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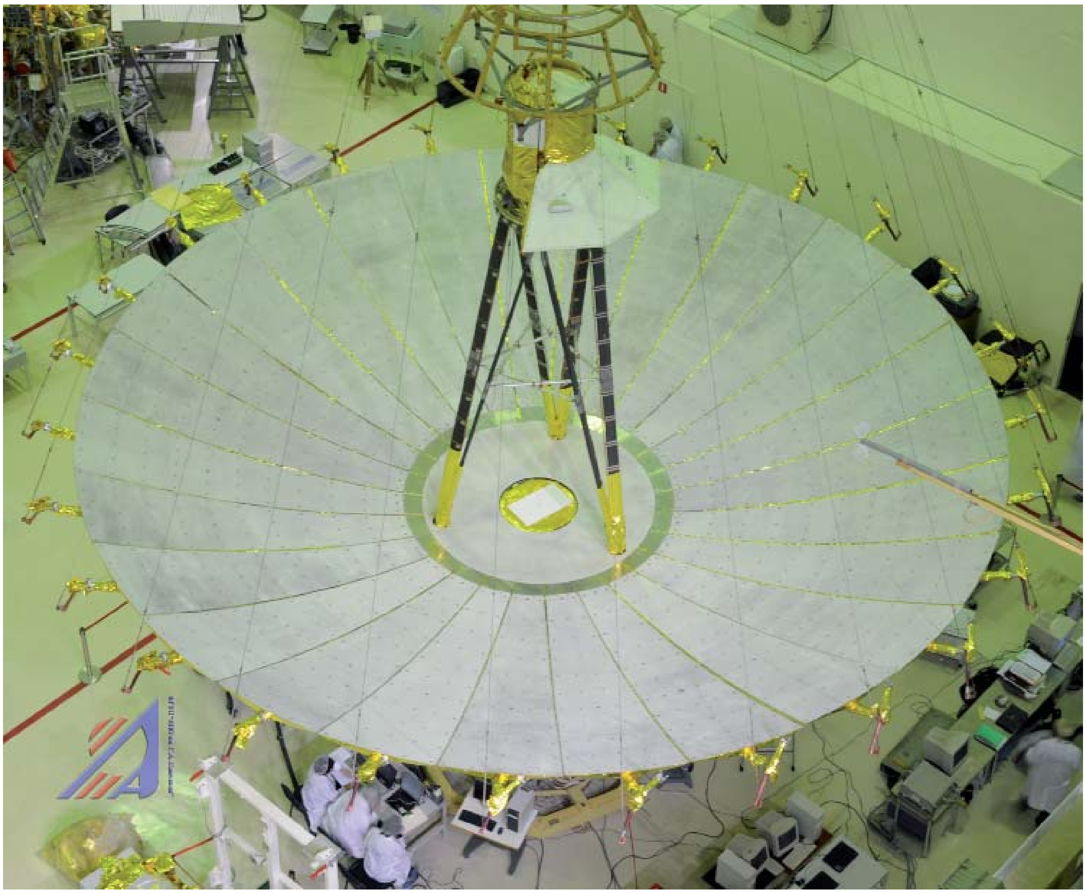

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Front cover: The 10 m RadioAstron Space Radio Telescope with the petals unfurled. See the paper by N.S. Kardashev, Y.Y. Kovalev, and I. Kellerman on pp. 22 - 29.

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The International Union of Radio Science (URSI) is a foundation Union (1919) of the International Council of Scientific Unions as direct and immediate successor of the Commission Internationale de Télégraphie Sans Fil which dates from 1913.

Editorial

Our Papers

The problem of the propagation of a radio wave from a source over a lossy Earth is a classic problem, dating back at least to the work of Sommerfeld in 1909. As Tapan Sarkar, Walid Dyab, Mohammad Abdallah, Magdalena Salazar-Palma, M. V. S. N. Prasad, Silvio Barbin, and Sio Weng Ting demonstrate in their paper, this classic problem is of considerable current importance. This is because it provides new and significant insight into the science of electromagnetic propagation for cellular communications systems. The paper begins with a review of the history of this problem. Several controversies surrounding the existence and nature of various types of surfaces waves are explored in detail. The basic questions of what constitutes a surface wave, and under what conditions a surface wave is associated with such propagation, are addressed. The controversies surrounding such surface waves are resolved. This includes showing that the source of an error in Sommerfeld's 1909 paper was not due to a sign error, as often claimed, but was rather due to a more-subtle mathematical issue. In a companion paper, the authors have shown that the electromagnetic fields associated with propagation in a cellular-communications cell decay over most of the cell with distance at a rate of 30 dB per decade, followed by a fringe region where the rate of decay is 40 dB per decade. This paper derives the fields that are responsible for this fading. Among other results, it is shown that the fields produced by a two-dimensional source, or by a line source, over an imperfectly conducting ground produce the initial fading rate. It is further shown that fields in the form of a Norton surface wave contribute only in the fringe region of the cell. A variety of experimental data related to the decay rate of fields over imperfectly conducting media is cited and examined in detail, and shown to support the theoretical conclusions. This includes classic experiments done in the 1930s specifically to investigate surface waves, as well as modern experiments with cellular communication systems. This leads to a clear and accurate physical representation of the fields associated with such systems. One of the most interesting consequences of this representation is that the basic propagation path losses for such systems are insensitive to the details of the propagation environment: a macro model is sufficient to accurately provide the basic path losses. This paper is important reading for anyone with an interest in either the classical problem of propagation over an imperfectly conducting medium, or in the propagation associated with modern cellular communication systems.

Fundamental physics says that everything else being equal, the larger the baseline of a radio telescope, the higher its resolution. Achieving baselines larger than an appreciable fraction of the Earth's diameter requires putting part of the radio telescope in space. The invited paper by N. S. Kardashev, Y. Y. Kovalev, and K. I. Kellermann describes RadioAstron, an Earth-space radio interferometer with an effective baseline that is more than a factor of 10 larger than what is possible on Earth. The paper begins with a review of the factors affecting the resolution of radio telescopes, and some comparisons with optical telescopes. This is followed by a brief introduction to radio interferometry. The use of independent oscillators located at the elements of an interferometer, along with remote recording of the data, are explained. These techniques remove two of the limitations to the baselines of very-long-baseline interferometry. Two earlier space-based long-baseline interferometers are reviewed. The development and specifications of RadioAstron are then reviewed. This instrument consists of a 10 m dish in space that works with a variety of Earth-based dishes in many different countries to provide a number of different observing opportunities. The spacecraft was launched in July 2011. The space dish is in a highly elliptical orbit, providing a baseline of as much as 350,000 km. The system operates in four bands, from 330 MHz to 22 GHz. The details of the hardware and the data system are given. The scientific goals of the project are reviewed, and early results are summarized. This paper provides a very nice review of space-based radio telescopes and RadioAstron. It also contains good resources for those seeking additional information.

This paper is one of the invited *Reviews of Radio Science* from Commission J. The assistance of Ondrej Santolik and members of Commission J in bringing us this paper are gratefully acknowledged.

Our Other Contributions

Thanks to Kristian Schlegel, we again have two book reviews in this issue. One is from a Young Scientist, and both cover books that the reviewers found to be quite valuable.

There are several calls for papers for important conferences for radio scientists in this issue. As readers may have noticed from the previous issue, we are now running the complete calls for papers as provided by the conferences. This should provide more information for our readers. We also have a report on a COSPAR session on "Global and Regional Representation of Ionospheric Peak Parameters for Space Weather Applications." The summary provided of the results should be of interest to anyone using ionospheric models.

This being the December issue, our usual updated material on the organization of URSI and key contact people within the Union is included.

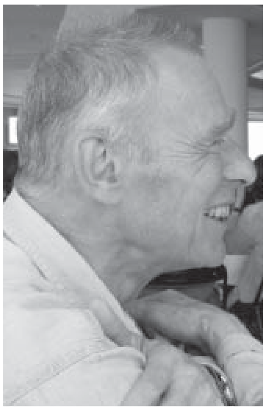
Best Wishes

This issue should reach the URSI community around the middle of December. My very best wishes to all of our readers for most joyous holidays, and for a very happy, healthy, safe, and prosperous New Year!

Ross

In Memoriam

Vladimír Fiala
1938 - 2012



Vladimír Fiala, an internationally recognized space-plasma physicist, a former Chair of URSI Commission H (Waves in Plasmas), and a former President of the Czech National Committee of URSI, passed away on September 8, 2012, after a courageous fight against cancer.

Dr. Fiala graduated from the Department of Mathematics and Physics of the Charles University in Prague in 1961. After doing post-graduate studies in the Lebedev Institute of Physics in Moscow with Alexander Gurevich, he received his PhD in space-plasma physics from the Geophysical Institute of the Czechoslovak Academy of Sciences in 1967. From 1967 to 1970, he worked in the Groupe de Recherches Ionospheriques/CNRS in France with L. R. O. Storey, and then returned to Prague to work in the Geophysical Institute. He also lectured on space physics at Charles University. In addition, for several years he worked in France, Russia, and the United States in various space-research laboratories on long-term fellowships. In 1994, he received a Fulbright Research Award to work at the University of Minnesota. For the rest of his life, he then worked in the Department of Space Physics, Institute of Atmospheric Physics of the Academy of Sciences of the Czech Republic.

Vladimir Fiala was elected Vice Chair of URSI Commission H at the 1993 Kyoto General Assembly. He became Chair of that Commission at the 1996 Lille General Assembly. From 1999 until 2008, he worked as the President of the Czech National Committee of URSI. The research interests of Vladimir Fiala were in theoretical space plasma physics, especially antenna-plasma interaction, propagation and excitation of plasma waves, and wave scattering by ionospheric irregularities. He significantly contributed to our understanding of the physics of probes and antennas in space plasmas. He researched and explained the behavior of magnetic and electric antennas in the context of planning or of data analysis for the FR-1 (France/NASA), Aktivnyi (USSR), CLUSTER (ESA), and OEDIPUS-C (Canada) missions. Dr. Fiala also took up and advanced the study of the probe-antenna response to waves propagating close to plasma resonances. These included the oblique resonance occurring in anisotropic plasmas in the whistler mode, and the Langmuir-wave resonance in a drifting isotropic plasma.

Vladimir Fiala was a keen proponent of international groups for working-level collaboration, as was evidenced by his organizational work in URSI. He championed and organized international group studies on diverse aspects of waves in space plasmas. A NATO Linkage Grant that he initiated led to the birth of the Resonance Cone Club consortium involving Russia, the Czech Republic, France, and Canada, which is just one example among many of his commitment to international scientific cooperation.

Dr. Fiala was a talented scientist, and he loved his work. He had a gift for sharing his enthusiasm with younger colleagues, whom he was always ready to help to do good scientific work. His deep voice and his sense of humor impressed all those who had the privilege of working with him. Discussions with him were open, thoughtful, pleasant, and inspiring. He will be sorely missed.

Edited by O. Santolik (Institute of Atmospheric Physics in Prague, Czech Republic; e-mail: os@ufa.cas.cz), Chair of URSI Commission H, with significant help from L. R. O. Storey and H. G. James

Physics of Propagation in a Cellular Wireless Communication Environment

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M. Salazar-Palma
M. V.S.N. Prasad
S. Barbin, S. Weng Ting

Abstract

The objective of this paper is to illustrate from a physics standpoint the nature of the fields that carry energy from a transmitter to a receiver located over an imperfectly conducting Earth. In an accompanying paper [1], it was shown from both the theoretical (developed from the classical Sommerfeld attenuation function) and experimental points of view that the fields inside a cellular-communication cell decay as 30 dB per decade, following a slow fading region. The 30 dB per decade region is followed by a region (in the fringe area) where the rate of decay is 40 dB per decade. This means that the fields decay as $1/\rho^{1.5}$ (where ρ is the radial distance between the transmitter and the receiver) and $1/\rho^{2}$, respectively, inside a cell. The first goal is to illustrate that Sommerfeld had no error in sign in his classic 1909 paper. However, while computing his asymptotic development of the branch-cut integral, Sommerfeld did not notice that beside the space wave, this contains the surface wave with a negative sign, which would cancel the residue of the pole. In other words, no surface wave can be generated from a pole that is a part of the original Sommerfeld solution for radiation from a dipole operating over an imperfectly conducting ground. Other type of waves, e.g., Norton's surface wave and a radiation field that decays as $1/\rho^{1.5}$, are part of the ground wave. They can be derived from the same Sommerfeld attenuation function, but using different types of approximations. As already mentioned, Norton's surface wave and the radiation field (decaying as $1/\rho^{1.5}$) are a part of the solution. These points were illustrated in an accompanying paper [1]: here, we focus on the physics of these waves. We also explain what the mathematical characteristics of a surface wave are, as there is a lot of confusion in the usage of the same word for different types of waves. The goal of this paper is hence to develop an understanding of the physics associated with radiating fields that decay with a rate of 30 dB per decade with distance, and with an emphasis on the following phenomena:

1. To illustrate that radiation fields emanating from a two-dimensional source and associated with the launching of a true surface wave are responsible for producing a field that decays as 30 dB per decade. This type of field can also be generated from a line source located over an imperfectly conducting ground.

2. To illustrate that radiation fields in the form of Norton's surface wave contribute only in the fringe areas of the cells, where the fields decay as 40 dB per decade.

3. To illustrate that the error in Sommerfeld's classical paper of 1909 had nothing to do with an error in sign. He did not consider the effect of the occurrence of a pole near the saddle point in his asymptotic expansion. In other words, the poles were not located on the proper Riemann sheet. The popular belief that he made an error in sign in his paper is indeed a myth!

4. To illustrate that the electromagnetic field produced in a cellular communication system (where the dipole constituting the base-station antenna is placed at a given height over the imperfectly conducting surface of the Earth) is due to an infinite set of images starting at the location of the image of the first point of the transmitting antenna and extending to negative infinity, resulting in a line source. This will be illustrated by both theoretical and experimental data. This further illustrates that ray tracing is not the appropriate tool to use in predicting the fields near the ground.

