (Figure 2), Vice Chair of the Ukrainian National URSI Committee, and associate member of NASU. The second to address the participants was Prof. Valeri M. Shulga, Deputy Director of IRA

Figure 1. The MSMW'2016 opening ceremony.

Figure 2. Welcoming words from the symposium Chair, Prof. Petr N. Melezhik.

Figure 3. Prof. Toshitaka Idehara telling about high-power THz technologies.

NASU, Academician of NASU. He was followed by Prof. Sergiy M. Shulga, Dean of the School of Radiophysics, Biomedical Electronics, and Computer Systems of KhNU. Prof. Nickolay T. Cherpak (IRE NASU), Chair of the IEEE AP/MTT/ED/AES/GRS/ NPS Societies East Ukraine Joint Chapter, concluded the opening ceremony with his speech.

The first morning plenary session consisted of the following invited talks:

"High-Power THz Technologies Opened by High-Frequency Gyrations Covering Sub-THz to THz Region,"
T. Idehara, A. Kuleshov, E. Khutoryan, Y. Tatematsu, Y. Matsuki, T. Fujiwara, S. Asai, T. Suehara, T. Yamazaki, A. Miyazaki Fukui (Figure 3)

"Inverse Problems of Electromagnetic Sounding: Gradient Medium and Periodic Boundary"
N. Yashina, A. Brovenko, P. Melezhik, A. Poyedinchuk, A. Vertiy

"Ground-Based Millimeter-Wave Ozone Monitoring in Moscow During Sudden Stratospheric Warmings"
S. Rozanov, E. Kropotkina, S. Solomonov, A. Ignatyev, A. Lukin

"High-Frequency Methods for Applied Problems of Electromagnetic Wave Scattering"
O. Sukharevsky, V. Vasilets, S. Nechitailo, G. Khlopov

Figure 5. The symposium session, "Scientific, Industrial, and Biomedical Applications."

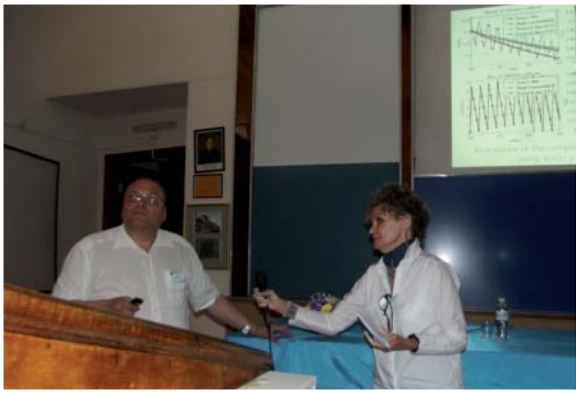

Figure 4. Prof. Oleg Drobakhin and Dr. Nataliya Yashina discussed techniques for measuring reflectivity in the microwave range.

"Techniques of Measuring Reflectance in Free Space in the Microwave Range"
O. Drobakhin, M. Andreev, D. Saltykov (Figure 4)

The Symposium continued with three parallel sessions, after lunchtime: Session A. "Scientific, Industrial, and Biomedical Applications" (Figure 5); Session B. "Radio Astronomy and Earth's Environment Study" (Figure 6); and Session C. "Vacuum Electronics" (Figure 7). The following invited papers were presented in Session C:

Figure 6. The symposium session, "Radio Astronomy and Earth's Environment Study."

Figure 7. The symposium session, "Vacuum Electronics."

Figure 8. The symposium's welcome party.

Figure 9. Prof. Vito Pascazio and Prof. Konstantin Lukin chairing the plenary session.

"The Qualitative Theory of Electron Beam Formation in a Surface Wave Magnetron"
G. Churyumov

"Spatial-Harmonic Magnetrons with Cold Secondary-Emission Cathode: Advances and Challenges"
D. Vavriv, V. Naumenko, K. Schünemann

The symposium's welcome party was organized at the university restaurant at 6:30 p.m. It gave the participants a perfect opportunity to converse in a friendly casual atmosphere (Figure 8).

June 22

The second day of the symposium started with a plenary session with the following invited talks:

"Resonant All-Dielectric Planar Metamaterials"
V. Khardikov, S. Mizrakhy, V. Tuz, S. Prosvirnin

"Diffraction of the THZ Radiation at Semiconductor and Metal Gratings. Theory and Experiment"
I. Spevak

"NMR and MW Techniques for Detection of Explosive and Illicit Materials"
B. Rameev, B. Aktaş

"Atomic Functions Theory: 45 Years Behind"
V. Kravchenko, O. Kravchenko, V. Pustovoit, D. Churikov, V. Volosyuk, V. Pavlikov

The Symposium continued working with three parallel sessions after lunchtime: Session D. "Antennas, Waveguide and Integrated Circuits;" Session E. "Solid State Devices, Waves in Semiconductors and in Solid State Structures, Radiospectroscopy;" Session F. "Artificial Materials: Metamaterials and Composite Structures, Terahertz Technologies." The following invited paper was presented in Session F: "Resonant Interaction of Electromagnetic Waves in the Defective Photon Crystal Bordering on Conducting Medium," N. Beletskii, S. Borysenko.

A walking tour was organized at the end of the day for all of the symposium participants. The tour was led by a famous Kharkiv guide, Max Rozenfeld.

June 23

The third day of the symposium started with a plenary session (Figure 9) with the following invited talks:

"Compressed Sensing for Imaging Radar and Radar Tomography"
V. Pascazio

Figure 10. Prof. Igor Lyubchanskii telling about superconducting photonic crystals.

Figure 11. The symposium session, "Wave Propagation, Radar, Remote Sensing, and Signal Processing."

Figure 12. The symposium session, "Microwave Superconductivity."

"Millimeterwave Noise Radar Tomography"
K. Lukin, P. Vyplavin, V. Palamarchuk, V. Kudryashev, S. Lukin, P. Sushchenko, N. Zaets, L. Yurchenko, D. Tatyanko, A. Shelekhov, O. Zemlyaniy, Yu. Shyian

"On the Nature and General Regularities of Optical Activity in Planar-Chiral Double-Layer Metamaterials"
A. Kirilenko, S. Prosvirnin, A. Perov, S. Steshenko, V. Derkach, N. Kolmakova, S. Prikolotin, D. Kulik

"Superconducting Photonic Crystals"
I. Lyubchanskii, N. Dadoenkova, Yu. Dadoenkova, A. Zabolotin, M. Krawczyk (Figure 10)

"Stepped Frequency Continuous Wave Ground Penetrating Radar Applications"
V. Sugak

The symposium continued with three parallel sessions after lunchtime: Session D. "Antennas, Waveguide and Integrated Circuits;" Session G. "Wave Propagation, Radar, Remote Sensing and Signal Processing;" Session H. "Electromagnetic Theory and Numerical Simulation.

That evening, the symposium banquet was held at the university restaurant. It was a great opportunity for the participants to remember the symposium's history, and to communicate in a friendly relaxed atmosphere.

Figure 14. The First Prize was awarded to Liubov Ivzhenko.

Figure 13. The MSMW'2016 symposium closing ceremony.

June 24

The fourth day of the symposium started with two parallel sessions: Session G. "Wave Propagation, Radar, Remote Sensing, and Signal Processing" (Figure 11); Session I. "Microwave Superconductivity" (Figure 12). The following invited paper was presented in Session I:

"Laser Scanning Microscopy of Superconducting Electromagnetic Metamaterials," A. Zhuravel, A. Ustinov, S. Anlage.

Plenary sessions continued the symposium program after a short coffee break, with the following invited papers:

"Spectral Polarimetric Method for Remote Sensing of Natural Environment"
F. Yanovsky

"Active-Passive Remote Sensing of Clouds and Liquid Precipitation"
G. Khlopov, O. Voitovych, S. Khomenko, A. Linkova, G. Veselovska, V. Kabanov, T. Tkacheva

"Modern Progress in the Area of Cylindrically Conformal Antennas: Theory, Design and Experiment"
A. Svezhentsev, V. Volski, S. Yan, Ping Jack Soh, G. Vandenbosch

Figure 15. A Second Prize was awarded to Simeon Zhyla.

Figure 16. Dr. Sergey Ponomarenko (l) receiving the award from MSMW'2106 Organizing Committee Co-Chair Dr. Mikhail Balaban.

The closing ceremony of MSMW'2016 started at 13:30 (Figure 13). The winners of the Young Scientist Paper Contest were first presented with the EuMA-MSMW prizes and certificates. This year, the European Microwave Association established a 1000 Euro fund to be awarded to the winners. This was divided into six prizes: one first prize, two second prizes, and three third prizes. The International Awards Jury consisted of the following members: Prof. N. Cherpak, Kharkiv, Ukraine; Prof. T. Idehara, Fukui, Japan; Prof. V. Pascazio, Napoli, Italy; Prof. O. Drobakhin, Dnipropetrovsk, Ukraine. The jury made the following decisions:

First Prize: Liubov Ivzhenko (Kharkiv, Ukraine) for "Crossed Metallic Gratings as Metasurface with Tuned Crossing Angle" (Figure 14)

Two Second Prizes: Simeon Zhyla (Kharkiv, Ukraine) for "Optical Coherence Tomography Imaging with a Planar Broadband Light Beam" (Figure 15) and Masha Bortsova (Kharkiv, Ukraine) for "Polarization Transfer Functions of Remote Sensing Objects"

Three Third Prizes: Jakub Sorocki (Krakow, Poland) for "Differentially Excited Coupled-Line Sensor for Small Dielectric Samples Detection;" Oleksii Patoka (Kharkiv, Ukraine) for "Spatial Structure of Five Star Forming Regions: 121.28+0.65, 34.403+0.233, 77.462+1.759, 99.982+4.17 and 37.427+1.518;" and Sergey Ponomarenko (Kharkiv, Ukraine) for "Development of Compact CW Clinotrons for DNP-NMR Spectroscopy" (Figure 16).

The Young Scientist Prize for the best poster presentation was awarded to Tatyana Kalmykova (Kharkiv, Ukraine) for "Simulation of the Electron Magnetic Resonance Peak Shape for Fe3O4 Nanopowder."

The final closing address was given by the MSMW'2016 Chair, Prof. Petr N. Melezhik. He announced that the next symposium, MSMW 2019, would be traditionally held in Kharkiv in June, 2019. He then thanked all the participants and organizers, and expressed the hope that the MSMW symposia series would continue. He acknowledged international institutions such as the IEEE, URSI, and EuMA for rendering valuable and timely support. The social program of the symposium concluded with a concert at Kharkiv Philharmonic.

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International Conference on Mathematical Methods in Electromagnetic Theory: MMET*2016

The 16th IEEE International Conference on Mathematical Methods in Electromagnetic Theory (MMET-2016) was held in Lviv, Ukraine, on July 5-7, 2016.

MMET is a biennial forum, held in Ukraine since 1990. It is famous as an efficient interface between Ukrainian and Western scientists and engineers in the broad area of electromagnetic wave theory, especially propagation, scattering, dissipation, and emission of electromagnetic waves across the wide spectrum of frequencies from microwaves to optics. Its program consists of only oral invited and regular presentations (no poster sessions), and English is the single working language. This year, the three-day technical program covered the state-of-the-art and current trends in modeling and simulation. This included analytical regularization, antenna modeling, computational techniques, graphene electromagnetics, wave scattering by gratings and other periodic structures, inverse problems, photonics and lasers, remote sensing, etc. Both the traditional and the hottest novel topics and applications of computational electromagnetics were covered, including terahertz wave effects, graphene-based devices, plasmon-assisted optical nanoantennas and sensors, and hybrid classical and quantum electromagnetics models.

Lviv (also known as Lwow and Lemberg), is a city of one million in the West Ukraine, near the border with Hungary, Poland, and Slovakia. For centuries, the city served as a gateway of Ukraine towards Central Europe. Since the late 20th century, Lviv has played an important and remarkable role as the center of the "Ukrainian Piedmont." That role is even greater today, after the dramatic events of 2014. For instance, a sizable part of Ukrainian IT industry has moved its premises to Lviv from the territories and the cities of East Ukraine. It is therefore not a surprise that Lviv is now the most visited Ukrainian city by foreign tourists. For the same reason, today it is more attractive for the participants of international conferences.

MMET*2016 was hosted by the I. Franko Lviv National University (LNU). Its history dates back to 1661, when a Jesuit college was established there by a decree of the King of Poland. The majestic main building of LNU was the venue of the Parliament of Galicia as a province of Austro-Hungary before 1918. Today, LNU is one of the leading classical universities in Ukraine, and enjoys many links with other European universities. It has three colleges, 16 schools, and 112 departments or chairs.

As before, MMET*2016 was organized and sponsored by the IEEE East Ukraine Joint Chapter. Cooperating organizations were the I. Franko Lviv National University, the O. Y. Usikov Institute of Radio-Physics and Electronics NASU, the G. V. Karpenko Institute of Physics and Mechanics NASU, the IEEE Central Ukraine Joint Chapter, the IEEE Ukraine Photonics Society Chapter, the IEEE West Ukraine Joint Chapter, and the IEEE IRE NASU Kharkiv Student Branch. It was also supported by URSI, OSA, TICRA, and IEEE GRS Society. The Chair of MMET*2016 was Prof. Z. T. Nazarchuk, and the Technical Program Committee was co-chaired by O. V. Shramkova and A. I. Nosich.

Figure 1. Prof. Koki Watanabe of Fukuoka, Japan, presenting his invited plenary paper at MMET*2016.

Figure 2. (l-r) Profs. Vladimir Schejbal and Jan Machac of the Czech Republic listening to a plenary presentation.

Figure 3. Participants of MMET*2016 listening to a session presentation by Dr. S. Mizrakhy of Kharkiv, Ukraine.

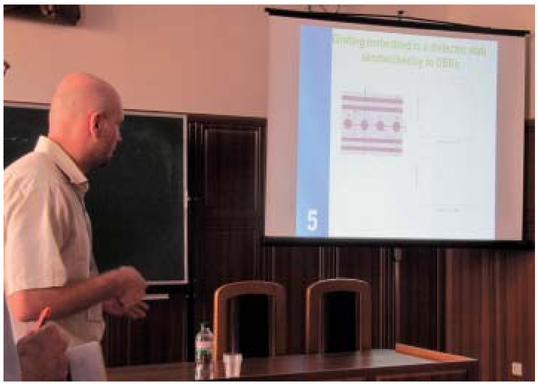

Figure 4. Mr. Volodymyr Byelobrov of Kharkiv, Ukraine, presenting his paper at a nanophotonics session.

The MMET*2016 technical program consisted of 103 papers, including 27 invited talks. 99 of the papers were presented at the conference. The actual participants numbered 107, and represented the following countries: Ukraine (61), Japan (6), Greece (5), Russia (5), Turkey (4), USA (4), Czech Republic (3), Georgia (3), Spain (3), China (2), Italy (2), France (2), Germany (1), Poland (1), and Slovakia (1).

The morning plenary sessions were held in the same Great Hall where the Parliament of Galicia worked before 1918 (see Figures 1 and 2). The contributed-paper sessions were held in auditoriums of LNU (see Figures 3 and 4).

The first working day of the conference, July 5, started with the opening ceremony, and continued with the plenary session of invited talks. These were by Dr. Grigorios Zouros, Greece, "Latest Advances in Computational Electromagnetic Solvers for Highly Inhomogeneous Anisotropic Objects;" Prof. Mario Lucido, Italy, "Examples of Analytically Regularized Scattering Problems via Helmholtz Decomposition and Galerkin Method;" Prof. Marian Marciniak, Poland, "Beam-Propagating Method and Physics Behind It – Revisited;" Prof. Kazuya Kobayashi, Japan, "Rigorous RCS Analysis of a Finite Parallel-Plate Waveguide with Material Loading;" Prof. Zinoviy Nazarchuk, Ukraine, "Methods of Singular Integral and Functional Equations in Dynamic Problems of Mathematical Physics;" Prof. Francisco Medina, Spain, "Accurate Circuit Models for the Analysis of Stacked Metal Gratings;" Prof. Hiroshi Shirai, "Ray-Mode Conversion Technique Applied to Thick Slit Diffraction;" and Dr. Vitalii Shcherbinin, Ukraine, "Circular Waveguide with Anisotropic Impedance Surface as an Equivalent Model for Dielectric Waveguides Used in Gyro-Devices."

After the lunch break, the following sessions were held: "Eigenvalue Problems," "Remote Sensing and Propagation," "Micro and Nano Optics and Plasmonics," and "Analytical Regularization."

The social program of the conference started the same evening, with a welcome party at the Lviv House of Scientists. This 150-year-old building used to be a club of horse breeders before 1918, and a casino in the 1920s and 1930s. The house is an architectural monument located in the city center, just around the street corner from LNU. The authors of the project were the well-reputed Viennese architects, H. Helmer and F. Felner (they were also the architects of the Odessa Opera House). The architects were inspired by spirit and traditions of the palace architecture of the Central European Baroque style. The imposing decoration of the facades of the building is combined with the exquisite elegance of the construction of the stairway

Figure 5. Participants of MMET*2016 at the welcome party in the Lviv House of Scientists.

Figure 6. Prof. Hiroshi Shirai of Tokyo, Japan, with musicians at the welcome party of MMET*2016.

Figure 7. Participants of MMET*2016 at the Mitskevich Square during the Lviv city tour.

Figure 8. The MMET*2016 conference gala dinner on the gallery floor of the Citadel Inn Hotel tower.

gallery in the house lobby. The welcome party was served with wines and refreshments, and enlivened with the music of a quartet of professional violinists (Figures 5 and 6). This contributed greatly to informal communication of scientists and exciting discussions around research topics that emerged on the first day of presentations.

At the second day's plenary session, on July 6, the following invited talks were presented: Dr. Mykhaylo Tymchenko, USA "Ultrathin Nonlinear Metastructures;" Prof. Akira Matsushima, Japan "Integral Equation Method of the Expansion Type Applied to Light Scattering from Nano Metal Strips;" Prof. Romanus Dyczij-Edlinger, Germany "Low-Frequency Stable Model-Order Reduction of Finite Element Models Featuring Lumped Ports;" Prof. Gerard Granet, France, "Advanced Modal Analysis of Crossed Gratings: Application to Bi-Periodic Composite Materials Made of Stacks of One-Dimensional Arrays of Rods;" Prof. Alejandro Alvarez, Spain, "Integral Equation Analysis of Capacitive Waveguide Circuits;" Prof. Koki Watanabe, Japan, "Accurate Analysis of Electromagnetic Scattering from Cylindrical Objects Located Near Periodically Corrugated Surface;" Prof. Vladimir Schejbal, Czech Republic, "Refraction Effects for Propagation Over Terrain;" and Prof. Alexander Ramm, USA, "Inverse Scattering with Non-Over-Determined Data."

The working sessions on that day were "Integral Equation Methods" and "Electromagnetic Modeling Applications."

The social program continued with a Lviv Sightseeing Tour on an open-platform bus train around the historical center of the city, and an amazing guided walk (Figure 7). As is known, Lviv is translated as "The City of Lion." Today, it is a city-museum, full of historical sites to see and to enjoy. It has a long history since its foundation in 1256, and remains one of the most charming and mysterious beauties of Eastern Europe. The "Ensemble of the Historic Centre" of Lviv is the only collection of buildings in Ukraine included in the UNESCO World Heritage List. During the tour, participants could see the main landmarks of Lviv, and learn of Lviv's fascinating history and local legends.