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5. Finally, to illustrate that all the experimental data indeed clearly show that the path-loss exponent in a cellular environment is three (at moderate distances from the transmitting antenna) or four (at larger distances), in spite of buildings and trees being present in the measurements. Hence, one of the surprising conclusions is that one can get by with macro modeling, and micro modeling of the environment is overkill!

1. Discussion of the Early History

As presented by Wait [2] and Collin [3], in the 19th century – after the initial work of Hertz [4] and Heaviside [5], and exemplified by Lodge [6] and followed through by Tesla [7], Popov [8], Bose [9], and others – researchers had irrefutable evidence of the correctness of Maxwell's equations, and the ability to generate and radiate electromagnetic waves. However, it was Marconi [10] who translated all these principles into reality, by transmitting electromagnetic waves over long distances. It was Marconi who proved to the scientific community that besides the line-of-sight communication, other modes of communication were possible. The conjecture at that time was that perhaps the transmission over such large distances took place through the surface wave, introduced earlier by Lord Rayleigh [11].

According to Schelkunoff [11], it was Lord Rayleigh who discovered that in a semi-infinite elastic medium, a source of finite dimensions excites two kinds of waves: 1) space waves that spread in all directions, and 2) *surface waves* that spread only along the boundary. If the medium is non-dissipative, it follows from the principle of conservation of energy that at large distances from the source, the energy density in a space wave varies inversely as the square of the distance from the source. In a surface wave, it varies inversely as the distance. This implies that the fields of a space wave vary as the inverse of the distance, while those of a surface wave should vary as the inverse of the square root of the distance. Surface waves seemed to be attached to the boundary of the solid, and tended to follow it, even if it was curved.

In the time of Marconi's famous experiments, and prior to the discovery of the Kennelly-Heaviside reflecting layer, there was much speculation about the possible existence of similar kinds of electromagnetic waves. It was already known that electric waves had a tendency to cling to parallel wires (*Lecher wires*, as they are called), and could thus be guided around corners. Did the surface of the Earth have a similar tendency to capture some of the energy from an antenna and guide it into the shadow region, thus explaining Marconi's success? That was the question!

This created a great interest in the study of surface waves. For completeness, in the Appendix, we define the terminology of the various waves that we use in this paper. The guiding of a plane electromagnetic wave along the flat interface separating air and the imperfectly conducting ground seems to have been first investigated by Cohn [12], and shortly thereafter by Uller [13]. Zenneck [14, 15] recognized the bearing of this research on the propagation of radio waves, and showed that the field equations admit a solution that can be interpreted as a surface wave guided by a plane interface separating any two media.

As further stated by Schelkunoff, according to Zenneck [15],

> ...there are waves which emanate from a transmitter placed in a homogenous insulating material and energy is radiated in straight lines, radially from the transmitter. Consequently, the energy varies as $1/\rho^2$ (ρ = distance from the source) and the amplitudes of the electric and magnetic field strengths vary as $1/\rho$, which are termed as space waves. A different kind of wave is obtained for an antenna located at the Earth's surface. The wave emanated into the air by an antenna at the Earth's surface may be conceived as consisting of two parts, one of which is of the nature of a space wave and the other of a surface wave. In the former, the energy $\propto 1/\rho^2$, the amplitude therefore varies as $\propto 1/\rho$; in the latter, the energy $\propto \frac{1}{R}$, and therefore the amplitude $\propto 1/\sqrt{\rho}$ The fact that in the latter there is a decrease in energy as the distance increases in contrast to a wave following a wire – and in addition to and entirely aside from such absorption as occurs – is explained by the fact that the energy is spreading itself out over in ever-increasing circles as the wave propagates. This much is relevant to the classical distinction between space and surface waves. Therefore, initially Zenneck and Sommerfeld accepted Rayleigh's definition of a surface wave as far as the most significant physical properties are concerned. However, later they have made an unfortunate slip in their analysis which subsequently confused the issue [11]. The controversy thus arose from the following statement of Zenneck [15]: While at short distances from the transmitter, the waves are almost entirely of the nature of space waves, as the distance increases the surface component becomes more and more predominant, as its amplitude decreases more slowly than that of the space component. That is the nature of the wave constantly approaches that of a surface wave. When the distance becomes very great, the surface wave may again give way to the space wave, as the former is more rapidly absorbed. It is questionable, however whether this effect is of practical importance.

The above-quoted conclusion of Zenneck's is based on the original formulas obtained by Sommerfeld. However, it was found later both from theory and experiment that the surface-wave term was missing from the final solution initially proposed by Sommerfeld.

Wait [2] also stated that the idea that a Zenneck type of wave could be employed to investigate the propagation of fields over the Earth was pointed out both by Zenneck himself, and his colleague, Hack [16]. In 1907, Zenneck [14, 15] showed that a plane interface between two semi-infinite media, such as the ground and the air, could support an electromagnetic wave that is exponentially attenuated in the direction of propagation along the surface, and vertically upwards and downwards from the interface. Zenneck showed that Maxwell's equations did provide a solution for a wave or an inhomogeneous plane wave that was attached to the interface between the air and the underlying medium, and could propagate over great distances with a small amount of attenuation [15]. Zenneck did not show that an antenna could generate such a wave, but because this "surface wave" seemed to be a plausible explanation of the propagation of radio waves to great distances, it was accepted. A Zenneck wave is an inhomogeneous plane wave, because the field decays (exponentially in this case) over the wavefront with an increase in the distance from the surface. A wave propagating along the x direction with a phase velocity greater than the speed of light has a magnetic-field distribution in air given by the real part of the corresponding phasor quantity, multiplied by $e^{j\omega t}$, where ω stands for the angular frequency corresponding to the frequency of operation, t stands for the time variable, and j is the imaginary unit. In a phasor notation, this term is suppressed, as $H_z = Ae^{-\gamma y}e^{-ux}$, where $\gamma = \alpha + j\beta$ The phasor components of the electric fields are given by $E_x = -A\left(\frac{\gamma}{j\omega\varepsilon_0}\right)e^{-\gamma y}e^{-ux}$ and $E_y = A\left(\frac{u}{j\omega\varepsilon_0}\right)e^{-\gamma y}e^{-ux}$ Here, ε_0 stands for the dielectric constant of vacuum, (x,y,z) are the Cartesian coordinates of the observation point, and A is a constant. This wave decays exponentially with the complex propagation constant u along the x direction, and also decays exponentially along the y direction, with the propagation constant, γ. Typically, these types of waves have a phase constant in vacuum that increases as the wavelength decreases, while the rate of evanescence is small and independent of the frequency [11]. As mentioned before, the characteristics of various waves are summarized in the Appendix. The Zenneck wave is not a true surface wave according to our use of Schelkunoff's characterization, as explained in the next section.

In 1909, Sommerfeld [17, 18] undertook a detailed analysis of the radiation from an infinitesimal vertical Hertzian dipole over an imperfectly conducting infinite ground medium, to complete the demonstration of the surface-wave component of the total field. Sommerfeld obtained the phasor for the potential from a dipole located in air (medium 1, with a propagation constant k_1) and radiating over a ground plane having a complex permittivity ε (medium 2, with a propagation constant $k_2 = k_1\sqrt{\varepsilon}$), as

$$\Pi_{1z} = P\left\{\frac{\exp\left(-jk_1 R_1\right)}{R_1}\right.$$

$$+\int_0^\infty \frac{J_0(\lambda\rho)}{\sqrt{\lambda^2 - k_1^2}}\left(\frac{k_2^2\sqrt{\lambda^2-k_1^2} - k_1^2\sqrt{\lambda^2-k_2^2}}{k_2^2\sqrt{\lambda^2-k_1^2} + k_1^2\sqrt{\lambda^2-k_2^2}}\right)$$

$$\left.\exp\left[-\sqrt{\lambda^2-k_1^2}\left(z+z'\right)\right]\lambda\, d\lambda\right\} \qquad (1)$$

for $\mathrm{Re}\left[\sqrt{\lambda^2 - k_{1,2}^2}\right] > 0$. Here, $k_1^2 = \omega^2\mu_0\varepsilon_0$, and $k_2^2 = \omega^2\mu_0\varepsilon_0\varepsilon$, where μ_0 is the permeability of vacuum. Furthermore,

$$P = \frac{I\,dz}{j\omega 4\pi\varepsilon_0}, \qquad (2)$$

$$\rho = \sqrt{\left(x-x'\right)^2 + \left(y-y'\right)^2}, \qquad (3)$$

$$R_1 = \sqrt{\rho^2 + \left(z-z'\right)^2}, \qquad (4)$$

$$R_2 = \sqrt{\rho^2 + \left(z+z'\right)^2}.$$

where λ is the variable of integration; (x', y', z') is the location of the dipole, placed vertically with respect to the Earth's surface; and $I\,dz$ is the dipole moment of the elementary current.

As part of his solution, Sommerfeld illustrated that a surface-wave contribution arose from the pole of the integrand (i.e., from the solution for λ of the equation $k_2^2\sqrt{\lambda^2-k_1^2} + k_1^2\sqrt{\lambda^2-k_2^2} = 0$), and other radiated waves evolved from the branch-cut contributions related to the two branch points located at k_1 and k_2. It was recognized from the onset by Sommerfeld that his total solution of Equation (1) could be interpreted as a bundle of plane waves reflected and refracted from the surface of the Earth at various angles of incidence. The surface integrals were extended over the plane Earth and over small spheres that excluded the singularities occurring at the source and at the point of observation. The mathematical details are available in [1]. Sommerfeld's approach was based on a deformation of the path of integration in the complex λ plane, as shown in Figure 1a. The denominator for the expression of the fields has branch points at $\lambda = \pm k_1$ and $\lambda = \pm k_2$, and poles at $\lambda_P = \pm\frac{k_1 k_2}{\sqrt{k_1^2 + k_2^2}}$. The corresponding Riemann surface has four sheets, on only one

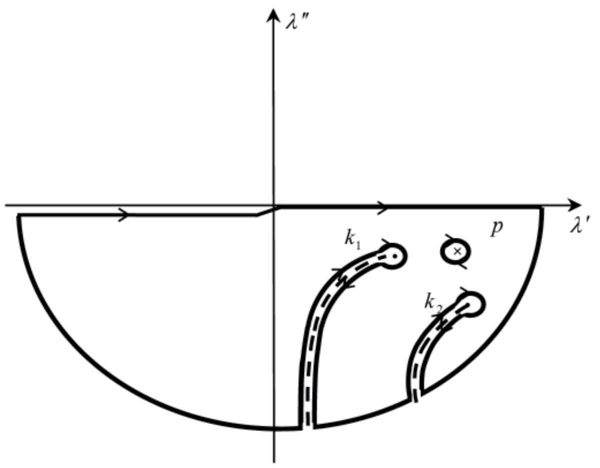

Figure 1a. The closed contour of integration as implemented by Sommerfeld in the lower complex λ plane.

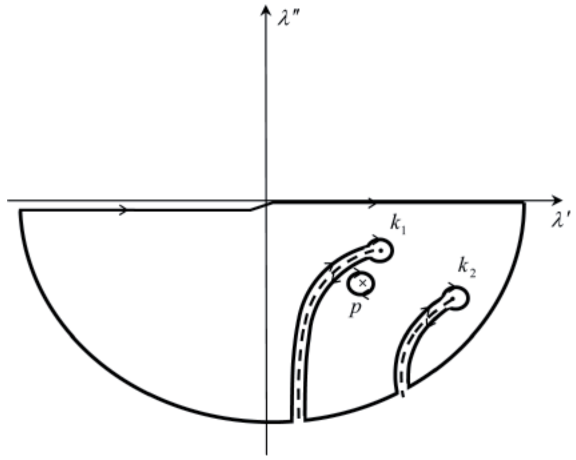

Figure 1b. The actual location of the pole in the lower complex λ plane.

of these are the necessary conditions for the convergence of the integral at infinity fulfilled. According to Sommerfeld, the path of integration can be resolved on this sheet into three parts. The first part is a loop from infinity about the branch point $\lambda = k_1$ the second part is a similar loop about $\lambda = k_2$, and the third part can be any small circle about the pole $\lambda = \lambda_P$, as seen in Figure 1a. The contributions of the loops about the branch points give the dominant terms at $\frac{e^{-jk_1R}}{R}$ and $\frac{e^{-jk_2R}}{R}$, which can be identified as the space waves. The residue at the pole has a variation of the form $\frac{e^{-j\lambda_pR}}{\sqrt{R}}$, which had all the hallmarks of a true surface wave, but not a Zenneck wave. (We will discuss the properties of a surface wave in the next section. However, suffice it to say that it is a slow wave for a lossless dielectric medium and there is practically no loss in the direction of propagation. The fields in the transverse directions are evanescent, and as the frequency increases, the wave is confined close to the surface. However, it is not a Zenneck wave, as it is a slow wave.) Here, R is the distance between the source and the observation (field) point. The mathematical subtleties that differentiate a surface wave from a Zenneck wave are explained in the next section.

Sommerfeld thus obtained results that lent considerable credence to Marconi's view that the electromagnetic wave was guided along the surface. As Collin noted in [3], as early as 1902, Kennelly [19] and Heaviside [20] predicted the existence of an ionized layer at a considerable height above the surface of the Earth. It was thought that such a layer could possibly reflect the electromagnetic waves back to the Earth. This was experimentally verified by Brett and Tuve in 1926 [21]. No serious challenge to the surface-wave mechanism for long-distance propagation thus occurred until a decade later, when Weyl published a paper on the same subject. Weyl obtained a solution very similar to that found by Sommerfeld [17], but without the surface-wave term [23]. Weyl [23] obtained an asymptotic series representing the diffracted field by applying a method of steepest descent. Weyl's solution also reduces to a form that can be interpreted as the superposition of a space and

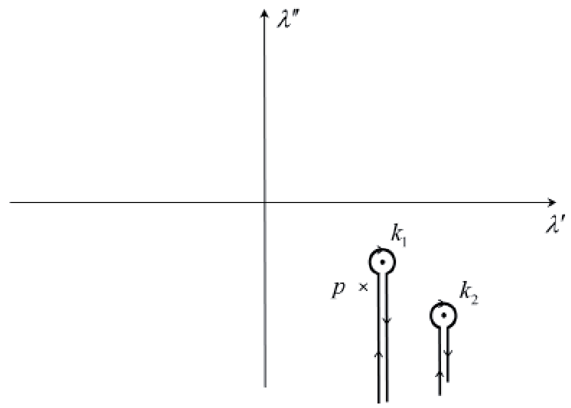

Figure 1c. The contribution of the pole generating the surface wave is excluded when the branch-cut contour is chosen vertically (Kahan and Eckart [22], Baños [6, pp. 55]).

a surface wave, but the Weyl surface wave is not identical to that of Sommerfeld [17] and Zenneck [15].

In 1926, Sommerfeld returned to the same problem. That time, he solved it [22] using a different approach, and confirmed the correctness of Weyl's solution [23]. With a better understanding of the ionospheric mode of propagation, the concept of the surface wave being the important factor for long-distance propagation lost favor. It is the presence of the Kennelly-Heaviside layer of the ionosphere that is responsible for the long-distance propagation of the long-wavelength fields. In 1930, Van der Pol and Niessen published a new solution to the old Sommerfeld problem, using yet another method of solution [24]. Again, the results of Weyl and the later results of Sommerfeld were confirmed. This was followed by another paper of Van der Pol on the same problem [25]. Each independent solution of the old Sommerfeld problem agreed with Sommerfeld's 1909 solution, except for the surface-wave term.

In the 1930s, Norton undertook the task of reducing the formulas of Van der Pol and Niessen to practical form for the radio engineer [26-28]. As a part of this undertaking, he apparently believed that he had found a sign error in Sommerfeld's 1909 paper. In 1935, Norton published a short paper in which he asserted that Sommerfeld had made an error in sign in one of Sommerfeld's formulas [28]. Unfortunately, Norton did not provide any specific details as to which of Sommerfeld's expressions had the sign error, or what had gone wrong in Sommerfeld's analysis. In 1937, Niessen published a paper in which Niessen also claimed that Sommerfeld had made a sign error in Sommerfeld's 1909 paper [29]. According to Niessen, the sign error came about because Sommerfeld did not take the value of the argument of the square root of a complex number using the convention that this should always be taken to be between 0 and 2π.

Charles Burrows of the Bell Laboratories [30, 31] carefully measured the field strength at 150 MHz for a distance ranging from 1 m to 2000 m over a deep, calm lake near Seneca, in upper New York. He showed that his measured results did not support a surface wave. His experimental results were conformed with the Weyl-Norton theory, namely that in the far field, a surface-wave type phenomenon is not observed. Burrows further concluded that these results, along with the experiments, proved that simple antennas do not generate a Sommerfeld surface wave [31].

In addition, Wise [32] published a paper that showed that a vertical dipole does not generate a surface wave that at great distances behaves like Zenneck's plane wave or a surface wave. A contemporary theoretical investigation by S. O. Rice [33] led to the same conclusion.

In spite of the apparent closure of the analytical debate, the controversies would not die. The late Kenneth Norton, an eminent radio engineer in the USA, exchanged numerous letters with Sommerfeld on this topic. An example is a letter [34] from Sommerfeld to Norton, which was written while the former was on holiday in the Austrian Tyrol. Sommerfeld never agreed that an error or miscue had ever been made. Two later letters from Norton [35, 36] indicated his views on the separation of surface waves and space waves. Sommerfeld acknowledged Norton's communications, and suggested he compare his results with those of Van der Pol and Niessen [24]. Of course, there is a consistency here, because Norton [26-28] based his papers on the results of Van der Pol and Niessen [2]!

As stated by Wait [2], the confusion was also caused when, in 1926, Sommerfeld [22] published a paper where Sommerfeld revisited his old paper of 1909, and changed the sign of the argument of the complex error function without any proper explanations. Subsequently, there have been many speculations that in the 1909 paper, Sommerfeld had an error in the sign, which he corrected in the 1926 paper. Since Weyl's method seemed mathematically simpler, Weyl's result was favored by public opinion in numerous papers by other authors. Finally, in 1935, Sommerfeld himself conceded that the surface wave had no reality. However, he never admitted to an error in the sign in his 1909 paper! Referring to F. Noether [37], he attributed this to an inaccuracy in the evaluation of his general solution. According to Noether's explanation, the pole is so close to one of the branch cuts that the integration method used by Sommerfeld was possibly not sufficiently reliable.

As Baños pointed out, Stratton [38, p. 585] summarized the above (confused) situation by saying that from the point of view of practical applications, the result of Sommerfeld and the charts of Rolf [39] based on them were not reliable when the electric displacement current in the conducting medium was appreciable, for example, at high frequencies. According to Brekhovskikh [40, p. 270] the question of the existence of Sommerfeld's surface wave was first properly clarified by Ott [41], who combined the methods of Weyl and Sommerfeld, and devised a method of effective saddle-point integration when there exists a first-order pole in the vicinity of the saddle point. In effect, Ott was thus able to re-derive Sommerfeld's results of 1926 in a more-efficient manner [42].

Baños [42] further stated that despite Ott's valuable contribution on the question of the existence or nonexistence of Sommerfeld's electromagnetic surface wave, this topic continued to be debated in the literature. In 1947, Epstein [43] published a paper in which he disqualified Sommerfeld's original formulation of the problem by proposing a new contour of integration excluding the pole, which was shown to be in error by Bouwkamp [44]. Kahan and Eckart [45, 46] next published a series of papers. They got their acts right in the latter papers, where they claimed, according to Bouwkamp [44], to accept Sommerfeld's original solution, and pointed out that Sommerfeld's evaluation of the integral around the branch cut was in error. They stressed that the correct evaluation would have yielded an expression that contains the surface wave with negative sign, so that the real result would have coincided with Weyl's result, the negative surface-wave term being cancelled by the positive term due to the residue of the pole of the integrand. This will happen because the true location of the poles was not as shown by Sommerfeld in Figure 1a, but more like the situation in Figure 1b. When the saddle path of integration is changed from Figure 1b to that of Figure 1c, the pole will thus again come into the picture. This explanation and clarification of the controversy was similar to that of Wise [32] and Rice [33], who showed that the existence of a surface wave is not a part of the total solution.

In summary, the correct location of the surface-wave pole is illustrated in Figure 1b. When the branch-cut integral is evaluated along the vertical lines as shown in Figure 1c, the integral over the cut must thus consequently contain the surface wave with an opposite sign. In other words, the surface-wave pole is not located in the appropriate sheet. This is also what was shown in Baños [42, p. 55], similar to Figure 1c. It turns out that when the contribution from the pole is included in the solution, there appears to be a discrepancy in the sign as outlined in Sommerfeld's 1909 paper. This can also be seen from the branch-cut integrals, as illustrated in a companion paper [1]: the saddle path never crosses the pole, and therefore their contribution is not relevant. This sentiment – that nothing was wrong with a sign in Sommerfeld's paper – was echoed by Collin [3] and Karawas [47]. However, the error in sign is not the issue. The important point is that the surface-wave pole is on the wrong Riemann sheet, and should not come into play.

However, the most succinct and clear explanation is available in Schelkunoff's book [48], which, interestingly is not referenced in any of the papers. In his book, Schelkunoff [48, p. 430] categorically states "that the denominator of the term inside the brackets in equation (1) can have no roots, the integrals can have no poles, and there are no surface waves. This conclusion is contrary to that reached by early writers on the subject."

Schelkunoff then proves his point by substituting the solution for the pole into the equation. When we substitute $\lambda_P = \pm \dfrac{k_1 k_2}{\sqrt{k_1{}^2 + k_2{}^2}}$ into the equation

$$k_1{}^2 \left[\varepsilon \sqrt{\lambda^2 - k_1{}^2} + \sqrt{\lambda^2 - k_2{}^2} \right]$$

$$= k_2{}^2 \sqrt{\lambda^2 - k_1{}^2} + k_1{}^2 \sqrt{\lambda^2 - k_2{}^2}$$

$$= 0$$

for the pole, it then becomes clear that

$$k_2{}^2 \sqrt{\lambda_P^2 - k_1{}^2} + k_1{}^2 \sqrt{\lambda_P^2 - k_2{}^2}$$

$$= k_2{}^2 \sqrt{\frac{k_1{}^2 k_2{}^2}{k_1{}^2 + k_2{}^2} - k_1{}^2} + k_1{}^2 \sqrt{\frac{k_1{}^2 k_2{}^2}{k_1{}^2 + k_2{}^2} - k_2{}^2}$$

$$= k_2{}^2 \sqrt{-k_1{}^4} + k_1{}^2 \sqrt{-k_2{}^4} \neq 0 \, .$$

There thus does not appear to be any surface wave in the final solution, a conclusion that everybody agrees with, and which Schelkunoff pointed out about 70 years ago [48]!

Next, we will observe what the mathematical properties of a classical *surface wave* are, so as to eliminate the confusion associated with the use of this word, and the turmoil it caused when Sommerfeld introduced the term surface wave in his solution. In addition, the difference between a classical surface wave and a Zenneck wave will also be illustrated.

2. What is a Surface Wave?

As explained by Barlow and Cullen [49], a *surface wave* is a wave that propagates without radiating energy along an interface between two different media. If both media have finite losses, the energy directed along the interface will be required to supply the losses in the media. This does not invalidate the description of the surface wave if radiation is construed to mean that energy is absorbed from the wave independently of the media supporting it. The surface-wave phenomenon arises primarily from its unique nonradiating characteristic. This enables high-frequency energy to be transferred intact from one point to another, except in so far as demands are made upon that energy to compensate for the losses in the two media. This definition agrees with the concept of Rayleigh, as we discussed in the previous section. However, the next statement of Barlow and Cullen [49] stated that the three distinctive forms of the surface wave, namely,

1. the Zenneck or inhomogeneous plane wave supported by a flat surface,

2. the radial cylindrical wave also supported by a flat surface, and

3. the Goubau [56, 57] or axial cylindrical wave associated with a transversely cylindrical surface,

represent basically one and the same phenomenon from their field distribution. This can cause some anxiety, as we will soon see.

In addition, Barlow et al. pointed out that Sommerfeld's theory for ground-wave propagation over a flat Earth also introduced a so-called *surface wave*. Sommerfeld divided the ground wave into two components, which he respectively called a "space wave" and a "surface wave." The surface-wave component is represented by one of the terms in the analysis of the total field, and its particular feature is that it needs to predominate near the Earth's surface. Both parts are required to satisfy Maxwell's equations. At long ranges, according to Sommerfeld, the surface-wave part varies inversely as the square of the distance, which is identical to the Norton surface wave. In similar circumstances, a true surface wave, radiated from a vertical line source over a horizontal surface, would be expected to decay exponentially with range, owing to losses. At the same time, it would be expected to fall in amplitude inversely as the square root of the range, due to the expanding wavefront. In Sommerfeld's original 1909 paper, a surface wave of this type appeared in the expression of the total field, which was later shown not to exist.

In addition, Wait [52] also provided a clarification between the terms surface waves and ground waves, which are the fields observed at the interface. According to Wait, "A surface wave is one that propagates along an interface between two different media without radiation; such radiation being construed to mean energy converted from the surface wave field to some other form," according to the definitions of Barlow and Cullen [49] and Cullen [53].

The *ground wave* is characterized per the IEEE definition [50, 51]: "A radio wave that is propagated over the Earth and is ordinarily affected by the presence of the ground and troposphere. The ground wave includes all components of a radio wave over the Earth except ionospheric and tropospheric waves."

The situation is particularly confused since in the IEEE test procedures, the surface-wave component of the ground wave was completely different from the definition used by Barlow and Cullen [49]. Wait [52] tried to clarify this state of confusion by adopting a model that would encompass all forms of waves that can propagate over an interface. This was carried out by expressing the total field from a vertical electric dipole at a height, *h*, radiating over an air-Earth interface. The vertical electric field at a vertical height, *z*, and a horizontal distance, ρ, could be written in the following form, consisting of three terms:

$$E = E_a + E_b + E_s ,$$

where E_a is the field that would be computed on the basis of geometrical optics. E_b and E_s are the *surface waves*, which are entirely different in character from one another. If the phase angle of the surface impedance is less than 45° [42], it was shown that E_s was not present. E_b could then be identified as a correction to the geometrical-optics field, E_a. Asymptotically, E_b varies as ρ^{-2}, whereas E_a varies as ρ^{-1}. In many high-frequency applications, E_a is thus dominant. However, at shorter distances and/or lower frequencies, when the asymptotic form for *E* is not valid, it turns out that E_b may be very important, and that it should be called a Norton surface wave [26, 27], rather than just referring to it as a surface wave.

When the phase angle of the surface impedance becomes greater than 45°, the contribution, E_s, is finite. In many cases, it dominates E_a and E_b. For example, it may be shown that [54] E_s varies as $\rho^{-1/2}$ for a purely inductive boundary. The contribution E_s, which is not present for a homogenous conducting half-space, is really a trapped surface wave, since the energy is confined to regions near the interface. It is suggested that this component of the total field be described as the *Barlow surface wave*. It is of interest to note that at least formally, E_s has the form of a Zenneck wave for the case of a homogenous Earth. As discussed in [49], it is not excited by a physically realizable source.

From these various interpretations of the term surface wave, it is very easy to get confused. We hence take recourse to Schelkunoff [11], as he clarified the situation from a mathematical perspective, and presented the definition of what a *surface wave* is in the true classical sense of Rayleigh. Schelkunoff [11] pointed out that these same words, *surface wave*, convey different meanings to different individuals. According to Schelkunoff, the preliminary list of different surface waves, compiled by Dr. James R. Wait, the then chair of a working group of URSI, mentioned 11 types of surface waves in the light of propagation of plane waves in two semi-infinite, nonmagnetic, non-dissipative media, separated by a plane boundary. These 11 types of surface waves consist of

1. *Zenneck Surface Wave* (at the interface of two half-spaces having different dielectric constants),

2. *Sommerfeld Surface Wave* (a dipole over a conducting half-space),

3. *Norton Surface Wave* (a dipole over a conducting half-space),

4. *Sommerfeld Axial Surface Wave* (an imperfectly conducting cylindrical wire),

5. *Goubau Axial Surface Wave* (a dielectric-coated wire),

6. *Plane Trapped Surface Wave* (a dielectric-coated plane conductor, corrugated surface, or other inductive boundaries),

7. *Cylindrical Trapped Surface Wave* (the same as above in cylindrical form),

8. *Plane Quasi-Trapped Surface Wave* (a stratified conductor when the surface impedance has both a resistive and inductive component),

9. *Cylindrical Quasi-Trapped Surface Wave* (the same as above in cylindrical form),

10. *Azimuthal Surface Wave* (on dielectric-coated and corrugated cylinders and spheres, for propagation in the azimuthal direction),

11. *Composite Axial-Azimuthal Surface Wave* (the same as above when propagation has a component in both the axial and azimuthal directions).