The third day of the conference, on July 7, started with the last part of the plenary talks. They were presented by: Dr. Georgiy Koshovy, Ukraine, "Wave Scattering by Pre-Fractal Gratings of PEC Strips;" Prof. Peter Markos, Slovakia, "Fano Resonances in Dielectric, Metallic, and Metamaterial Photonic Structures;" Prof. Stephen Shipman, USA, "Dynamic Resonance in the High-*Q* and Near-Monochromatic Regime;" Prof. Tsuneki Yamasaki, Japan, "Scattering of Electromagnetic Waves by Inhomogeneous Dielectric Gratings Loaded with Conducting Strips – Matrix Formulation of Point-Matching Method;" Prof. Dmytro Pesin, USA "Nonlocal Electrodynamics of Helical Metals;" Prof. Fernando Quesada, Spain, "Green's Functions for 2D Periodic Structures and Applications to the Analysis of Waveguide Components;" Prof. Andrey Andrenko, China, "Simultaneous Quasi-RHCP and LHCP Radiation in the Near Field of Planar RFID Antennas;" and Prof. Zbynek Raida, Czech Republic, "Body Area Networks: Numerical, Experimental, and Approximate Characterization."

After the invited talks, there were four working sessions: "Electromagnetic Theory," "Non-Classical Electromagnetics," "Antenna Modeling," and "Inverse Problems."

After the last session, the Awards Ceremony and the Farewell Dinner were held at the "Harmata" Restaurant at the Citadel Inn Hotel. The restaurant is considered one of the best in Lviv. It is known for its hospitality, impeccable service, and, of course, delicious European and Ukrainian cuisine. It is located on the highest floor of the Citadel Inn, the first five-star hotel in Lviv, which is located on a hilltop in the park area in the very heart of the cultural and historical part of the city. The hotel is actually a circular tower of a medieval fortress, rebuilt by the Euro-2012 football championship. Participants enjoyed the buffet dinner, the jazz and classical music played by a trio of black-suited musicians including a pianist with a white grand piano (Figure 8), and the charming mid-summer evening view of the city from the circular open-air gallery around the restaurant.

Figure 9. Ms. Nino Tkeshelashvili (l) of Tbilisi, Georgia, received the Third Prize of MMET*2016 for the best Young Scientist paper from Prof. Alex Nosich.

Figure 10. Ms. Francesca Ortolani of Rome, Italy, received the Second Prize of MMET*2016 for the best Young Scientist paper.

The post-conference day was devoted to the castle tour "Golden Horseshoe" around four castles in Svirzh, Zolochiv, Pidhirtsi, and Olesko.

MMET*2016 continued the tradition of serving young researchers, engineers and PhD students. This year, the Young Scientist Paper Contest prizes were supported by URSI. They consisted of power banks of different capacity, the most powerful going with the first prize, and bottles of fine red champagne plus a certificate. The following awards were selected among the papers presented by the young scientists and students by the international jury, consisting of Profs. F. Yanovsky (Chair), Ukraine; A. Alvarez, Spain; G. Granet, France; A. Matsushima, Japan; and N. Tsitsas, Greece:

Third Prize: Mrs. Nino Tkeshelashvili, University of Georgia, Tbilisi, Georgia (Figure 9)
"Model-Based Parameter Estimation for Speeding Up the Computation of Plasmonic Structure"

Third Prize: Dr. Maksim Kaliberda, Kharkiv National University, Kharkiv, Ukraine
"Analysis of the E-polarized Electromagnetic Wave Diffraction by an Infinite Periodical Strip Grating without One Strip"

Third Prize: Sergii Kukhtaruk, Institute of Semiconductor Physics NASU, Kiev, Ukraine
"Interaction of THz Radiation with Plasmonic Grating Structures Based on Graphene"

Second Prize: Mrs. Francesca Ortolani, University La Sapienza, Rome, Italy (Figure 10)
"Widely Linear Quaternion Adaptive Filtering in the Frequency Domain"

Second Prize: Mrs. Dr. Oksana Trischuk, Institute of Physics and Mechanics NASU, Lviv, Ukraine (Figure 11)
"Axially Symmetric TM-wave Illumination of the Sphere-Conical Resonator"

Figure 11. Ms. Oksana Trishchuk of Lviv, Ukraine, received the Second Prize of MMET*2016 for the best Young Scientist paper.

Figure 12. Ms. Daria Titova of Taganrog, Russia, received the First Prize of MMET*2016 for the best Young Scientist paper.

Figure 13. Prof. Mario Lucido received the V. G. Sologub MMET Award for his work on analytical regularization.

Figure 14. Prof. Kazuya Kobayashi (l) received the M. A. Khyzhnyak MMET Award for contributions to electromagnetic theory.

First Prize: Mrs. Daria Titova, Southern Federal University, Taganrog, Russia (Figure 12)
"Influence of the Dielectric Loss in a Dielectric Filled Rotating Spherical Resonator on the Precision of the Rotation Rate Measurement"

Besides the Young Scientist Prizes, the MMET conference series has two traditional special awards, named after two prominent Ukrainian scientists who worked in electromagnetics in the second half of the 20th century. Traditionally, their recipients are selected by the MMET Organizing and Program Committees. In 2016, the V. G. Sologub MMET Award was given to Prof. Mario Lucido of Casssino, Italy, "For contribution to development of the method of analytical regularization" (Figure 13); and the M. A. Khyzhnyak MMET Award was given to Prof. Kazuya Kobayashi of Tokyo, Japan, "For contribution to electromagnetic theory" (Figure 14).

The awarding of the MMET*2016 prizes can be seen in the photos in this report (two third-prize winners of the Young Scientist Contest, M. Kaliberda and S. Kuktaruk, were absent, and their prizes were mailed to them later).

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EMTS 2016 Conference in Espoo, Finland

Along with the URSI General Assembly, the other main meeting within Commission B is its own triennial Electromagnetic Theory Symposium (EMTS). The EMTS2016 conference was organized on the campus of Aalto University in Espoo, Finland, in August 2016. The conference gave an all-embracing view of the present state of research on fields and waves in radio science.

Radio science covers the study, understanding, and application of electromagnetics and electronics in natural and manmade environments. The impact and importance of radio science for modern technology and society cannot be overstated. Telecommunications, nanotechnology, radio astronomy, and remote sensing for monitoring of the environment and global change are but some of the fields that rest on the foundations of radio science.

As the Chair of Commission B of URSI, I could even go further and claim that the foundations of radio science rest on electromagnetics – the study of fields and waves – which is the domain of Commission B of URSI!

In addition to the General Assemblies, Commission B activities triennially culminate in the electromagnetic theory conferences. The tradition of the Electromagnetic Theory Symposium (EMTS) is impressive. It spans a history of over 60 years. The first gathering was in Toronto, Canada, in 1953. The year 2016 marked the twenty-second time the conference was held, this time in Espoo, Finland. EMTS2016 took place on the campus of Aalto University on August 15-18, 2016.

During the four days of the conference (see the visual design shown in Figure 1), a full output in electromagnetics of radio science was offered. The program of EMTS2016 consisted of 49 technical sessions, two poster sessions, and four plenary talks. The technical content of the meeting concentrated on fundamental and theoretical aspects of electromagnetics, from both the analytical and computational points of view. Examples of approaches were scattering and diffraction, high-frequency and beam methods, transformation optics, and boundary problems involving random media. However, several application areas were also covered, such as on-body antennas and metamaterials.

The 261 papers submitted to the conference were evaluated by the review board, which consisted of 60 experts in electromagnetics. On average, a single submission received 2.3 reviews. The final program included 247 presentations. Of course, EMTS2016 was a perfect platform for scientific interactions after the presentations (Figure 2) and during coffee breaks (Figure 3).

The amount of no-shows was pleasingly low: there were only four accepted contributions that were not presented onsite. It was also encouraging that many of our Turkish colleagues were able to participate, despite the tense political situation in their country in the summer of 2016. Altogether, 228 participants and 21 accompanying persons attended the EMTS2016 conference. They came from 30 different countries. All contributions that were presented in EMTS2016 have now been published on IEEE Xplore.

In addition to the contributed presentations, each day of the conference included a one-hour plenary talk. The talks covered the scope of Commission B, from theory through computations to engineering physics (video recordings of three of the plenary talks are available on the conference Web site at http://www.emts2016.org/):

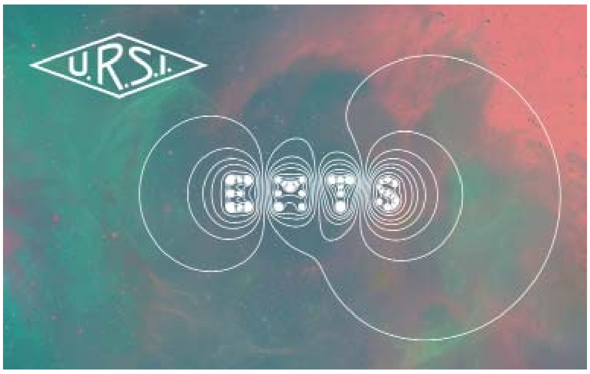

Figure 1. The logo of EMTS2016 consisted of equipotential contours of electrically charged monopole constellations.

Figure 2. Friedrich Hehl is shown making his point during the discussion period of the session on the history of electromagnetics (photo: Viktar Asadchy).

Figure 3. As usual in conferences, coffee breaks were scenes of intensive technical discussions. Ludger Klinkenbusch (r) tried to convince Ari Sihvola that exact solutions exist for wave diffraction from cones and wedges (photo: Viktar Asadchy).

Figure 4, Not only radio science: outside activities of Young Scientists during the URSI Commission B School for Young Scientists (photo: Henrik Wallén).

- Prof. Friedrich W. Hehl (Universität zu Köln, Germany), "Generally Covariant Maxwell Theory for Media with a Local Response: Progress Since 2000"
- Prof. Mats Gustafsson (Lund University, Sweden), "Stored Energy and Antenna Current Optimization"
- Prof. Mário G. Silveirinha (University of Lisbon, Instituto Superior Técnico, Portugal), "Topological Photonics in a Continuum"
- Prof. Jin-Fa Lee (Ohio State University, USA), "Computational Electromagnetics – Past, Present, and The Future"

In the best of URSI traditions, a strong emphasis was put on young scientists. 20 Young Scientist Awardees (YSAs) were selected from 43 applicants. These YSAs were given free registration to the conference, free accommodations, and banquet tickets. One of the poster sessions of EMTS was dedicated to these young scientists, who also gave a poster presentation in addition to their talk in one of the oral sessions.

Based on the submitted summaries and poster presentations, the Young Scientist Program Committee of EMTS2016, chaired by Kazuya Kobayashi, awarded three YS best paper prizes. These were given to Simon B. Adrian (Technical University of Munich, Germany, and Télécom Bretange, France; 1000€); Marko Mikkonen (Aalto University, Finland; 750€); and Alberto Favaro (Imperial College, UK; 500€). Honorary mention was conferred on Dimitry Valovik (Penza State University, Russia) and Xiaoyan Xiong (The University of Hong Kong).

Commission B also continued the tradition of Young Scientist Schools. On Sunday, August 14, before the main conference, the 2016 URSI Commission B School for Young Scientists took place in the Finnish Nature Centre Haltia in the Nuuksio National Park. The topic of this short course was "Electromagnetic Fields and Waves: Mathematical Models and Numerical Methods." The course instructor was Prof. Yury Shestopalov, assisted by Dr. Eugen Smolkin, both from University of Gävle (Sweden). During the day, besides electromagnetics, the 31 participants also enjoyed the wild nature of rural Espoo during the afternoon outside activities, as can be seen in Figure 4.

Expanded contributions of selected presentations in the conference will be published in the "Special Issue of the 2016 URSI International Symposium on Electromagnetic Theory" in the journal *Radio Science.* In addition, the *Radio Science Bulletin* will honor the prize-winning young scientists, who have been invited to write follow-up articles on their research, to appear in a forthcoming issue.

If you missed EMTS2016, don't worry: the next EMTS event is in preparation. I hope to see you in May 2019 for EMTS2019 in San Diego, California!

Ari Sihvola
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Report on the 2016 Spanish URSI Symposium

The 31st edition of the Spanish URSI Symposium was held at Madrid, Spain, from September 5-7, 2015. This symposium was organized by the Higher Technical School at the Autonomous University of Madrid (UAM), Spain, and was chaired by Prof. Javier Ortega García.

The purpose of this symposium was to meet Spanish young and senior scientists, covering the following topics: antennas; biomedical applications; mathematical applications: modeling and simulations; bioelectromagnetism; microwave active circuits and components; microwave passive circuits and components; active components and circuits; mobile and wireless communications; satellite communications; education: new technologies and tools; electromagnetism; photonic and optical communications; metamaterials; new services and security in communications; audio and video signal processing; radar; radiation, scattering, and radio propagation; communication systems; applications and technologies at THz (beyond 74 GHz); and telematics.

The 181 accepted papers were scheduled in 27 technical sessions, which gathered about 200 participants for fruitful discussions. The technical program included three plenary sessions: "Terahertz Antennas in the European Project Graphene Flagship," by D. Juan R. Mosig, Director of LEMA-EPFL (École Polytechnique Fédérale de Lausanne); "Radio Technology in the Evolution of Radar Applications and Sensors in Radar Band" by D. José M. Pascual Ruiz of INDRA; and "Technological Advances in Radio Astronomy: Gigahertz, Microns, and Millikelvins" by D. José A. López Fernández, Director of the Observatory of Yebes.

The social program included a visit to the Madrid of the Austrians and to San Ildefonso (Segovia), where we visited the Royal factory of glass and crystal of La Granja, as well as the Royal Palace of La Granja (Figure 1).

At the gala dinner, young scientist best paper awards were given (Figure 2). An international committee had previously evaluated the six best papers among 49 entrants less than thirty-five years old. During the symposium, these young scientists presented their papers in a special season. Finally, the awards committee selected two winners, and four awards for runners-up. These outstanding papers were the following:

Winners:
L. Alonso González of the University of Oviedo, for her paper, "Textile Integrated Waveguide Cavity-Backed Slot Antenna for 5G Wearable Applications," coauthored with S. Ver Hoeye, C. Vázquez, M. Fernández, A. Hadaring, and F. Las-Heras.
Abstract: In this work, a fully textile integrated waveguide (TIW) cavity-backed slot antenna for its use in a 5G wearable network operating at 58.68 GHz is presented. The TIW antenna is based on a substrate integrated waveguide (SIW) cavity-backed slot antenna, and it is designed to be manufactured completely with conductive and non-conductive threads using textile machinery, avoiding subsequent adhesive processes for its integration in wearable or conformable systems. The antenna works in the 58-59 GHz band (magnitude of the reflection parameter less than –15 dB), and its directivity at the main lobe direction was found to be 7.9 dBi. Firstly, a design of the equivalent SIW slot antenna structure is simulated and optimized and then the translation into a fully woven TIW cavity-backed slot antenna is presented. The proposed TIW antenna design is provided with a TIW-to-microstrip-line transition for its experimental validation.

Figure 1. Some of the participants visiting the Royal Palace of La Granja de San Ildefonso (Segovia).

Figure 2. Leticia Alonso González (second from the left) and Victor Pacheco (right) receiving the Young Scientist Best Paper Award, together with the finalists.

V. Pacheco Peña of the Public University of Navarra, for his paper, "Transformation Electromagnetics for Nanoantennas and Localized Emitters," coauthored with M. Beruete, A. I. Fernández Domínguez, Y. Luo, and M. Navarro Cía.
Abstract: The advances in nanofabrication have made it possible to shape metallic structures with nanometer features that interact strongly with light in a similar fashion as transmission lines and antennas do with microwaves. Hence, one could think that microwave engineering techniques may be applicable also in photonic devices like nanoantennas in this new scenario. Of particular relevance for physical chemistry and quantum information is to understand the electrodynamics of a molecule/quantum emitter near a nanoantenna. We develop here a full analytical description based on transformation electromagnetics of a localized emitter, modeled as a point dipole, in an arbitrary position next to a bowtie nanoantenna. The technique allows us to transform the original nanoantenna problem, which is complex and does not have an analytical solution, into a classical multiple parallel-plate transmission lines problem with analytical solution, gaining at the same time a deep physical insight of the underlying mechanism. The analytical decay rates and field distributions of different bowties thus calculated show good agreement with finite-element-method simulations. The work contributes to fill the gap of design methodologies for nanodevices.

Awards for Runners-Up:

A. Berenguer of the University Miguel Hernández of Elche for his paper, "Calculation of the Electrostatic Field in a Dielectric-loaded Waveguide Due to an Arbitrary Charge Distribution on the Dielectric Layer," coauthored with A. Coves, F. Mesa, E. Bronchalo, B. Gimeno, and V. Boria.
Abstract: The goal of this paper is to study the electrostatic field due to an arbitrary charge distribution on a dielectric layer in a dielectric-loaded rectangular waveguide. In order to obtain this electrostatic field, the potential due to a point charge on the dielectric layer is solved in advance. The high computational complexity of this problem requires the use of different numerical integration techniques (e.g., Filon, Gauss-Kronrod, Lobatto) and interpolation methods. Using the principle of superposition, the potential due to an arbitrary charge distribution on a dielectric layer is obtained by adding the individual contribution of each point charge. Finally, a numerical differentiation of the potential is carried out to obtain the electrostatic field in the waveguide. The results of this electrostatic problem are going to be extended to model the multipactor effect, which is a problem of great interest in the space industry.

A. Correas Serrano of the Technical University of Cartagena for his paper "SIW-Based True Time Delay Reflectarrays," coauthored with J. S. Gómez Díaz, E. Carrasco Yepez, M. Barba Gea, J. A. Encinar Garcinuño, and A. Álvarez Melcón.
Abstract: A novel design for true-time delay reflectarray antennas based on unit cells implemented with substrate integrated waveguides (SIWs) is proposed. The unit cell structure is based on aperture-coupled patches, using SIWs instead of usual microstrip lines (MSLs). SIW-based unit-cells display lower losses than MSLs at high frequencies, with the intrinsic advantages of requiring one less dielectric layer than current configurations – thus simplifying the design and reducing the manufacturing cost – and eliminating the issue of back radiation from the MSLs. In addition, the proposed unit-cell allows true time delay responses, leading to a significant increase of the bandwidth in large reflectarrays. For the sake of illustration, a single unit-cell and an entire reflectarray have been designed and analyzed, fully confirming the multiple advantages of the proposed technology.

S. Marín of the Polytechnic University of Valencia for her paper, "Microstrip Filter with Wide Stopband Using m-Derived Terminations," coauthored with J. D. Martínez, C. I. Valero, and V. E. Boria.

Abstract: A procedure for improving the stop-band response of planar bandpass filters is presented in this paper. The technique is based on the introduction of transmission zeros (TZs) by using m-derived networks as input and output terminations of the filter. These networks can be conveniently designed to provide a good matching at the filter pass-band while introducing a transmission zero at a higher or lower frequency. Moreover, the parasitic elements associated with the lumped components used for implementing the termination can introduce an additional TZ per section. As an example, a three-pole 10% FBW bandpass filter with Chebyshev response centered at 1 GHz has been designed, manufactured, and measured in microstrip technology based on strongly-loaded combline resonators. Then, lumped element bisected pi-networks have been introduced at the input and output stages in order to provide up to four adjustable TZs, that have been used for conveniently rejecting the spurious responses of the original combline filter. Thus, a rejection better than 30 dB has been obtained at almost $10\times f_0$ without affecting the in-band filter response. The proposed solution can be used on any planar topology in order to improve the stop-band performance of the filter with a negligible additional footprint.

L. Moreno Pozas of the University of Malaga for his paper, "The Nakagami-q (Hoyt) Fading Distribution: A Particular Case of the Rician Shadowed Model," coauthored with F. J. López Martínez, J. F. Paris, and E. Martos Naya.