As a group these wave types have no important physical properties in common. Calling these wave types by the same name, even with qualifying adjectives, encourages one to assume that the most significant physical properties of one wave type are shared by other wave types and can cause serious misunderstandings [11].

As Schelkunoff explained [11], when a wave is incident at an air-dielectric boundary, then there can be partial transmission and partial reflection, in the form of radiation, from the boundary. However, if the wave contains a component the magnetic field of which is parallel to the boundary and the wave is incident at a Brewster's angle, then the wave will be totally transmitted to the dielectric. If there is a reflected wave, it will be horizontally polarized, as the Brewster's angle applies only to vertically polarized waves. The Brewster's angle is thus associated with the zeros of the reflection coefficient (zeros of the numerator of the term placed inside brackets in Equation (1)). If the medium is slightly lossy, then again there will be minimal reflection from the boundary. In this case, the wave is not tied to the boundary. The Brewster's angle is independent of the frequency and so is the exponential rate of attenuation of this wave with the increasing distance from the interface, which is small. The phase constant in vacuum increases with the decrease in the wavelength for this wave. If the dielectric medium has a finite conductivity, then there may be an attenuation at right angles to the direction of propagation. The wave is also a fast wave, and essentially passes through the dielectric medium without seeing it. The first four of the eleven wave types listed above belong to this class, and are therefore not true surface waves in the classical sense [11] of Lord Rayleigh.

However, when a wave is incident at a boundary from a denser to a rarer medium (which is not our problem of interest), then there will be total internal reflection if the incident wave is incident at an angle equal to or greater than the critical angle of the medium. The wave may even get trapped in the denser dielectric medium and may never come out, except providing an evanescent field to the rarer medium. The wave in this case is a slow wave, and the evanescent fields in the rarer medium will be concentrated near the interface as the frequency increases. The attenuation in the vertical direction away from the interface in the rarer medium will also be frequency dependent, and as the frequency increases, the wave will be confined to the interface. Such a situation occurs for the poles of the reflection coefficient (zeros of the denominator of the term placed inside the brackets in Equation (1)). In this case, even when the incident field goes to zero, the amplitude of the surface waves does not decrease. Typically, these waves do not have a decay along the direction of propagation, in contrast to a Zenneck wave. However, if the dielectric medium is lossy, there may be an anomalous velocity of propagation towards the interface [11]. Physically, these types of trapped waves may be stirred up by the incident field. According to Schelkunoff, waves of types 5-11 listed above satisfy the characteristics of a *true surface wave* in the classical sense introduced by Lord Rayleigh. Note that as mentioned before, the Zenneck wave is not a true surface wave in the classical sense [11].

In Sommerfeld's expression for the potential in medium 1, the reflection coefficient is represented by the term inside the brackets in Equation (1). The expression for the reflection coefficient for the air-dielectric boundary has two poles and two zeros. The poles and zeros have the same magnitude, but they are distributed on four different Riemann sheets of Equation (1). Since we have seen that the Sommerfeld denominator in Equation (1) has no pole on the proper Riemann sheet, no true *surface wave* can arise in this situation that we are analyzing. According to Schelkunoff, a dipole radiating above an interface between two media thus does not produce any *true surface wave* as defined by Lord Rayleigh. Moreover, the term Norton "surface wave" [50, 51] is not related to any of the surface waves discussed so far. This wave was defined as the difference between the exact field of a dipole above an imperfect ground and the field calculated by the rules of geometrical optics, as explained in the Appendix. This is exactly the same definition used in the *IEEE Standard Definitions of Terms for Radio Wave Propagation* [50]. This Norton "surface wave" does not even satisfy Maxwell's equations. There is also the term *ground wave*, which is also defined in the *IEEE Standard Definitions of Terms for Radio Wave Propagation* [50]. It is the total wave (the space wave plus the surface wave) that would have existed in the proximity of the ground if the Kennelly-Heaviside layer was absent [50]. Schelkunoff further clarified the situation by stating that a wave reflected from the ionosphere is defined as the sky wave. In the primary service area for all broadcasting stations operating in the low- and medium-frequency ranges, the sky wave is very weak, and the ground wave is important. This ground wave is somehow related to the *Norton surface wave* but is not identical to it. The *Norton surface wave* vanishes for a perfectly conducting ground when the ground wave is the strongest. This ground wave has also been confused with the *Zenneck wave*, or sometimes with a true *surface wave* [15].

Booker and Clemmow [58], in interpreting the Sommerfeld theory of propagation over a flat Earth in the presence of finite losses, invoked the aid of a Zenneck wave. They particularly discussed the two-dimensional case of a horizontal line source above the Earth. In doing this, they showed that a hypothetical Zenneck wave – when diffracted under a vertical plane screen the lower edge of which coincided with the image in the Earth of the line source, and extending to $+\infty$ in the other direction, as shown in Figure 2 – made equivalent provision for the effect of the

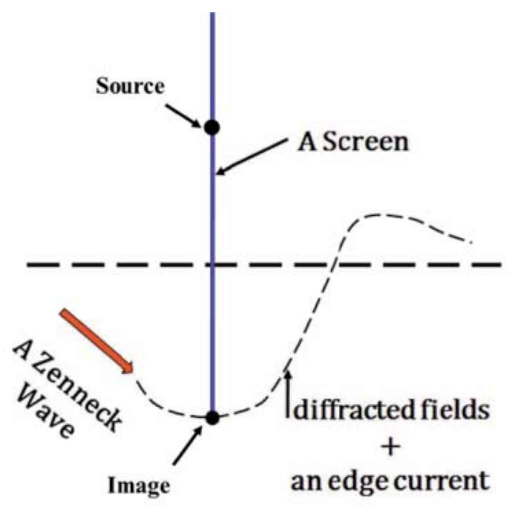

Figure 2. An illustration of how diffraction of a Zenneck wave generates the desired radiation fields at the interface.

Earth losses. In Figure 2, the field in the upper half-space is generated by the sum of the fields produced by a line source located at the image point of the original source, and the diffracted waves generated by a Zenneck wave incident on a screen without the presence of the Earth, as also shown in Figure 2. Booker and Clemmow [58] were very careful to point out that this was merely a convenient physical interpretation, and that it did not mean that a Zenneck wave actually existed above the Earth's surface. However, it nevertheless appears that there has been some misunderstanding that can no doubt be attributed to the use of the term surface wave for two different things.

In a companion paper [1], it was shown that the fields in the intermediate region of a cell in a cellular wireless communication system have a slope of 30 dB per decade, and that indeed this result can be obtained from a particular treatment for the Sommerfeld attenuation function. Our objective is to see what types of sources generate such fields, which have a decay of $1/\rho^{1.5}$ with distance. The other unique feature that we are going to point out is that all measurements do show such a characteristic of the fields inside the cell, without any exception. As we have already mentioned, a *true* surface wave does not produce such types of fields. The question is thus, what type of waves behaves in this peculiar fashion?

3. Burrows Experimental Data First Illustrated the Propagation Path Loss of 30 dB per Decade in Intermediate Regions

To verify Sommerfeld's prediction about the surface wave in the solution of the fields over an imperfect ground, Burrows was the first to carry out an experiment. Seneca

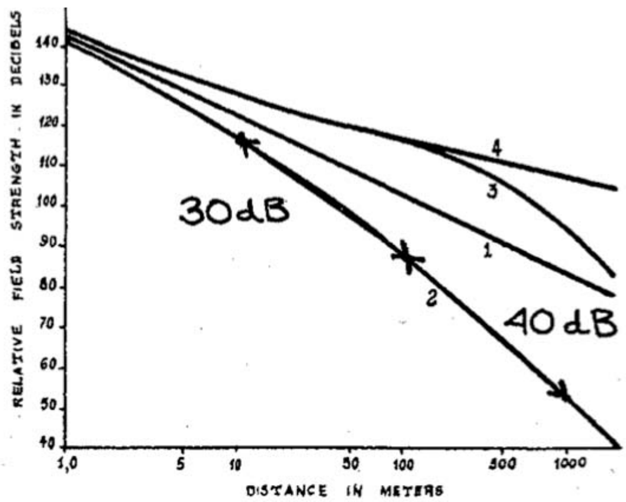

Figure 3. The propagation path loss of 30 dB per decade, followed by 40 dB per decade for the radiation fields, in the measurements of Burrows over Seneca Lake ([30, Figure 3; 46, Figure 6]).

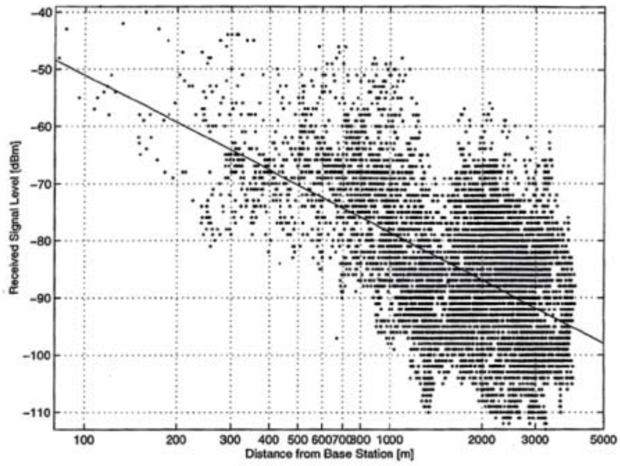

Figure 4. An empirical model of macrocell propagation at 900 MHz. The dots are measurements taken in a suburban area, whereas the solid line represents a best-fit empirical model (reproduced by permission from Simon R. Saunders, "Advances in Mobile Propagation Prediction Methods," in Kyohei Fujimoto (ed.), Mobile Antenna Systems Handbook, Third Edition, Norwood, MA, Artech House, 2008, Chapter 3; ©2008 by Artech House, Inc.).

Lake in New York State was chosen by Burrows for these experiments, because of its great depth [30]. Burrows first experimentally attempted to decide the question of the existence of Sommerfeld waves around 1933. A wavelength of two meters (150 MHz) was chosen as the frequency of operation. In this experiment, the receiver was located near the stern of a small motor boat, which towed a rowboat containing the transmitter. The antennas were loaded vertical quarter-wave doublets, which were respectively connected to the receiver and transmitter at the antennas' mid-points by short two-wire transmission lines. The distance between the transmitting and receiving antennas was measured by means of an auxiliary line. Curve (1) of Figure 3 plots the inverse distance field that would result from propagation over a plane Earth of infinite conductivity. It would result in a field-strength decay of 20 dB per decade (the field will be the vector addition of two spherical waves: the direct line-of-sight wave from the source, and the direct line-of-sight from its image; both of these decay with a rate of $1/R$). Curve (2) in the same figure is a plot of the received field strength according to Weyl and Norton. This curve also coincided with Burrows experimental data, which are not overlaid on this plot. It is seen that in the intermediary region of this plot, the fields decayed as 30 dB per decade, whereas for the far field, the decay was 40 dB per decade, as would be expected from the Norton surface wave. Curves 3 and 4 were generated based on the original Sommerfeld formulation of 1909, and they did not display the right slopes for the measured data.

Burrows experimental data thus illustrates that in the intermediate region of his plots, the fields displayed a decay of 30 dB per decade. In conclusion, the wave having a decay of 30 dB per octave cannot be due to a surface wave.

4. Other Supporting Data

In [59, Figure 2.2.14] it was also illustrated that the path-loss exponent in urban propagation is about three, leading to a decay of the fields of 30 dB per decade with distance from the antenna. This figure was been generated from Okumura's experimental data [59]. Figure 4, reprinted from [60], showed that the path-loss slope in a macrocell environment at 900 MHz was 30 dB per decade, exactly for the distances from 100 m to 2 km, as shown by the theoretical predictions and accurate numerical computations carried out in [1]. Figure 5, for a picocell environment (indoors), reprinted from [60], showed that the path-loss exponent was almost 30 dB per decade for distances up to 20 m from the base station, which is the effective cell radius of an in-building picocell. Beyond that, the slope changed to 40 dB per decade, as expected from the theoretical analysis [1]. We therefore observed that independent measurements that were reported in the literature support the statement that the fields inside a cell decay as $1/\rho^{1.5}$. These fields cannot therefore be generated either by a space wave or a *true* surface wave.

5. Experimental Data from Suburban Environments at 900 MHz

The objective of this section is to present further experimental data for two different cellular scenarios: suburban and coastal environments. Experimental data for the path loss as a function of distance are available for various stations operating in a dense urban environment at frequencies of 1800 MHz [61] and 900 MHz [62, 63] as illustrated in [1]. They all displayed a path-loss exponent of three in the intermediate region, without any exception.

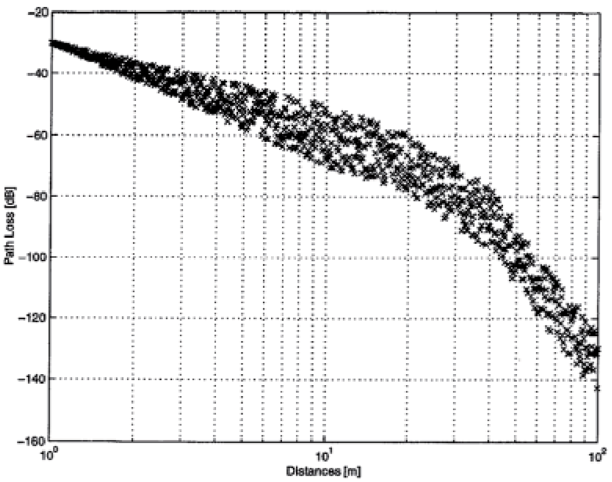

Figure 5. A prediction from an Ericsson in-building path-loss mode (reproduced by permission from Simon R. Saunders, "Advances in Mobile Propagation Prediction Methods," in Kyohei Fujimoto (ed.), Mobile Antenna Systems Handbook, Third Edition, Norwood, MA, Artech House, 2008, Chapter 3; ©2008 by Artech House, Inc.).