Abstract: This paper shows that the Rician shadowed fading model includes, besides the Rician model, the Nakagami-q (Hoyt) fading model as a particular case. This has important relevance in practice, as it allows for the connection of the classical noncircularly symmetric model with the group of classical circularly symmetric models, i.e., the one-sided Gaussian, Rayleigh, Nakagami-m, and Rician models. We also derive simple and novel closed-form expressions for the asymptotic ergodic capacity in Rician shadowed fading channels, which illustrate the effects of the different fading parameters on the system performance. By exploiting the unification here unveiled, we unify the capacity analysis for all classical fading channels.

The next edition of the Spanish URSI Symposium will be held at Cartagena (Murcia), Spain, September 6-8, 2017. It will be organized by the Technical University of Cartagena (UPC).

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Report on Metamaterials' Congress 2016

The 10th International Congress on Advanced Electromagnetic Materials in Microwaves and Optics – Metamaterials'2016 was held in Chania, Crete, Greece, September 17-22, 2016. The conference was organized by the *METAMORPHOSE VI AISBL* (www.metamorphose-vi.org, Figure 1) and hosted by the Foundation for Research and Technology–Hellas (FORTH). The local organizing committee, chaired by Prof. Costas M. Soukoulis and Prof. Maria Kafesaki, chose the Minoa Palace Resort and Spa as the congress venue, the entrance of which is shown in Figure 2. It is located in the beautiful city of Platanias, just 11 km west of Chania, Crete.

The 2016 Congress followed its highly successful predecessors, the Metamaterials 2007-2015 versions. They all have continued the traditions of the highly successful series of International Conferences on Complex Media and Metamaterials (Bi-anisotropics) and Rome International Workshops on Metamaterials and Special Materials for Electromagnetic Applications and Telecommunications. The Metamaterials Congress always provides a unique topical forum for sharing the latest results of metamaterials research in Europe and worldwide. It brings together the engineering, physics, and material-science communities working on artificial materials and their applications, from microwaves to optical frequencies, as well as now in acoustics, mechanics, and thermodynamics.

Technical Program and Plenary Sessions

The conference proved to be very attractive: about 350 papers were submitted, and about 280 were accepted as oral and poster presentations. More than 300 scientists from 25 different countries attended the event. The Technical Program Committee, chaired by Prof. Sergei Tretyakov, selected about 200 oral presentations, of which 38 were invited and more than 160 were regular or extended oral versions. 80 poster presentations were accepted. The scientific program was organized into 32 thematic oral sessions, an ensemble covering all the fields of active research in electromagnetic metamaterials at microwave, terahertz, and optical frequencies; acoustic and mechanical metamaterials; and other novel artificial materials exhibiting exotic effects.

Figure 1. The METAMORPHOSE VI logo.

The Technical Program Committee organized three fantastic plenary sessions:

Andrea Alù, "Enhancing Metasurfaces and Metamaterials with Time-Modulation and Nonlinear Responses" Abstract: Metasurfaces and metamaterials have been enabling a new and exciting platform to manipulate the propagation, transmission and reflection of electromagnetic waves, sound, heat, and other wave phenomena. In this talk, I will provide an overview of our recent efforts to enhance metasurfaces and metamaterials by enabling time modulation and giant nonlinearities in their basic inclusions, opening new horizons for metamaterial technology in various fields of science and technology. I will discuss how suitably tailored temporal modulation and nonlinearities may be able to overcome some of the conventional constraints associated with passive, linear, and time-invariant metamaterial devices, including bandwidth constraints, reciprocal responses, and the large influence of losses.

Che Ting Chan, "Topological Principles and Exceptional Point Physics Realized Using Simple Meta-Crystals" Abstract: Many modern notions, such as "topological materials" and "exceptional point physics," are thought to belong to the realm of quantum mechanics. Novel phenomena associated with these concepts can actually be

Figure 2. The entrance of the Minoa Palace Hotel, conference venue of Metamaterials 2016.

Figure 3. The main room of the congress venue during the announcement of the winners of the student paper competition, during the closing ceremony.

realized in classical wave systems. For example, photonic crystals and metamaterials can have fairly complex band dispersions in the momentum space, allowing for the possibility of realizing topological entities and phenomena such as Weyl points, synthetic gauge flux, and topologically protected edge states. Likewise, "exceptional point" concepts can be demonstrated in simple acoustic systems. We will use a few examples to illustrate these ideas.

Anthony Grbic, "Electromagnetic Metasurfaces: Science and Applications"
Abstract: This talk will review advances made by my team over the past few years in the emerging area of electromagnetic metasurfaces. The development of passive metasurfaces with electric, magnetic, as well as magneto-electric and electromagnetic properties will be described, and their field tailoring properties and functionalities explained. In addition, the development of tunable, active, and nonreciprocal designs will be touched upon. The presentation will include two broad classes of metasurfaces. The first class of metasurfaces includes those that can manipulate electromagnetic wavefronts incident from free space. Such metasurfaces can tailor reflected and/or transmitted waves, acting as lenses and/or reflectors with unparalleled field control. The second class of metasurfaces that will be described includes metasurfaces that can guide or radiate waves. These metasurfaces act as either waveguiding structures or support traveling/leaky waves that radiate tailored far-field patterns

Moreover, the program included a special event commemorating the fact that this was the 10th anniversary of the congress series. It was organized by Prof. Filiberto Bilotti and Prof. Alexander Schuchinsky. It included the following presentations:

- "Origins and History," Sergei Tretyakov (Aalto University), Filiberto Bilotti (University Roma Tre), Alexander Schuchinsky (Queen's University Belfast)
- "10 Years Metamaterials Congress: Status and Breadth of the Field," Martin Wegener (Karlsruhe Institute of Technology)
- "The Next Ten Years," Nader Engheta (University of Pennsylvania)
- "What You Always Wanted to Know About the Future of Metamaterials, But Were Afraid to Ask," Nikolay Zheludev (University of Southampton, UK & NTU, Singapore).

Awards and Student Paper Competition

The Student Paper Competition and Award Committee, chaired by Prof. Mário Silveirinha, selected the best student papers, the best theoretical and experimental papers, and the best poster paper. During the closing ceremony, the names of the winners were announced in front of hundreds of participants, as shown in Figure 3.

Student Paper Competition First Prize

Student: Georgia Papadakis
"Broadband Non-Unity Magnetic Permeability in Planar Hyperbolic Metamaterials" by G. T. Papadakis and H. A. Atwater

Abstract: We report metal/dielectric/semiconductor multilayer metamaterials with non-unity effective magnetic permeability. By relaxing the usually imposed constraint of assuming nonmagnetic effective response and taking into account the finite size of the superlattice, we show that hyperbolic metamaterials with high-index contrast layers can even exhibit negative values of the magnetic permeability, expanding the properties of hyperbolic metamaterials to both polarizations. We theoretically identify the origin of this effective magnetic response, and experimentally validate the values of magnetic permeability with spectroscopic ellipsometry. We investigate the usefulness of such metamaterials as TE hyperbolic media and for TE surface-wave propagation.

Second Prize

Student: Mykhailo Tymchenko
"Circuit-Based Magnetless Floquet Topological Insulator" by M. Tymchenko and A. Alù
Abstract: We explore the design and realization of a topological Floquet insulator in the form of a graphene-like honeycomb network of wye resonators, in order to achieve nonreciprocal transport with zero backward reflection over a continuous frequency range. The topological insulator here consists of two domains, with different topological orders induced by a periodic spatio-temporal modulation of the resonance frequency in each branch of suitably arranged wye resonators, creating a form of local "spinning." The modulation in opposite directions breaks time-reversal symmetry in the lattice and produces a topologically protected edge state with a gapless dispersion crossing the bulk bandgap. The topologically protected edge states possess unique properties, such as one-way guiding, small group velocity dispersion, absence of backscattering, and immunity to structural disorder. Our analysis allows unveiling their peculiar propagation and confinement properties, and their inherent robustness to defects and loss.

Third Prize

Student: Vladislav Popov
"Advanced Effective Medium Approximation For Sub-Wavelength Multilayers to Overcome Maxwell-Garnet Approach Breakdown" V. Popov and A. Novitsky
Abstract: We develop a more precise definition of effective medium approximation for sub-wavelength multilayer structures. It allows overcoming anomalous behavior of the ordinary Maxwell-Garnet effective medium for all-dielectric multilayers, investigated theoretically and observed experimentally. We reveal that the correct effective medium should possess both magnetic and gyrotropic properties, and reveal spatial dispersion. We show that the transmission through this effective medium matches well with that of the generic multilayer in the cases when the ordinary effective medium fails.

Best Theory Paper Award

Maxim Gorlach and Pavel Belov, *"Nonlocality in Discrete Nonlinear Metamaterials"*
Abstract: We propose a non-local homogenization approach to calculate effective nonlinear susceptibilities of discrete metamaterials taking spatial dispersion into account. It is demonstrated that significant deviations from local effective medium model take place in the vicinity of effective permittivity resonance. We prove that spatial dispersion gives rise to a number of new physical phenomena, including dependence of nonlinear susceptibilities on the propagation direction of the fundamental wave. Our results suggest that nonlocality should be necessarily taken into account in a wide class of metamaterials with resonant nonlinearity.

Best Experimental Paper Award

Angela Demetriadou, Anna Lombardi, Jan Mertens, Ortwin Hess, Javier Aizpurua, and Jeremy Baumberg, *"Anomalous Spectral Shifts in Extreme Plasmonic Nano-Cavities"*
Abstract: Nanoplasmonics have the ability to confine light in sub-wavelength cavities, with recent nano-fabrication developments allowing for the realization of nanometer and sub-nanometer plasmonic cavities. We show that for such extremely small nano-cavities, the correlation between the field-enhancement resonance and the radiative (far-field) resonance breaks down. This dissociation dominated the excitation and interference of higher-order modes in these nano-cavities. We discuss and demonstrate the impact of this anomalous spectral behavior for the strong coupling of quantum emitters with plasmonic nano-cavities, where it is imperative to have nanosized cavities.

Best Poster Award

Artemios Karvounis, Jun-Yu Ou, Behrad Gholipour, Kevin F. MacDonald and Nikolay I. Zheludev, *"Nanomechanically Reconfigurable All-Dielectric Metasurfaces for Sub-GHz Optical Modulation"*
Abstract: Ultra-thin, free-standing, all-dielectric sub-wavelength gratings and arrays of nano-cantilevers can act as resonant nanomechanically reconfigurable metasurfaces at telecommunication wavelengths. Actuation by electrostatic and optical forces delivers reversible reflectivity changes up to 20% and a giant sub-GHz frequency optomechanical nonlinearity.

EUPROMETA Doctoral School "Metamaterials from THz to Optics"

The XXXII edition of the Distributed Doctoral School on Metamaterials was held in Chania, Crete, just before the 2016 Metamaterials Congress. The school, part of the EUPROMETA program (Figure 4), was organized by FORTH, the Foundation

Figure 4. The EUPROMETA School logo.

for Research and Technology Hellas, and METAMORPHOSE VI AISBL. The school's topic was "Metamaterials from THz to Optics" (http://school.metamorphose-vi.org).

As a brief summary, the event was a great success. The school's topic and its wonderful program attracted more than 30 students from all around the world. They had the opportunity to attend lectures from eleven international experts:

"Challenges and Recent Progress in Metamaterials and Metasurfaces at Optical Frequencies," T. Koschny

"Dielectric Metamaterials and Metasurfaces," R. Domininguez

"3D Optical Metamaterials and 3D Optical Cloaking," M. Wegener

"Active and Quantum Metamaterials: From Full Loss Compensation to Quantum Self-Organized Criticality," K. Tsakmakidis

"Graphene in Terahertz and Optical Metamaterials," P. Tassin

"Preparing Publications for *Nature* Journals," M. Maragkou

"Complex Plasmonics: Chiral and Nonreciprocal," H. Giessen

"Losses in Plasmonics and Metamaterials and Prospective," J. Khurgin

"Thermal Metamaterials," Z. Jacob
"Design and Analysis of Nonlinear and Tunable Metamaterials," M. Lapine

Figure 5. The XI Edition of the Metamaterials congress will be held in Marseille, France.

"Selectivity, Prestige, and High Impact in Science Publishing: An APS Perspective," M. Antonoyannakis

Metamaterials' 2017

The next edition of the Metamaterials congress will be held in Marseille, France. It will comprise a four-day conference (August 28-31), and a two-day Doctoral School (September 1-2). The banner of the congress event is shown in Figure 5. It is organized by the METAMORPHOSE VI AISBL (www.metamorphose-vi.org), and will be hosted by the Institute Fresnel of Marseille. More information can be found at the congress Web site: http://congress2017.metamorphose-vi.org/

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International Conference on Electromagnetics in Advanced Applications and IEEE AP-S Topical Conference on Antennas and Propagation in Wireless Communications

The 18th International Conference on Electromagnetics in Advanced Applications (ICEAA) and the 6th IEEE AP-S Topical Conference on Antennas and Propagation in Wireless Communications (IEEE-APWC) were held in Cairns, Queensland, Australia, September 19-23, 2016. The scope of these combined conferences included all kinds of advanced applications in electromagnetics and new technology developments.

The conferences were organized by the Politecnico di Torino and by Macquarie University. I gratefully acknowledge both institutions' support in the preparations for this year's meetings. The ICEAA conference was technically supported by the Istituto Superiore Mario Boella, with the principal co-sponsorship of the IEEE Antennas and Propagation Society and technical co-sponsorship by the International Union of Radio Science (URSI). The cooperation of URSI and the support of the IEEE Antennas and Propagation Society are gratefully acknowledged.

Figure 1. Mahta Moghaddam (r) at the reception with a koala and its handler.

Cairns is a relatively small city that has a very beautiful location in far north Queensland, with proximity to the Great Barrier Reef in the Coral Sea, and inland to the rainforest and tablelands. With its central location and easy accessibility to the hotels, the Cairns Convention Centre proved to be an excellent venue for the meeting. It had a layout that facilitated interaction amongst delegates by providing large common spaces, but keeping all attendees close together. There were numerous opportunities for interaction during the oral sessions, poster sessions, and workshops, as well as the reception and conference banquet, which were held on-site. Some scenes from the reception on Monday evening appear in Figures 1 and 2.

The Local Organizing Committee (LOC) would like to thank Prof. Mike Jensen, who welcomed delegates in his capacity as 2016 IEEE AP-S President, to the meeting at the opening session. There were also speeches of welcome by Roberto Graglia and Paul Smith, as Chairs of Organizing Committees for ICEAA and IEEE-APWC, and by the Technical Program Chair, George Uslenghi. The opening session continued with two plenary lectures. Mike Jensen presented a state-of-the-art lecture entitled "Reconfigurable Over-the-Air Chamber for Multi-Antenna

Figure 2. (l-r) Mike Jensen and Roberto Graglia at the reception with a koala and it handler.

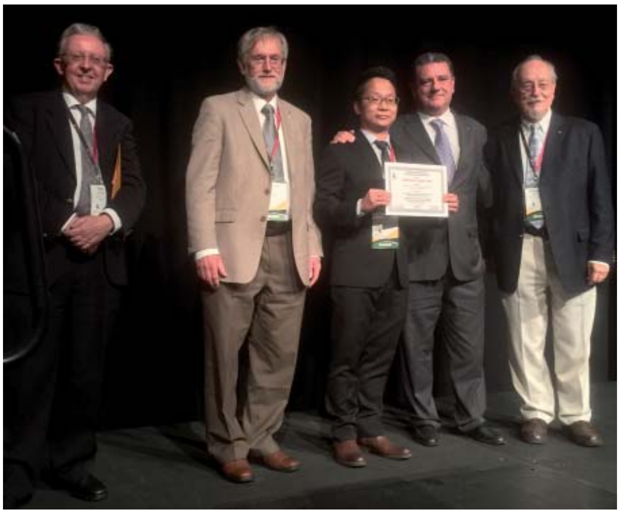

Figure 3. The presentation of the best paper award at the banquet to Shengjian Jammy Chen (c), with (l-r) Paul Smith, Trevor Bird, Roberto Graglia, and George Uslenghi.

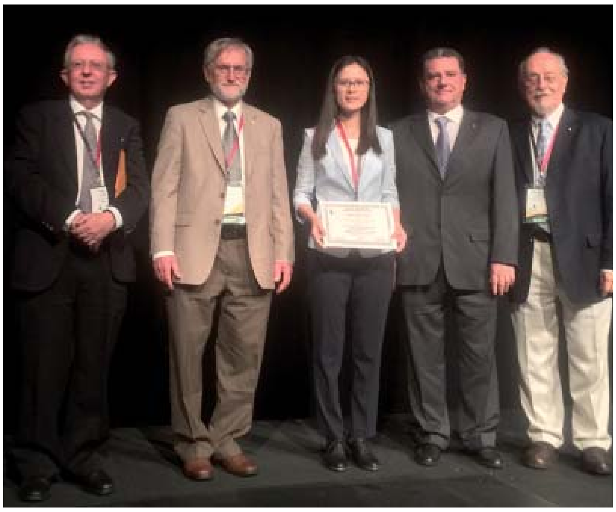

Figure 4. The presentation of the best paper award at the banquet to Bingyuan Liang (c) with (l-r) Paul Smith, Trevor Bird, Roberto Graglia, and George Uslenghi.

Wireless Device Testing." This described the development of a reconfigurable chamber offering significant control over testing devices, with results that were comparable to those normally achieved only in much more expensive multi-antenna anechoic chambers. The second lecture was presented by Dr. Stuart Hay (CSIRO, Australia), who surveyed the Australian Square Kilometre Array Pathfinder (ASKAP). This is a new telescope for radio astronomy being developed by CSIRO on a radio-quiet site in Western Australia. It provided a fascinating glimpse of the future directions in the international SKA project.

The meeting attracted 250 registrants from 35 countries, about 80% of whom were international, with strong representations from Asia, Europe, and the Americas. Altogether, the two conferences featured 38 sessions, including 19 special sessions organized by renowned experts. The two conferences featured a number of invited papers, giving recent information on the state of the art and new technologies. The ICEAA 2016 conference program consisted of 27 sessions and included 16 special sessions. The IEEE APWC 2016 conference program consisted of 11 sessions, including three special sessions. About 275 papers were scheduled, out of around 500 submissions. About 70% of the papers were ICEAA conference papers, and the remaining 30% belonged to the IEEE-APWC conference.

The IEEE Antennas and Propagation Society kindly provided monetary support for eleven students who were awarded travel bursaries, each valued at 2,000 Australian Dollars. These bursaries were awarded on a competitive basis for the highest-quality papers submitted and presented by Australian and New Zealand students at the conference.

The 2016 ICEAA-IEEE APWC conferences established two awards to recognize the students who

Figure 5. Some attendees at the banquet (l-r): Yury Shestapalov, Sergey Kharkovsky, Gennady Alekseev, Yury Yukhanov, Diana Semenikhina, and Elena Vynogradova.

authored and orally presented the best papers in terms of content and impact on electromagnetics. This year's Award Panel comprised Drs. Trevor S. Bird, Y. Jay Guo, Hisamatsu Nakano, and Ajay Poddar. In selecting the awardees, the panel considered originality, clarity, and timeliness of the papers.

The first award, for the best paper submitted by a student from an Australian or New Zealand university in Region 10, went to Shengjian Jammy Chen (Figure 3). His paper was entitled "Snap-On Buttons as Detachable Shorting Vias for Wearable Textile Antennas," coauthored with D. C. Ranasinghe and C. Fumeaux. The second award, for the best paper presented by a student from a university in any IEEE Region, went to Bingyuan Liang (Figure 4). Her paper was entitled "Three-Dimensional Frequency Selective Structure with Wide Pass Band and Sharp Roll-Off," coauthored with M. Bai and J. Miao. The announcement and presentation of the awards were made at the ICEAA-IEEE APWC 2016 banquet on September 21, 2016. Each winner received a certificate and a prize of 1,000 Australian Dollars. Some of the attendees at the banquet appear in Figure 5.