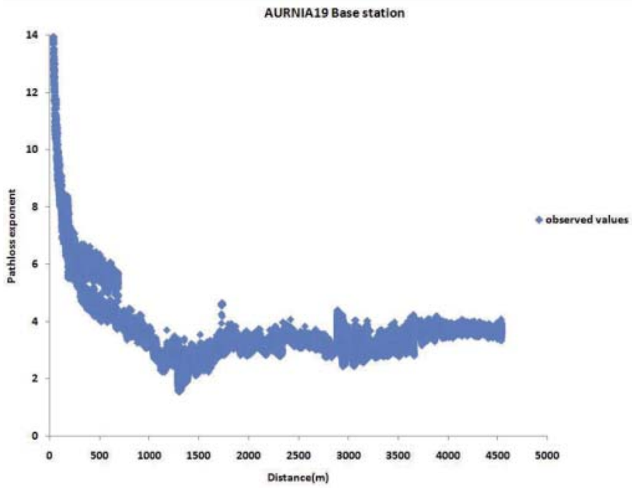

Figure 6. The variation of the path-loss exponent with distance for the AURNIA19 base station (900 MHz).

It was also shown in [1] that the ground parameters did not have any marked influence on the propagation-path loss in this intermediate region.

Experimental data from a suburban environment are now presented to further illustrate that the path-loss exponent inside a cell is three, and four in the fringe regions, the latter following the dictums of an asymptotic form of a Norton surface wave.

Experimental data from suburban environments at 900 MHz are now described. The experiment was carried out with the help of Aircom International Limited, a UK company based in India. The transmitting power of all the base stations used in this study was 40 dBm, and the transmitting antenna gain was 8 dBi for all the base stations. The gain of the receiving antenna was 0 dB, and the height from the ground was 1.5 m. The receiver was standard Nokia equipment used as a drive-in tool for measuring the field strengths. The position of the mobile was determined from a GPS receiver. This information, with the coordinates of the base station, was utilized to deduce the distance traveled by the mobile from the base station. The signal-strength information, recorded in dBm, was converted into path-loss values utilizing the gains of the antennas. The data were recorded with 512 samples in one second on a laptop computer. The number of samples collected for each site varied from 1×10^5 to 2×10^5 . The measured rms (root-mean-squared) error was around 1.5 dB. The data were averaged over a range of 40λ . Here, λ stands for the wavelength of operation.

Figure 6 shows the variation of the path-loss exponent from the base station AURNIA 19. This station was located in an industrial area in the city of Aurangabad, in the Maharashtra state of western India. The transmitter height was 50 m from the ground. In Figure 6, we observed the path-loss exponent as a function of distance. The path-loss exponent was expected to start at three at approximately a distance of $\frac{4H_{TX}H_{RX}}{\lambda} = \frac{4\times50\times1.5}{1/3} = 900$ m, [69] as the operating frequency was 900 MHz. This region started

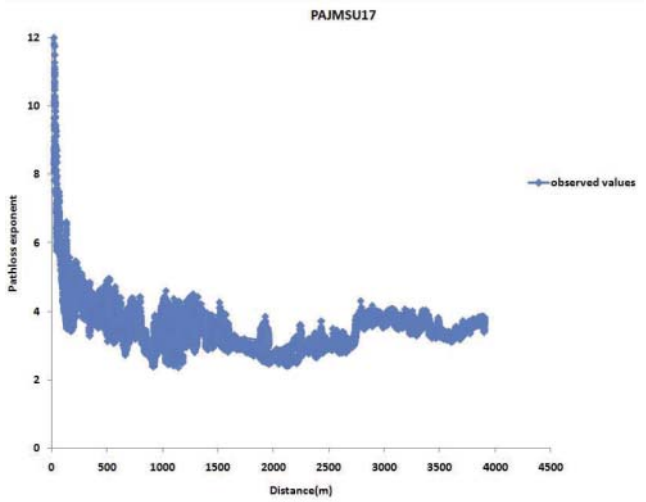

Figure 7. The variation of the path-loss exponent with distance for the PAJMSU17 base station (900 MHz).

where the slow-fading region ended, as illustrated in [69]. After some distance, the path-loss exponent gradually increased to four in the far-field region. Here, H_{TX} and H_{RX} represent the heights of the transmitting and the receiving antennas over the ground. The experimental data confirmed the theoretical predictions.

Finally, in Figure 4 we observed the decay of the field strength for the base station PAJMSU17, which was located in the Panjim suburban region of the sea port of Goa, located in the western region of India. The transmitter height was again 50 m from the ground, and the transmitter power was 40 dBm. From Figure 7, it was seen that the path-loss exponent also started at 3.0 from a distance of 900 m, as predicted by theory [69], and then increased to 4.0.

It may be concluded that within the range of the cell, after the slow fading is over [69], the path-loss exponent starts at three, and then in the fringe areas, increases to four, irrespective of the environment. It also was illustrated in [1] that these predictions could be arrived at using the Sommerfeld attenuation function. The question now is, what type of wave has a decay of 30 dB per decade?

6. In Search of a Wave that Decays as 30 dB per Decade, Equivalent to a Path-Loss Exponent of Three

In an accompanying paper [1], we observed not only from a theoretical point of view but also from an experimental view point that the path-loss change in cellular wireless communication is 30 dB per decade, and this gives rise to a path-loss exponent of three. The question now is, what are the physics behind such a wave, and also, what type of waves propagates with such a characteristic? What has been clear is that neither the Zenneck wave nor the Norton surface wave produces a 30 dB-per-decade decay of the fields with distance. Depending on which of Sommerfeld's papers one chooses to look at, a wave with a decay of 30 dB per decade is nonexistent. However, in the far field, the Norton surface wave indeed has a path-loss exponent of four.

Barlow and Cullen [49, 53, 55], and Booker and Clemmow [58], introduced the *true* surface wave. They demonstrated that not only does this type of surface wave not generate radiative fields, but also these slow-wave fields are orthogonal to the fields that are responsible for radiation. However, associated with these true surface waves is an additional field component: a radiation field that meets our criteria. The question is therefore, which waves do follow a 30 dB-per-decade decay? These are of particular interest in a cellular wireless communication system.

Cullen [53] showed that when a wave is launched by a horizontal slot situated over a corrugated or a dielectric coated guiding surface it can be shown that in addition to the surface wave there is a radiation field and that field decays asymptotically as $1/R^{1.5}$. He further illustrated that Booker and Clemmow [58] gave an elegant interpretation of the Sommerfeld theory of radiowave propagation over a flat Earth. It is interesting to examine the present problem from their viewpoint, as shown in Figure 2. Consider a slot located at $(0,h)$ above an imperfectly conducting ground radiating into space. The total scattered field then consists of a field component, E_1 , produced by the same slot over a perfectly conducting surface, plus a "correction field," E_2 , resulting from diffracting a characteristic Zenneck wave under a screen extending upwards to infinity from $(0,-h)$, the location of the image line of the source, as shown in Figure 2. This correction field involves an integration over the "aperture" extending from minus infinity to $-h$, as shown in Figure 2. It is complicated by the fact that the integrand contains a factor that has the form of the Zenneck wave, and so tends exponentially to infinity at the lower limit of integration. This difficulty is avoided by regarding the correction field as the Zenneck wave seen directly, E_2' , minus the field, E_2'' , obtained by diffracting the Zenneck wave over a screen extending downwards from minus h to minus infinity. This is depicted in Figure 2. This integral is obviously convergent, and can be expressed in terms of Fresnel integrals. The field E_2'' then takes the form of a radiation field for which the leading term varies as $1/\sqrt{R}$. Near the surface, the leading term of E_2'' exactly cancels the leading term of E_1 . The remaining terms give a field varying as $1/(kR)^{3/2}$, together with the Zenneck wave itself. However, in calculating the field near the surface, there is a slight disadvantage in splitting up the integral into separate parts, as Booker and Clemmow [58] did. This is because this leads to two separate asymptotic series the leading terms of which cancel, so that an extra term must be taken in each to get a given degree of approximation in the final result. However, the only fundamental difference is that Booker and Clemmow [58] expressed the fields from the source in terms of an infinite spectrum of Fourier components in a vertical plane, whilst Cullen [53] chose a horizontal plane. This choice has advantages in considering the launching of surface waves, for they enter into the analysis in a way that provides an intuitive explanation of their presence in the final field. Macfarlane [64] made calculations of Zenneck-wave excitation due to a chopped surface-wave excitation by this method. His result for a highly reactive loaded surface is exactly equivalent to that given in [49].

According to Macfarlane [64],

> From the behavior of the surface wave field at large distances from the surface, it is clear that a surface wave cannot exist as a complete field all by itself, just like a waveguide mode in a perfectly conducting waveguide. Hence, the surface wave is a pseudo-mode and not a pure one. The surface wave field is an incoming progressive wave, whereas the field at large distances from the surface must be an outgoing progressive wave. Therefore, there must always be a radiation field associated with the surface-wave field.

This radiation field is orthogonal to the surface-wave field. The only exception could be if the fields were produced by an aperture of infinite extent: then, the radiation field would not be present. It has been shown that this radiation field decays as $1/R^{1.5}$, and provides a decay of 30 dB per decade. It thus has a path-loss exponent factor of three. It is this radiation field that resembles fields emanating from a two-dimensional structure that has the mathematical decay rate of $1/R^{1.5}$.

Furthermore, Hill and Wait [65] pointed out that for a finite vertical aperture over a homogenous conducting flat ground, the fields are similar to the Zenneck wave near the aperture, but resemble the usual ground wave at large distances. According to them, the electric field at large distances decays from the source as $\rho^{-3/2}$, where ρ is the horizontal distance from the aperture. This occurs when there is a cancellation of the direct and reflected rays at grazing incidence. This is in contrast to the typical exponential decay of the Zenneck wave.

Tai [66] and Clemmow [67] have shown when analyzing radiation from a line source over a grounded dielectric slab that the radiation fields from such a source decay as 30 dB per decade with distance.

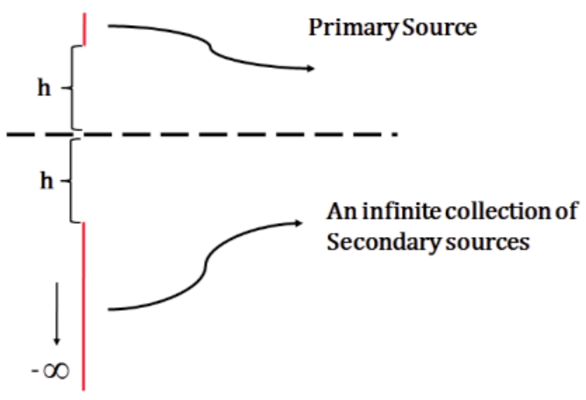

Figure 8. Equivalent image sources that generate the desired radiation fields at the interface.

The results of Booker and Clemmow [58], Barlow and Cullen [49], Cullen [53], Hill and Wait [65], Tai [66], and Clemmow [67] thus indicate that a radiation field from a two-dimensional source asymptotically decays as $R^{-3/2}$. This gives rise to a path-loss exponent of three, and a decay of the fields of 30 dB per decade, which is what we are interested in. In short, in cellular wireless communication, the fields that carry the energy behave as the radiation fields from a two-dimensional source.

It is important to note what Tai [66] pointed out:

> ...that for certain angles of incidence and for certain parameters of the ground the saddle-point path may intersect the second branch cut and this will provide a field which also has a three-halves power dependence on distance but also has an exponential damping factor.

7. A Physical Representation of the Fields Associated with Cellular Wireless Communication Systems

Van der Pol [68] pointed out that the results of Sommerfeld and Weyl were, as a rule, not very transparent, on account of the fact that the approximations or developments used were more of a mathematical nature. This lead Van der Pol to recast the same problem without any approximation whatsoever, which lead to a solution in the form of a simple space integral that allows a direct physical interpretation. The integration extends over the part of space occupied by the second medium below the geometrical image. This scenario is seen in Figure 8, which is similar to Figure 2, in many respects. It is shown that the field in the first medium where the dipole is located – apart from the direct radiation from an elementary dipole – can be described as due to a secondary wave originating in the integration space extending from its image from $-h$ to $-\infty$. In other words, the image of a source over an imperfect ground consists of a line source starting from its image and continuing to $-\infty$, as shown in Figure 8. The amplitude of the wave from the image is determined by the amplitude of the primary wave. It can be considered to spread from the geometrical image of the point source, with the propagation constant and absorption of the second medium. The higher the conductivity of this second medium, the more the primary wave is concentrated near the image of the point source, until, for infinite conductivity, it is wholly concentrated at the image itself.

This result – that the fields produced by a dipole over an imperfect ground plane are due to the direct contribution from the source, plus the effect of the ground represented by an equivalent image that consists of a line source that extends from $-h$ to $-\infty$ [18, p. 250] – has been used by

Figure 9. An elongated image of the sun over a rippled lake (http://fineartamerica.com/featured/alexandria-bay-sunset-steve-ohlsen.html).

other researchers. In fact, the same physical picture was available in Booker and Clemmow [58, p. 19, Figure 3b]. Sommerfeld also wrote a similar expression [18, p. 250, Equation (10d)]. The detailed derivation was available in Van der Pol's work [68]. One obtains the following expression for the Hertz potential due to a normalized point source located at a height z_a, when the observation point is located at z_b:

$$\Pi_{1z} \approx \frac{\exp(-jk_1R_1)}{R_1} + \frac{\exp(-jk_1R_2)}{R_2}$$

$$-\frac{2\,jk_1^2}{k_2}\exp\left[-a(z_a+z_b)\right]$$

$$\int_{\zeta=z_a+z_b}^{\zeta=z_a+z_b+\varepsilon\times\infty} \frac{\exp\left(-jk_1\sqrt{\rho^2+\zeta^2}\right)}{\sqrt{\rho^2+\zeta^2}}\exp(a\zeta)\,d\zeta \qquad (5)$$

where

$$a = -\frac{jk_1^2}{k_2}$$

and

$$\zeta = z_a + z_b + \varepsilon z\ .$$

As stated by Van der Pol, the third term in Equation (5) can be interpreted as a wave spreading from the geometrical image of the point source, while all points of the second medium below the level of the geometrical image apparently send secondary waves to the observer. When $\varepsilon \gg 1$, the distance from an arbitrary point in the second medium to the observer, as given in the exponent of the third term, contains z multiplied by ε, i.e., to the observer, the vertical part of the distance below the image of the point source is multiplied by ε. The wave originating from the image will therefore be observed as vertically elongated, like the very vertically elongated image of the sun over a wind-rippled lake, as shown in Figure 9 [68].