A luncheon meeting of IEEE AP-S Chapter Chairs was organized by Dr. Trevor Bird (Past President, IEEE Antennas and Propagation Society) and Dr. Ajay Poddar (Chair, IEEE AP-S Chapter Activities Committee) on Tuesday, September 20. It was well attended by representatives from several Australian and international branches. A total of 16 Chapter officers presented their reports, which demonstrated a range of interesting and supportive activities for members in their regions.

Three short courses were offered at the conference. Prof. Tapan Sarkar presented a half-day course on the physics and mathematics of the signal propagation mechanism in cellular wireless communication systems, while full-day courses on aperture antennas and radar were presented by Dr. Trevor Bird (Antengenuity and Macquarie University) and on high-power electromagnetics by Dr. Dave Giri (University New Mexico).

In conclusion, I would like to express my deep appreciation to the members of the LOC, the Scientific Committee, and the Steering Committee for their support and efforts in making the meeting a great success. The next edition of the ICEAA IEEE-APWC conference will be held in Verona, Italy, September 11-15, 2017 (Web site: http://www.iceaa.net).

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Report on the 7th VLF/ELF Remote Sensing of Ionospheres and Magnetospheres Workshop

1. General information

The 7th workshop of the URSI/IAGA Joint Working Group on ELF/VLF Remote Sensing of Ionospheres and Magnetospheres (VERSIM) took place in Hermanus, South Africa, over the period September 19-24, 2016. Due to its scientific synergy and large overlap in membership, the VERSIM workshop held a coordinated meeting together with the Radiation Belt Workshop, and was renamed VERSIM-RB to reflect this joint theme. The workshop was organized by the South African National Space Agency (SANSA), under the direction of Prof. Michael Kosch and Ms. Karen Wurbach. More details can be found on the workshop Web site: https://events.sansa.org.za/versim-information. The scientific sponsorship and financial support for this workshop were provided by the Union Radio-Scientifique Internationale (URSI), the International Association for Geomagnetism and Aeronomy (IAGA), and the Scientific Committee on Solar-Terrestrial Physics' (SCOSTEP's) Variability of the Sun and its Terrestrial Impacts (VarSITI) program.

The scientific program committee for the workshop consisted of Prof. Jacob Bortnik (IAGA co-Chair of VERSIM, University of California at Los Angeles, USA),

Figure 1. The VERSIM workshop attendees photographed on the entrance steps of the South African National Space Agency (SANSA), before the conference banquet on Wednesday, September 21, 2016.

Dr. Mark Clilverd (URSI co-Chair of VERSIM, British Antarctic Survey, UK), Prof. Michael Kosch (meeting organizer, SANSA Chief Scientist, South Africa), Prof. Craig Rodger (University of Dunedin, New Zealand), and Dr. Geoff Reeves (Los Alamos National Laboratory, USA).

2. Participants and Financial Support

The workshop attracted 55 participants from 16 different countries (Figure 1). These are considered to be excellent attendance numbers, especially given the fairly distant conference location in South Africa (e.g., compared to the 6th VERSIM workshop, held in Dunedin, New Zealand, in 2014, which had 35 participants from 14 different countries).

Due to the financial support received by VERSIM, we were able to provide financial support for the meeting for 11 individuals. This was prioritized on supporting participants who were either students/young scientists, or came from developing countries. In order to maximize the impact, sponsorship from different sources was pooled. The recipients received support covering all expenses except for international flights to Cape Town. The following 11 individuals, including five students, were supported:

Miss Emma Douma (student), Dunedin, New Zealand
Miss Sneha Gokani (student), Mumbai, India
Mr. Venkatesham Kammari (student), Allahabad, India
Miss Liliana Macotela (student), Sodankyla, Finland
Mr. Victor Nwankwo (student), Kolkata, India
Dr. Sandip Kumar Chakrabarti, Kolkata, India
Dr. Andrei Demekhov, Apatity, Russia
Dr. Ajeet Kumar Maurya, Georgia Institute of Technology, USA
Dr. David Shklyar, Moscow, Russia
Dr. Ashok Kumar Singh, University of Lucknow, India
Dr. Kaiti Wang, Taipei City, Taiwan

Sponsorship was received from IUGG/IAGA, URSI, SCOSTEP/VarSITI, and local South African sources. It was predominantly used for the support of young/foreign scientists (see above). The funds were converted to South African Rands (1 USD $\approx$ 15 ZAR), and allocated as in the follows:

- Conference registration: ZAR 4,000. This included two dinners and airport shuttle from Cape Town.

- Six days daily subsistence allowance (Monday to Saturday): ZAR 880.
- Seven nights accommodation (Sunday to Saturday, bed and breakfast): ZAR 5,250.
- Total per person ZAR 10,130.
- Grand total: ZAR 111, 430.

The conference banquet took place on Wednesday, September 21, and was held at Spookfontein in the Hemel-en-Aarde valley. The participants were welcomed by SANSA Executive Director Mr. Amal Khatri, and featured the Zwelihle marimba band, followed by the local Abalone Gold choir. The conference excursion was a nearby penguin colony visit.

At the conclusion of the workshop, a committee was formed to discuss and select the VERSIM nominee for the IAGA Young Scientist award. The committee consisted of Jacob Bortnik, Mark Clilverd, Craig Rodger, Michael Kosch, Janos Lichtenberger, and Jyrki Manninen. There were several eligible candidates for the IAGA Young Scientist award (i.e., under 30 years of age, and either currently studying or within two years of receiving their highest degree). Those candidates were: Ms. Emma Douma (NZ), Ms. Barabara Bezdekova (Czech Rep), Ms. Lilian Macotela (Finkand), Ms. Sneha Gokani (India), and Ms. Sello Molele (South Africa). We note that all the candidates were young women, represented five different countries, and gave outstanding presentations. After much deliberation, the committee decided to nominate Ms. Emma Douma, who gave a talk entitled, "MeV Electron Microbursts Detected by SAMPEX: Comparison of Microburst Distributions and Chorus Activity for Various Geomagnetic Activity Levels." The committee also selected the VERSIM nominee for the IAGA 2017 Summer School, and gave the nomination to Ms. Barbara Besdekova.

3. Abstracts and Sessions

There were a total of 69 abstracts received, 59 of which could be accommodated as oral presentations, and 10 of which were presented as posters. More information on presenters and abstracts can be found on the abstract Web page: https://events.sansa.org.za/abstracts. The abstracts were organized into six days, the first four days of which were devoted to core VERSIM topics, and the last two days transitioned into more of a radiation-belt focus. The VERSIM scientific program can be found here: https://events.sansa.org.za/versim-programme.

4. Scientific Highlights

The VERSIM workshop continued to be the scientific highlight of the VERSIM group, and was well supported with many outstanding presentations and broad international participation. The scientific content was thematically divided into:

1. An introductory and historical talk (which was recorded and placed online for future integration into the VERSIM Web page: https://www.youtube.com/watch?v=27Xf8k7_jZQ).
2. D-region Ionosphere, Monday September 19, three sessions
3. Lightning: Monday September 19 - Tuesday September 20, two sessions
4. Whistler Waves: Tuesday September 20, Thursday September 22, two sessions
5. Plasmasphere: Tuesday September 20, one session
6. Chorus Waves, Thursday September 22, three sessions
7. Electromagnetic Ion Cyclotron Waves (EMIC), Thursday September 22, one session
8. Radiation Belts, Friday September 23 - Saturday September 24, five+ sessions

The VERSIM business meeting took place on the evening of Tuesday, September 20. The poster session, together with a tour of SANSA, the conference tour, and the banquet took place on Wednesday, September 21.

There were many outstanding presentations given at the meeting that are too numerous to list in this brief report. However, a few common themes emerged regarding the improved detection and characterizations of whistler waves for remote sensing of the plasmasphere; detection of VLF transmitter waves for measuring and characterizing the lower ionospheric density profile; the importance of whistler-mode and EMIC waves in controlling the dynamics of the radiation belts; the significantly expanded and improved multi-platform observational network that is now available to the VERSIM community, including the Van Allen Probes, THEMIS, CLUSTER, MMS (spacecraft) as well as ground-based lightning-detection networks, WWLLN and GLD360. A detailed listing of talks and abstracts is given in Section 3, above.

5. Next Workshop

During the VERSIM business meeting, there were two presentations given as bids to host the next VERSIM workshop in 2018. These were by:

Andrei Demekhov, a Russian location in either Apatity or Murmansk

Geoff Reeves, a US location in either Arizona or New Mexico.

There will be an online poll created over the next few weeks, and the VERSIM community as a whole will vote on the next venue.

Jacob Bortnik
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Report on PRE 8 Workshop

The 8th International Workshop on Planetary, Solar, and Heliospheric Radio Emissions (PRE 8) was organized by the Space Research Institute of the Austrian Academy of Sciences. The workshop took place at the conference hotel Schloss Seggau in Seggauberg, near Leibnitz/Graz, Austria, from October 25-27, 2016. October 24 was the arrival day, and October 28 was the departure day. A total of 50 participants attended the workshop, with 20% female scientists (Figure 1). There were 13 other scientists who could not come to Austria in person, but sent posters that were presented by other scientists at the workshop. 68 abstracts were submitted in total, which were presented as 42 talks and 26 posters in nine oral sessions and one poster session. Key topics of the workshop were the recent developments in the study of non-thermal radio emissions from the sun, the five radio planets, the heliosphere, and potential radio emissions from exoplanets.

On the first conference day, one oral session dealt with the new findings of Juno at Jupiter, two oral sessions were about Jovian radio emissions, and one oral session was about Saturn radio emissions. One highlight of the workshop was the first presentation of scientific results from the Juno/Waves radio instrument. The NASA mission to Juno had entered an orbit around Jupiter in early July 2016, and the first periapsis pass with scientific data took place on August 27. First dynamic spectra revealed the multitude of the Jovian radio spectrum, with the first view of Jovian radio emissions from high latitudes with frequencies close to the cyclotron frequency suggesting that Juno passed very close to the emission's source region. Juno/Waves also observed electron and proton whistlers, dust impacts, lightning whistlers, quasi-periodic (QP) bursts, and upstream Langmuir waves and ion-acoustic waves during the approach. Juno is also a good example where space-based observations are supported by ground-based observations, which was a topic at PRE 8. Radio telescopes, such as the French NDA (Nançay Decameter Array), have observed Jupiter for almost 40 years. From this abundance of radio data, it was shown in presentations at PRE 8 that there are radio emissions induced by the Jovian moons of Ganymede and Europa. The changing periodicity of Saturn kilometric radiation was an important topic concerning Saturn radio emissions. The first day was concluded with a wine-tasting event at the wine cellar of Schloss Seggau.

The topics of the second day were terrestrial radio emissions, developments of radio instruments, and theory. For terrestrial radio emissions, the observations of higher-harmonic electron-cyclotron emissions from the aurora with ground-based radio stations in Antarctica were an interesting finding. The technical development of antennas

Figure 1. A group picture of the PRE 8 workshop in Schloss Seggau, October 25-27, 2016.

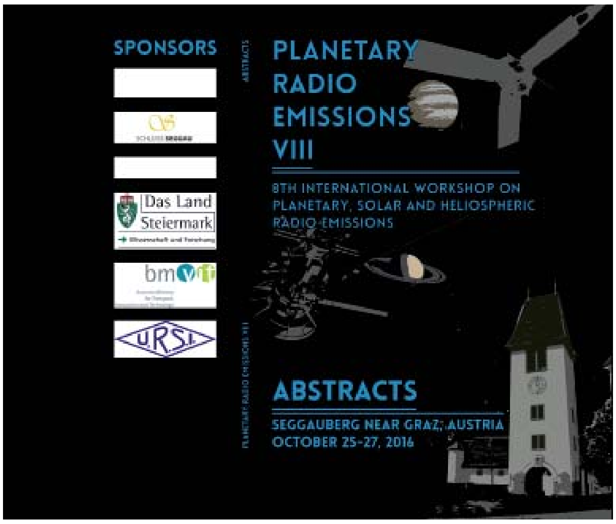

Figure 2. The cover of the PRE 8 abstract book with the logos of the sponsors.

and receivers for ground-based radio stations was also discussed, such as the novel usage of small cubesats for the investigation of solar radio emissions, or the usage of small portable radio arrays as interferometric detectors.

In the afternoon, we took a bus tour with an excursion to the chocolate factory "Zotter" in Bergl, close to Riegersburg. Everybody enjoyed the walk through the transparent chocolate factory to see the transformation from the cocoa bean into chocolate – mostly because there were numerous places where chocolate could be tasted, according to the motto "all you can eat."

On the third day, there were two oral sessions about solar radio emissions, one oral session about potential exoplanetary radio emissions, and the poster session. A new technique, called tied-array imaging – which uses multiple beams pointing at the radio source – has been used with LOFAR to obtain new results on solar S (short) bursts. This interesting invited talk was presented by Diana Morosan, a young scientist from Trinity College Dublin, who was supported by funds from URSI. The solar S bursts were also observed with the UTR-2 radio telescope during the solar maximum in 2013/14. Another interesting talk about a multi-wavelength analysis of solar EUV jets was presented by Sargam Mulay, a student from Cambridge University who was the second person supported by URSI funds. Exoplanetary radio emissions have not yet been detected. However, the radio emissions of brown dwarfs are thought to be created by the same mechanism as auroral kilometric radiation, and the search for exoplanetary radio emissions will continue. The last session of the day and the workshop was the poster session.

Planetary and solar radio emissions can be measured either by antennas on spacecraft or by ground-based radio telescopes. At PRE 8, special emphasis was put on current space missions such as Juno (at Jupiter), Cassini (at Saturn), Stereo (observing the sun), and the Earth-orbiting missions Themis, the Van Allen Probes, and Hisaki. New findings from data of older missions such as the Voyagers, Fast, or Wind were also discussed. Key questions for radio-wave measurements with future missions such as ESA's large mission JUICE (Jupiter Icy Moons Explorer) or the small cubesat mission HeRO (Heliophysics Radio Observer) were addressed. New developments and scientific data from the following ground-based radio telescopes were discussed. Here, the main telescopes were the European network LOFAR (LOw Frequency ARray); UTR-2 and URAN in the Ukraine; the NDA (Nançay Decameter Array) in France, with its new LOFAR station called NenuFAR; the LWA (Long Wavelength Array) and VLA (Very Large Array) in the USA; the MWA (Murchison Widefield Array) in Australia; and the Japanese IPRT (Iitate Planetary Radio Telescope).

In summary, PRE 8 showed the most recent developments in the study of planetary, solar, heliospheric, and possible exoplanetary radio emissions. It should lead to new collaborations among the participants. This was the main objective of the PRE workshop series. PRE 8 was the continuation of the series of international workshops that took place in 1984, 1987, 1991, 1996, 2001, 2005, and 2010. The abstracts of PRE 8 were compiled in a printed abstract book (Figure 2), which can also be downloaded from the Web site at http://pre8.oeaw.ac.at/. A proceedings book was published after all previous PRE workshops, and we will keep up this tradition. All participants were asked to submit a written version of their contribution, and the manuscripts will be collected and reviewed. It is planned to publish the proceedings book with the Austrian Academy of Sciences Press in late 2017. PRE 8 was sponsored by the International Union of Radio Science (URSI); Europlanet; the Province of Styria; the Austrian Ministry for Transport, Innovation and Technology; and the Space Research Institute of the Austrian Academy of Sciences. The sponsors were mentioned in a press release, and their logos were displayed on the conference Web page, in and on the abstract book (Figure 2), and will also be displayed in the proceedings. There might be a PRE 9 workshop in future, maybe in the year 2020.

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URSI Conference Calendar

January 2017

USNC-URSI NRSM 2017
USNC-URSI National Radio Science Meeting 2017
Boulder, CO, USA, 4-7 January 2017
Contact: Dr. David R. Jackson, Department of ECE, University of Houston, Houston, TX 77204-4005, USA, Fax: 713-743-4444, E-mail: djackson@uh.edu; Logistics: Christina Patarino, E-mail: christina.patarino@colorado.edu, Fax: 303-492-5959, https://nrsmboulder.org/

February 2017

URSI-France 2017 Workshop dedicated to "Radio Science for Humanity"
Sophia Antipolis, France, 1-3 February 2017
Contact: Prof. Tullio J. TANZI, Intitut Mines Télécom, Telecom, ParisTech. E-mail: tullio.tanzi@telecom-paristech.fr, ursi-france@mines-telecom.fr, http://ursi-france.telecomparistech.fr/evenements/journees-scientifiques/2017/2017-en.html

March 2017

URSI - RCRS 2017
3rd URSI Regional Conference on Radio Science 2017
Tirupati, Andhra Pradesh, India, 1-4 March 2017
Contact: Dr. T.V.Chandrasekhar Sarma, National Atmospheric Research Laboratory, Gadanki, India, E-mail: ursircrs2017@narl.gov.in, https://ursircrs2017.narl.gov.in

EUCAP 2017
11th European Conference on Antennas and Propagation
Paris, France, 19-24 March 2017
Contact: Alain Sibille, Mail: eucap2017@b2c-congress.com, http://www.eucap.org/

URSI-ICTP School on Radio Physics
Miramare-Trieste, Italy, 27-31 March 2017
Contact: Prof. Iwona Stanislawska, Prof. Simonetta Paloscia, Prof. Ondrej Santolik, Prof. Patricia Doherty ; Local Organiser: Bruno Nava, Secretary: Gabriela De Meo, CTP - Strada Costiera, 11, I - 34151 Trieste Italy, E-mail: stanis@cbk.waw.pl, http://indico.ictp.it/event/7956/

August 2017

URSI GASS 2017
XXXIInd URSI General Assembly and Scientific Symposium
Montreal, Canada, 19-26 August 2017
Contact: URSI Secretariat, Ghent University - INTEC, Technologiepark - Zwijnaarde 15, 9052 Gent, Belgium, E-mail info@ursi.org

Metamaterials 2017
The Eleventh International Congress on Advanced Electromagnetics Materials in Microwaves and Optics The Eleventh International Congress on Artificial Materials for Novel Wave Phenomena
Marseille, France, 28-31 August 2017
http://congress2017.metamorphose-vi.org
Contact: contact@metamorphose-vi.org

May 2018

AT-RASC 2018
Second URSI Atlantic Radio Science Conference
Gran Canaria, Spain, 28 May – 1 June 2018
Contact: Prof. Peter Van Daele, URSI Secretariat, Ghent University – INTEC, Technologiepark-Zwijnaarde 15, B-9052 Gent, Belgium, Fax: +32 9-264 4288, E-mail address: E-mail: peter.vandaele@intec.ugent.be
http://www.at-rasc.com

March 2019

C&RS "Smarter World"
18th Research Colloquium on Radio Science and Communications for a Smarter World
Dublin, Ireland, 8-9 March 2019
Contact: Dr. C. Brennan (Organising Cttee Chair)
http://www.ursi2016.org/content/meetings/mc/Ireland-2017-CRS Smarter World CFP.pdf

AP-RASC 2019
2019 URSI Asia-Pacific Radio Science Conference
New Delhi, India, 9-15 March 2019
Contact: Prof. Amitava Sen Gupta, E--mail: sengupto53@yahoo.com

May 2019

EMTS 2019
2019 URSI Commission B International Symposium on Electromagnetic Theory
San Diego, CA, USA, 27-31 May 2019
Contact: Prof. Sembiam R. Rengarajan, California State University, Northridge, CA, USA, Fax +1 818 677 7062, E-mail: srengarajan@csun.edu

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

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