According to Hill and Wait [65, p. 974] a finite vertical aperture over a dielectric half-space – resembling the fields from the image of the dipole over a ground – indeed generates a field that has a path-loss exponent of 30 dB per decade. We now demonstrate this mathematical representation using the example of Figure 10.

Consider a rainy night, when the ground is wet, representing a partially reflective surface. Try then to observe how the city lights are stretched along the ground by waves propagating over the surface. Compare such a view as shown in Figure 10 to the situation as described by Van der Pol in Equation (5). Imagine that the existence of the green traffic light is the information to be transmitted by the source. Now, notice how a wet ground helps to transfer the information to a point where there is no line-of-sight path. In fact, in cellular systems, the ground is always an imperfect reflecting

Figure 10. Waves on wet ground due to the partial reflectivity of the surface. The figure gives an impression of the physical propagation mechanism to be expected in cellular environments at frequencies where a wet Earth represents a complex impedance surface.

surface, and the way light propagates in Figure 10 is what we should expect as a propagation mechanism in a cellular system. In other words, the transmitting antennas (usually tilted down toward the ground) excite a radiating field in the cell. In the intermediate region, this behaves as a radiating field from a line source, and in the far-field region, it behaves as a Norton surface wave. This wave then represents one of the main dominant means by which the base-station antenna communicates with the mobile device. This mechanism of propagation is shown in Figures 8-10. The stretching of the lights in Figures 9 and 10 hence essentially represents the image of the primary source. Again, it is important to note that what we are observing in Figure 10 is not a surface wave as in the true classical sense of Schelkunoff, but the radiated fields associated with a surface wave.

Figures 9 and 10 give us physical insight into how waves propagate in mobile communications. They thus illustrate why smart antennas and beamforming have not been very successful in cellular communications until now, despite all of the research efforts done in those fields. If the real scenario of propagation is something similar to what we see in Figures 8-10, then we should change our outlook of the implementation of multiple antennas and adaptive arrays in cellular systems. The important point is that the effect of the ground plays a dominant role. This equivalent line source, formed from the images, generates a field in the air that decays as 30 dB per decade. As observed in [1], this decay of the fields at 30 dB per decade with distance is generated in the intermediate region, approximately where the slow-fading region ends. This is approximately at a distance of about $\frac{4H_{TX}H_{RX}}{\lambda}$ [69] from the base-station antenna. Here, H_{TX} and H_{RX} represent the heights of the transmitting and the receiving antennas over the ground, and λ is the wavelength of operation.

Conventionally, in wireless communications textbooks (such as [70]), this problem of propagation modeling is tackled first by explaining the two-ray model over a flat perfectly conducting Earth. In the two-ray model – the incident and the reflected ray – the reflection coefficient is taken to be -1, and θ (the angle of incidence) is always $\pi/2$ (i.e., a perfectly reflecting Earth is considered). However, the two-ray model illustrates that the intermediate path loss is 20 dB per decade instead of 30 dB per decade, as we have presented. After explaining the two-ray model, empirical models are usually presented, such as the well-known Okumura-Hata model [60]. Although empirical models have been extensively applied with good results, they suffer from some disadvantages. The main disadvantage is that empirical models provide no physical insight into the mechanism by which propagation occurs. In addition, these models are limited to the specific environments and parameters used in the measurements. To find more satisfactory models, researchers usually follow one of two paths: They either choose more sophisticated physical models – which encounter other propagation mechanisms, such as diffraction, scattering, and ray tracing [60] – or they delve into statistical modeling [70]. We quote a very interesting conclusion from [60]:

> Although the plane Earth model has a path loss exponent close to that observed in actual measurements (i.e., 4), the simple physical situation it describes is rarely applicable in practice. The mobile is always almost operated (at least in macrocells) in situations where it does not have a line-of-sight path to either the base station or to the ground reflection **point**, so the two-ray situation on which the plane Earth model relies is hardly ever applicable. To find a more satisfactory physical propagation model, we examine diffraction as a potential mechanism.

Instead of examining diffraction as a potential mechanism or going to statistical modeling, the work presented in this paper gives a rigorous mathematical solution based on the exact Sommerfeld formulation of the two-ray model, but with an imperfectly reflecting Earth taken into consideration. This approach directly implies that the physical model of propagation in the cellular environment described above is the radiation field associated with a line source. Namely, the power decreases with the distance from the transmitter tower by 30 dB per decade for most of the practical area of a typical cell. The multipath fading and shadowing due to buildings and large obstacles then appear as small variations around the main 30 dB-per-decade slope line, as seen in the measured data. Almost none of the physical models – such as the dielectric canyon model, the flat edge model, and sophisticated ray-tracing models [60] – take fields produced by a line source into consideration. Actually, it is easy to illustrate the difference between the "*two-ray perfectly reflecting Earth*" model (used conventionally) and the "*imperfectly reflecting Earth*" model. In the companion paper [1], the mechanism of propagation was illustrated using a diffraction model, and, alternately, using an infinite line of sources, generated by the imperfectly conducting ground, representing the image due to the original source, as illustrated here.

In summary, the ray theory can never predict a decay of the fields as $1/R^{1.5}$. The analysis of Van der Pol presented here provides a physical picture of how the wave, which is not a surface wave, propagates over an imperfect ground from the base-station antenna to the mobile device. In short, besides the direct ray from the source, there are the fields from a line source, generated by the image of the original source over the imperfectly conducting ground, which can be easily visualized in Figures 9 and 10.

8. Conclusion

The objective of this paper was to illustrate that the propagation path loss in the intermediate region of a cell in a cellular communication system is three, which leads to a path loss of 30 dB per decade. This type of field resembles that of a radiation field associated with a two-dimensional source. These statements can be derived from the classical

Sommerfeld attenuation function, using different types of approximations. Finally, we have illustrated the physical mechanism of wave propagation, which provides a path-loss exponent of 30 dB per decade.

9. Appendix: Definitions of the Various Waves Used in this Paper

In this appendix, we present the definitions for the various waves that we have used in this paper. Our definitions are slightly different from [50], and are included here for completeness.

Diffracted wave: An electromagnetic wave that has been modified by an obstacle or spatial inhomogeneity in the medium by means other than reflection or refraction.

Ground wave: From a source in the vicinity of a flat Earth. A wave that would exist in space in the absence of the ionosphere. *Note*: A ground wave near the surface of the Earth can be identified with a Norton surface wave for a grazing angle of incidence, or when both the transmitter and the receiver are located near the Earth's surface.

Inhomogeneous plane wave: A wave for which the planes of constant magnitude and planes of constant phase are not parallel.

Lateral wave: A wave guided along the interface between two media. For sufficiently large distances from the source, the field decays as the square of the distance. This wave is present when a wave is incident from a denser to a rarer medium, undergoing total internal reflection. In this case, it displays the Goos-Hanchen effect of a lateral shift in the reflected wave. (We have not used this wave in the paper, but some researchers define the Norton surface wave as a form of lateral wave. This is not valid in our opinion, as a lateral wave is generated when fields are incident from a rarer to a denser medium and the phenomenon of total internal reflection occurs, and the Goos-Hanchen effect of a lateral shift in the reflected wave is observed. The Norton surface wave does not display the Goos-Hanchen effect, which is the hallmark of a lateral wave.)

Norton surface wave: A propagating electromagnetic wave on the surface of the Earth, when both the transmitters and the receivers are close to the ground. Asymptotically, this wave decays as the square of the distance.

Sky wave: A radio wave propagated obliquely toward, and returned from, the ionosphere. *Note*: This wave has sometimes been called an ionospheric wave, but that term is intended to connote internal waves in ionospheric plasmas.

Surface wave: A wave guided by a boundary of two dissimilar media that has a phase velocity smaller than the velocity of light. Its field perpendicular to the direction of propagation is evanescent in nature. As the frequency increases, the wave is more confined to the interface. There are no radiative fields associated with a surface wave.

Zenneck wave: This is a wave that is a solution of Maxwell's equations, and that decays exponentially, both in the transverse plane and along the direction of propagation. It has a phase velocity faster than the speed of light, and the propagation constants of this wave are generally not highly dependent on frequency. In addition, a cylindrical Zenneck surface wave decays as $1/\sqrt{R}$. According to Schelkunoff, this is strictly not a *true* surface wave.

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RadioAstron: An Earth-Space Radio Interferometer with a 350,000 km Baseline

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Abstract

RadioAstron is a Russian space-based radio telescope with a ten-meter dish, in a highly elliptical orbit with an eight-to-nine-day period. RadioAstron works together with Earth-based radio telescopes to give interferometer baselines extending up to 350,000 km, more than an order of magnitude improvement over what is possible from Earth-based very-long-baseline interferometry. Operating in four frequency bands corresponding to wavelengths of 1.3 cm, 6 cm, 18 cm, and 92 cm, the corresponding resolutions are 7, 35, 100, and 500 microarcseconds, respectively, in the four wavelength bands.

1. Resolution of Radio Telescopes

The first observations of cosmic radio emission in the 1930s by Karl Jansky [1-3], using a Bruce array only a few wavelengths across at a 15 m wavelength, had an angular resolution of a few tens of degrees. Later in the decade, Grote Reber [4] used a 32 ft parabolic dish at 2 m wavelength to improve the resolution to about 4°. The resolution of any instrument is limited by diffraction to an angle, θ, of the order of the wavelength of observation divided by the dimensions of the instrument. Because of this and the fact that radio wavelengths are longer than light waves by a factor of $\sim 10^5$, for many years it was thought that the resolution of radio telescopes would always be limited compared with that of optical telescopes.

However, for several reasons, it turns out that the reverse is true. First, due to their longer wavelength, it is much easier to build large diffraction-limited telescopes at radio wavelengths than at optical wavelengths, since the required mechanical tolerances are greatly relaxed at radio wavelengths. Second, at optical wavelengths, the path-length fluctuations in the Earth's troposphere limit the resolution of optical observations by "seeing" to angles of the order of an arcsecond. Recent developments in adaptive optics using nearby stars or laser signals as a reference at infrared wavelengths are able to obtain resolutions somewhat better than 0.1 arcsec. The same is true for optical telescopes operating from space, such as the Hubble Space Telescope. However, at radio wavelengths, tropospheric path-length fluctuations are only comparable with the wavelength, and can easily be calibrated from observations of reference sources. For these reasons, the history of radio astronomy has been one of ever improving the angular resolution through a series of innovative technical developments.

The largest fully steerable radio telescopes are those in Effelesberg, Germany, and in Green Bank, West Virginia in the USA, each with an effective diameter of 100 m. Variations in mechanical tolerances due to wind, temperature variations across the structures, and the effects of gravity as the structures are moved limit operation to wavelengths as short as about 1 cm. This gives an angular resolution of about 30 arcsec.

2. Radio Interferometry

Unlike light waves, radio signals from one part of the telescope can be amplified, split, and compared coherently with signals from other parts of the instrument. Starting in the 1940s, radio astronomers began to use widely spaced interferometers of modest-size parabolic-antenna elements to give resolutions determined by the interferometer spacing, and not by the dimensions of the individual antennas. Since each interferometer pair measures one Fourier component of the brightness distribution of the radio source, observations with multiple element arrays are used to reconstruct the two-dimensional radio-source structures [5]. In the typical radio interferometer or array, a common local-oscillator signal is sent to each of the distant elements, where it is used

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Figure 1. The Karl G. Jansky Very Large Array (VLA), located in central New Mexico, includes twenty-seven 25 m antennas, operating from a few hundred MHz to 50 GHz. Each antenna moves on railroad tracts along three arms to cover configurations ranging from 1 km to 36 km. The angular resolution at the shortest wavelength and in the largest configuration is 0.04 arcsec, about that of the Hubble Space Telescope.

to convert the received RF signal to a lower intermediate frequency (IF). This is then sent to a common point, where it is correlated with the signals from the other antennas. One of the most powerful radio telescopes of this type is the recently upgraded Karl G. Jansky Very Large Array (VLA), located in central New Mexico. With twenty-seven antenna elements, each of 25 m diameter, the resolution of the VLA at 1 cm wavelength in its largest configuration is about 0.1 arcsec, comparable to that of the Hubble Space Telescope (see Figure 1).

Although in principle the dimensions of radio interferometers can be extended without limit, practical considerations of routing the local-oscillator transmission and broadband IF transmission lines have limited conventional interferometers and arrays to dimensions of the order of a few tens of kilometers. It is also possible to use radio links to distribute the IF and local-oscillator signals within a multi-element array, but the bandwidths are limited by available spectrum allocations. More recently, the global fiber optic network has become an effective means of joining antennas spaced hundreds and even thousands of miles apart. However, unless subsidized, the cost required to transmit IF bandwidths of hundreds of megahertz large data rates are prohibitively expensive.

3. Independent-Oscillator Remote-Recording Interferometry

To avoid these complexities, radio astronomers routinely implement very-long-baseline interferometers (VLBI) using independent local oscillators, stabilized by hydrogen maser or other atomic frequency standards [6]. Until a few years ago, the data were recorded on magnetic tape, at data rates up to 256 Mbps. However, the often unreliable and logistically difficult tapes have now been replaced with conventional computer disc drives. Compatible independent-oscillator disc-recording VLBI systems are now in routine use in the US, Europe, Asia, and Australia. Separate networks of antennas in the US, Europe, Russia, and East Asia routinely operate with nominal recording rates up to 512 Mpbs to 1024 Mbps, and prototype systems are being tested at 2 Gbps and 4 Gbps recording rates.

4. Space VLBI: TDRSS and HALCA

Interferometer baselines for these Earth-based antennas are of course limited to some fraction of the Earth's diameter. Higher angular resolution can only be obtained by placing one end of the radio interferometer in space. In 1986, a team of scientists from the US, Japan, and Australia used an antenna onboard the NASA Tracking and Data Relay Satellite at 2.3 GHz and 15 GHz, together with ground-based antennas of the NASA Deep Space Tracking Network, to demonstrate the feasibility of radio interferometry using an orbiting spacecraft, with projected interferometer baselines up to two Earth diameters [7]. In 1997, Japanese radio astronomers placed an 8 m diameter antenna aboard the HALCA (Highly Advanced Laboratory for Communications and Astronomy) spacecraft in low Earth orbit. Unfortunately, the 22 GHz (1.3 cm) radiometer failed on launch, so that observations with the remaining 5 GHz (6 cm) and 1.6 GHz (18 cm) systems had a resolution only comparable to that achieved with conventional ground-based systems, operating at shorter wavelengths [8].

5. RadioAstron: Development and Specifications

On July 18, 1981, Roald Sagdeev, then Director of the Soviet Cosmic Research Institute in Moscow, authorized the development of the Spectrum-R space interferometer mission, also known as RadioAstron [9]. RadioAstron was to be one of three missions, the others being Spectrum-

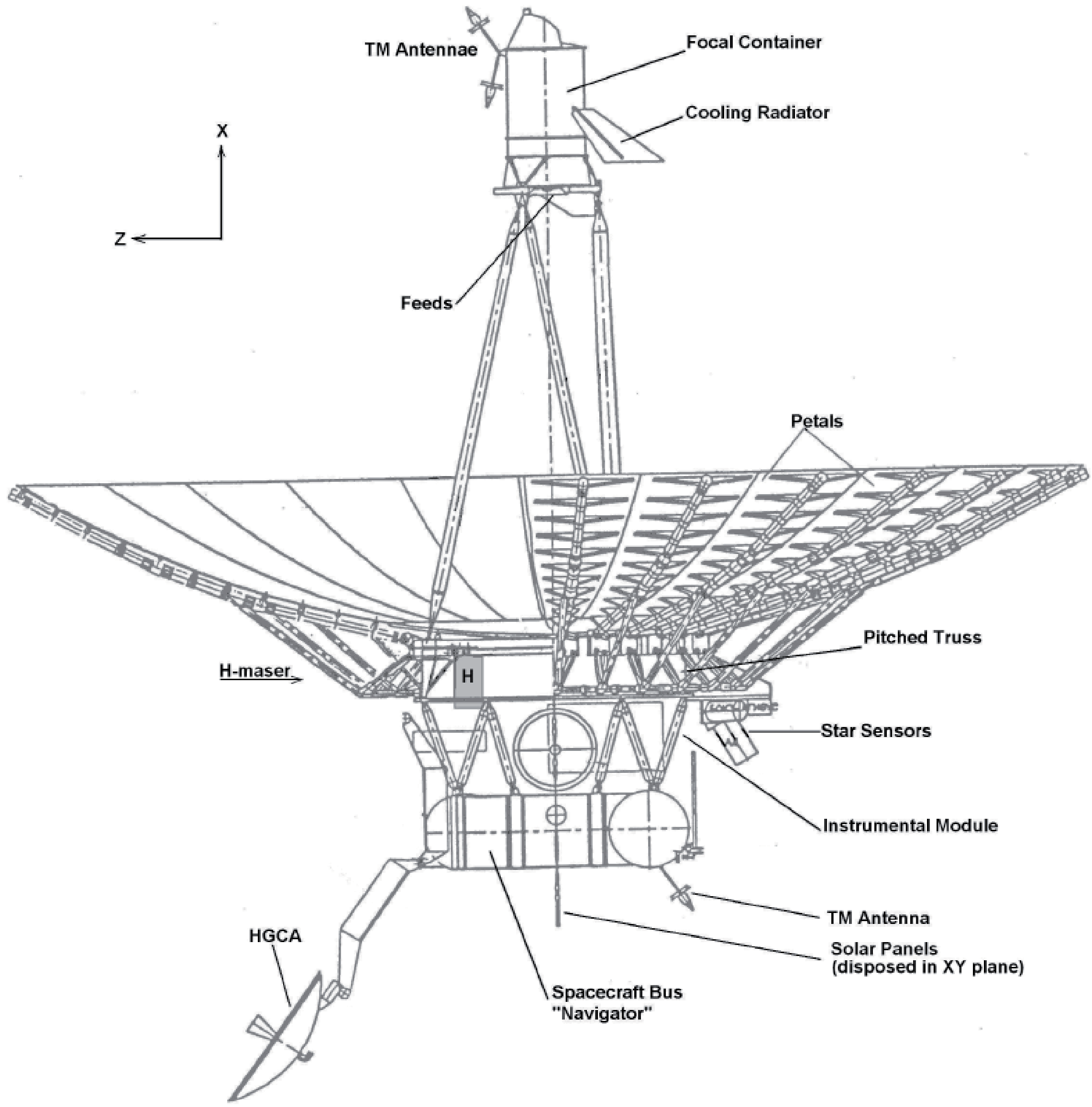

Figure 2. A schematic diagram of the RadioAstron Space Radio Observatory, showing the location of the navigator service bus, the hydrogen maser frequency standards, the high-gain communications antenna (HGCA), and other subsystems. The solar panels are oriented orthogonally to the diagram.

X-Gamma and Spectrum-UV, to operate at X/γ-ray and ultraviolet wavelengths, respectively. However, the challenging technical goals of the three missions, combined with the political and economic difficulties following the fall of the Soviet Union, resulted in lengthy delays in the completion of RadioAstron. It was later transferred to the Astro Space Center (ASC) of the P. N. Lebedev Physical Institute of the Russian Academy of Science. Spectrum-X-Gamma and Spectrum-UV are currently under construction: the launch of the former is planned for 2014. The locations of the major substructures are illustrated by the schematic diagram of the spacecraft shown in Figure 2. The assembled dish structure is shown in Figure 3, as seen by the visit of the RadioAstron International Steering Committee in 2008.

Frequency (GHz)	Ts **(K)**	θ **(μarcsec)**	σ **(mJy)**
0.33	200	530	46
1.66	45	100	5
4.6	130	35	6
22	77	7	20

Table 1. The main characteristics of the four RadioAstron frequency bands.

After 30 years of development of this ambitious space VLBI project by scientists and engineers at the ASC, the 3660 kg RadioAstron spacecraft was finally launched from the Baikonour Cosmodrome on July 18, 2011. A day later, it was placed in a highly elliptical orbit, extending out beyond 300,000 km, with an eight-to ten-day period.

Figure 3. The 10 m space radio telescope as seen by the RadioAstron International Steering Committee during their visit to the Lavochkin Association construction facility, in October 2008.

The 10-m space RadioAstron radio telescope was fabricated from 27 carbon-fiber panels. It has an F/D ratio of 0.43. RadioAstron is equipped with feeds and receivers for four frequency bands, as shown in Table 1. In this table, column one is frequency band; column two is the typical system temperature, Ts; column three is the maximum resolution in microarcseconds; and column four gives the rms noise in a typical coherence time of five minutes, when joined with the NRAO 100-m radio telescope in Green Bank, West Virginia, USA. The front side of the unfurled dish structure is seen in Figure 4. Figure 5 shows the dish with the 27 panels folded and ready to be placed in the rocket. Figure 6 shows the folded antenna installed in the Zenit rocket. Figure 7 conveys an artist's impression of the RadioAstron spacecraft in orbit, with the antenna and solar panels unfurled.

The RadioAstron mission has enjoyed widespread international participation. The space radio telescope, the spacecraft bus, and the instrumentation were designed and developed by the Astro Space Center; the Moscow S. A. Lavoshkin Federal Research and Production Association Industries; and the Russian Space Agency, Roscosmos. The specialized radio-interferometry instrumentation was developed at the Astro Space Center. The low-noise amplifier for the 330 MHz (92 cm) radiometer was built

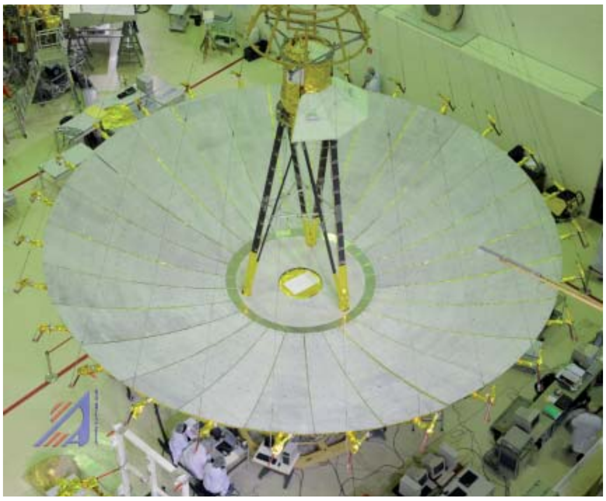

Figure 4. The Space Radio Telescope with the petals unfurled in the Lavochkin laboratory.

Figure 5. The 10 m RadioAstron dish, shown with the 27 petals folded and ready for launch in the Zenit rocket.

Figure 6. RadioAstron sitting on the Zenit rocket at the Baikonur launch site, ready for launch. The insert shows the imbedded plaque, displaying the international nature of RadioAstron.

by the NCRA in India, and the 1.6 GHz (18 cm) receiver was manufactured by CSIRO in Australia. A 5 GHz (6 cm) receiver was constructed in the Netherlands, on behalf of a consortium of European radio observatories. The 6 cm low-noise amplifier was provided by the MPIfR in Germany. The European Space Agency conducted thermal tests of the antenna panels in their vacuum chamber located in the Netherlands. The 22 GHz (1.3 cm) receiver was initially designed and built by the Helsinki Technical University. Due to the delays in the RadioAstron launch, both the original 5 GHz and 22 GHz receivers were considered to have exceeded their shelf life, and were replaced by newer units built by Russian industry. To obtain enhanced sensitivity and cover a wide frequency range, from 18 GHz to 25 GHz, the 22 GHz system uses low-noise HEMT amplifiers constructed by the US National Radio Astronomy Observatory. These are the same amplifier types as used for IF amplifiers in the WMAP spacecraft, used to map the cosmic-ray anisotropies. Each RadioAstron receiver operates in two (USB and LSB) 16-MHz-wide channels (4 MHz wide at 330 MHz), in each of two orthogonal circular polarizations.

Figure 7. An artist's conception of the RadioAstron spacecraft.

After conversion to baseband, each 16 MHz intermediate-frequency signal is digitized using one-bit Nyquist sampling, and the 128 Mbps digital data stream is sent to the ground over a 15 GHz link. On the ground, the 128 Mbps data are recorded on RadioAstron Data Recorder discs [10]. The data are then played back and sent over fiber to Moscow, or to the Max-Planck-Institute in Bonn, Germany, where they are correlated with data recorded at various ground radio telescopes throughout Russia, Ukraine, Europe, China, the United States, Japan, Australia, South Africa, and India. Correlation of the incoming data streams is performed in Moscow using a high-performance computer cluster. This runs a specialized RadioAstron software correlator, developed by the ASC team [10] and in Germany, using a modified version of the standard *DiFX* software correlator [11].

The RadioAstron spacecraft is equipped with two hydrogen masers, manufactured by the Russian company Vremya-Ch. The masers are used to stabilize the onboard local-oscillator system, by generating a 5 MHz reference signal used to control a frequency synthesizer that provides the independent stable local-oscillator signal. As a backup – in case of failure of the masers – a closed-loop system operates at 7.2/8.4 GHz, which can synchronize the RadioAstron local oscillator with an oscillator at the ground tracking station.

Ground-tracking support is currently provided using the 22 m antenna located at the radio observatory near Puschino, outside of Moscow. Since the spacecraft is not always visible from Puschino, an additional tracking station is under development at the US National Radio Astronomy Observatory in Green Bank, as well as one in South Africa. The South African tracking station will provide critical tracking support when the spacecraft is near perigee in the southern hemisphere. These external tracking stations will use the same instrumentation as at Puschino, thus insuring the uniformity of the data to facilitate the correlation. The precise orbit determination needed for radio interferometry is made utilizing five different methods: conventional radio-delay and Doppler measurements, laser ranging, optical observations of the spacecraft sky position, and VLBI tracking.

Data recorded simultaneously at the various tracking stations on the Earth and from RadioAstron are being used to reconstruct crude but extremely high-resolution images of celestial radio sources. Because of the very elliptical orbit of RadioAstron, the resolution of the Earth-space interferometer is essentially one dimensional. Precession of the orbit resulting from gravitational perturbations by the moon will give some degree of two-dimensional coverage, although changes in the radio source's structure during this period will make the detailed interpretation of the interferometer data more difficult.

6. RadioAstron Scientific Goals

Probable targets of Radioastron studies include pulsars, blazars, and cosmic masers. Previous ground-based VLBI observations of blazars suggested the presence of structure on angular scales as small as 50 microarcsec [12]. These expected small-scale structures are supported by observations of the radio spectra and rapid time variability.

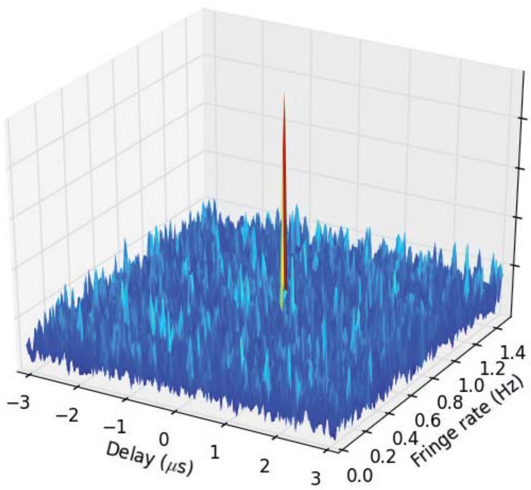

Figure 8. The first fringes found by the space-VLB interferometer RadioAstron. Shown is the interference signal from the quasar 0212+735 on an 8,100 km projected baseline between RadioAstron and the 100 m MPIfR radio telescope near Effelsberg, Germany, observed on November 15, 2012. The wavelength of the observations was 18 cm. The plot shows the fringe amplitude as a function of the residual delay and the residual fringe rate in a single 16 MHz-wide channel.

Of particular interest are the so called blazars, which are quasars the relativistic outflow of which is directed toward the Earth. Because of the enhancement of the radio synchrotron emission that is beamed along the direction of motion due to relativistic boosting, the apparent brightness of blazars can appear to be boosted by factors of thousands. Since the radio-emitting plasma is thought to be moving at nearly the speed of light along the line of sight, the radiating source is also nearly keeping up with its own radiation, giving the appearance of faster-than-light motion. The high-resolution observations made possible with RadioAstron will allow unprecedented detailed observations of blazars, reaching an order-of-magnitude closer to the super massive black holes thought to lie at the base of the relativistic jets.

Clouds of hydroxyl (OH) ions and H_2O molecular gas are also found in the regions surrounding highly evolved stars, as well as in regions where new stars are being formed. Excited by ultraviolet radiation from the associated star, these clouds can act as cosmic masers, giving intense, rapidly variable radio emissions from very small regions.

Pulsar radio emission is formed within the highly organized strong magnetic fields surrounding rapidly rotating neutron starts. The pulsar radiation comes from such small regions that they will remain unresolved, even by RadioAstron. However, the RadioAstron observations, especially at the longer wavelengths, will study the very-small-scale structures in the intervening intergalactic medium that scatter the radiation, resulting in apparent angular dimensions greater than the intrinsic values.

Interferometer baselines between RadioAstron and ground-based radio telescopes have an angular resolution more than an order-of-magnitude better than used in any previous astronomical observation. Specifically, at 22 GHz, the longest baselines are more than 2×10^9 wavelengths, giving an angular resolution of only 7×10^{-6} arcsec to study the radio emission from quasars and cosmic masers. Early science observations have been in progress since February, 2012. Starting in mid-2013, access to RadioAstron and the supporting ground facilities will be open to peer-reviewed proposals from any scientist, independent of their institutional or national affiliation.

7. Early Results

Following the launch of the spacecraft in July 2011, the first four months in orbit were spent in checking and calibration of the various mechanical and electronic components, and in calibrating the pointing of the antenna using the moon and other strong cosmic radio sources. These observations confirmed the performance of the four radiometers, each of which had a measured system temperature close to the design value.

Small uncertainties in the position and motion of the spacecraft at any time result in corresponding uncertainties in the interferometer fringe rate, and in the path-length delay between the RadioAstron and the ground antennas. A series of fringe-finding observations at each of the four observing frequencies was begun in November 2011 to verify the performance in each of the four frequency bands, and to determine the corresponding residual fringe rate and delay for a variety of cosmic sources. Since RadioAstron will observe primarily in a previously unexplored range of angular resolution, the early fringe-finding observations were mostly made using strong sources, with projected interferometer spacings that were comparable with previous Earth-based observations having sufficient fringe amplitude for detection with RadioAstron.

These observations resulted in the successful detection of fringes in all four RadioAstron frequency bands. In three of them – corresponding to wavelengths of 18 cm, 6 cm, and 1.3 cm – first fringes were found on a quasar. The 0.3 GHz band was successfully tested using a bright pulsar on a very long projected baseline. The detection of interference fringes is illustrated in Figure 8. This shows the observed fringe amplitude as a function of the residual fringe rate and delay, compared with the values corresponding to the space-to-ground interferometer baseline calculated from the spacecraft's orbital parameters.

Regular scientific observations with RadioAstron are organized by three international RadioAstron early-science-program working groups being coordinated by the Astro Space Center. They have been underway since February 2012, with 0.3 GHz and 1.6 GHz observations of pulsars; 1.6 GHz observations of OH masers; 22 GHz observations H_2O masers; as well as 1.6 GHz, 5 GHz, and 22 GHz observations of quasars. By mid-2012, important results were achieved by all the groups. There was quasar detection up to a projected interferometer baseline of 92,000 km (7.2 Earth diameters), pulsar detection at up to 220,000 km (about 20 Earth diameters), and water maser detection at 1.3 cm just over one Earth diameter.

8. Acknowledgments and Additional Information

The ambitious RadioAstron program owes its success to the dedicated scientists and engineers at the Astro Space Center and Lavochkin Association, many of whom have worked for decades to bring the mission to fruition. It success is also due to the international observatories (Kvazar network, Russia; Evpatoria, Ukraine; Effelsberg, MPIfR, Germany; Medicina and Noto, Italy; Yebes, Spain; Westerbork, the Netherlands; other EVN telescopes; Arecibo and GBT, USA; Usuda, Japan; LBA telescopes and Tidbinbilla, Australia; etc.) and colleagues who have supported the development and early operations. This paper used material from the RadioAstron user handbook (http://www.asc.rssi.ru/ radioastron/documents/rauh/en/rauh.pdf) and the RadioAstron *Newsletter* (http://www.asc.rssi.ru/radioastron/news/news.html). More-detailed information on RadioAstron can be found on the RadioAstron Web site, http://www.radioastron.ru. The National Radio Astronomy Observatory is a facility of the National Science Foundation, operated under a cooperative agreement by Associated Universities, Inc. Y. Y. K. was supported in part by the Dynasty Foundation.

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The International Council for Science Pledges Support for Scientists in the L'Aquila Case

The International Council for Science (ICSU), as representative of the global scientific community, expresses its strong concern regarding the case of the six scientists who have been found guilty of manslaughter and sentenced to six-year prison terms because of their role in providing scientific advice prior to the earthquake in L'Aquila, Italy, in 2009.

While ICSU is not privy to all the information that was available to the prosecutors, it appears that these scientists are being penalized essentially for using their experience and knowledge to provide evidence for decision-making. In the field of natural hazard risk, such scientific evidence has its limitations. The timing and strength of earthquakes cannot be accurately predicted. Nevertheless, science can, and does, make important contributions to hazard response strategies. In the case of L'Aquila, six scientists accepted their responsibility to society to try and support decision-making in a situation of inherent uncertainty. That these scientists should be condemned to prison for so doing is a gross injustice.

The L'Aquila earthquake was a tragic event in which more than 300 people died and ICSU endorses the need to determine whether these lives might have been saved if the public authorities had reacted differently before the event. The role of scientific advice in the decision-making processes prior to the earthquake is a legitimate area of enquiry. We all need to learn the lessons from the past to be better prepared for the future. In the meantime, blaming scientists and scientific advice for the deaths that occurred in L'Aquila is a grave error that will, unfortunately, make many scientists reluctant to accept public advisory roles.

We call on the responsible authorities to take urgent and decisive steps to correct this error and ensure due justice for Franco Barberi, Enzo Boschi, Giuli Selvaggi, Gian Michele Calvi, Mauro Dolce and Claudio Eva.

[The above material is taken from an ICSU press release dated October 25, 2012.]

Book Reviews for Radioscientists

[Editor's note: The Young Scientists who received an award at the 2011 Istanbul URSI GASS were asked to review their favorite textbook, even if it was a classic book. This is in contrast to our usual reviews, where we try to have new books reviewed. The reviews in this issue are from Young Scientists.]

RF Microelectronics

By by Behzad Razavi, Upper Saddle River, NJ, Prentice Hall, 1998; ISBN: 0-13-887571-5 [new edition: 2011]

RF and microwave wireless communications have become popular and been part of modern life: applications include radios, cellular systems, and satellite systems. RF engineering has become important and critical in the wireless industry, which basically can be divided into system design and hardware development. RF engineers should have knowledge and technical skills in both fields. This book presents the basic concepts of RF architecture and circuit design. It can be regarded as an advanced textbook for microelectronics and analog circuits, as most of the presented concepts can be realized by various technologies, such as CMOS and MMIC. This book demonstrates the methods for implementing wireless systems through circuit design. It details core components of RF systems, including transceivers and amplifiers, which are essential to RF circuits. Hence, this is an extremely useful book for RF folk.

This book can be divided into three parts: 1) background and basics of wireless and RF design (Chapters 1-2); 2) overview of communication systems, including modulation and multiple-access techniques (Chapters 3-4); 3) RF systems and components (Chapters 5-9). Although communication systems may be learned by a different path, the author of this book provides readers a good way to be familiar with the design process, and to verify the accuracy of the RF design by referring to the theory of communications. Readers can thus understand how the theory and formulation are implemented by the RF integrated circuit.

Chapter 1, "Introduction to RF and Wireless Technology," describes multiple disciplines used in RF design such that an RF system is an integration of communication theory, system architecture, and IC design. An "RF design hexagon" shows the tradeoffs among design parameters in order to meet specified targets. Since the same concept can be applied to many applications, experience is usually a key to making the decision in engineering to balance performance, cost, and scheduling of products.

Chapter 2, "Basic Concepts in RF Design," describes the nonlinearity and time variability of the components themselves, and then migrates to interference among components. Many effects of nonlinearities, such as harmonics, desensitization, and intermodulation, are key factors in determining and debugging the accuracy of outputs. Inter-symbol interference in a linear system results in signal distortion due to insufficient bandwidth; Nyquist signaling is then introduced to reduce that impact. After briefly reviewing random processes, noise and dynamic range are explained. It is shown how these two terms provide a straight way for evaluating the performance of the system and of circuit designs.

Chapter 3, "Modulation and Detection," presents the work performed by the RF transceiver, as a bridge between RF and baseband. The pros and cons of analog and digital modulations are emphasized, which reflects on the merits and limitations in the design of RF circuits. Each of these can provide unique signal quality, spectral efficiency, and power efficiency. Optimum detection, and why non-coherent detection is adopted in many RF systems, are well introduced.

Chapter 4, "Multiple Access Techniques and Wireless Standards," describes how to build communications between multiple transceivers, and what rules to follow in various wireless systems. Definitions of general behaviors and phenomena in mobile RF communications are given first. The difference between TDD and FDD is explained. FDMA, TDMA, and different types of CDMA are then introduced. This is followed by 2G and 3G cellular systems, where power control and diversity are briefly reviewed.

Chapter 5, "Transceiver Architectures," explains the criteria for selecting transceivers, such as bandwidth, in-band loss, IP3, noise, sensitivity, and dynamic range. Various receiver and transmitter architectures are reviewed. The superiority of popularly used heterodyne receivers, and the design concerns of spectrum image and IF issues, are analyzed in great detail. Image-rejection techniques are included, as well. Homodyne receivers are compared here. Transmitters bridging baseband, RF, and the antenna are then explained. The duplexer and switch in the RF front end, used to separate the transmitted and received signals, sometimes yield losses that cannot be compensated for in the system. This chapter is concluded with some examples of actual products used in FM and GSM radios.

Chapter 6, "Low-Noise Amplifiers and Mixers," presents their implementations using bipolar and CMOS technologies, which are suitable for VLSI. The low-noise amplifier's performance is governed not only by the image-rejection filter and mixer, but is also limited by the impedance matching for the antenna. The noise behavior, power gain, and stability are priority design parameters of the low-noise amplifier. Similarly, the noise figure, conversion gain, and port-to-port isolation are considerations in both single- and double-balanced mixers. To further understand mixers, qualitative and quantitative analyses can be performed.

Chapter 7, "Oscillators," starts by explaining their functions, then showing the concepts of how they work and how to build them, and finally generating desired output waveforms. Topologies of LC oscillators and voltage-controlled oscillators are presented next. The feedback circuit, frequency stability, *Q* factor, and phase noise are fundamental to constructing oscillators. The behavior of the phase noise and its impact on communications are investigated, and a tradeoff is always present between noise and power dissipation. Examples of a negative-Gm oscillator and an interpolative oscillator are given. Methods to generate quadrature and single-sideband signals are discussed; these are often applied in the design of transceivers.

Chapter 8, "Frequency Synthesizers," shows how to generate specific signals for a transceiver, which usually requires a phase-locked loop (PLL) and a programmable frequency doubler/divider. In addition to the phase noise generated at different stages, phase detection, loop bandwidth, fractional spurs, and lock-time have to be seriously considered in order to obtain very accurate frequencies. Several PLL and synthesizer architectures are presented and well explained. The approaches of analog and digital synthesis are also reviewed. This chapter ends with the topologies of numerous frequency dividers (prescalers), designed for monolithic implementations.

Chapter 9, "Power Amplifiers," gives an overview of linear and nonlinear power amplifier designs, and what determines the wireless applications for which they are good. Matching networks with different configurations between the power amplifier and the load, such as the antenna, can fatally affect the performance of the power amplifier's efficiency. Characteristics of popular power amplifiers, including classes A, B, C, E, and F, are introduced and clearly explained. Linearization techniques, such as feed-forward, feedback, EER, and LINC, specified for some classes of amplifiers, can be utilized to obtain higher efficiency with extra cost. Some design examples are given for RF amplifiers at the end of this book.

This book does not use many equations to analyze RF microelectronics. Instead, it tries to use simple descriptions to help readers easily understand the core concepts of each component, and to know what parameters and limitations are critical to the design. Typical design examples are given in each chapter, and many useful references are listed at the end of each chapter for further study. It is a good textbook and reference, not only for college and graduate students, but also for people in industry, and those who want to learn more about RF.

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Principles of Modern Radar

edited by M. A. Richards, J. A. Sheer, and W. A. Holm, Raleigh, NC, SciTech Publishing, 2010, 960 pp.; ISBN 9781891121524.

This is an ambitious book, covering the whole field of radar systems through 900 pages, with plenty of figures, references, and exercises for practicing and clarifying the concepts. The chapters are written by different authors, thus providing a multi-perspective view of the different areas, which is nice for system description. This is also a modern book, with a strong accent on digital signal processing.

Generally speaking, the book is based on a typical system approach. It starts from high-level user-oriented descriptions, and progressively goes into details, avoiding equations as much as possible. This is indeed an efficient approach for system-level understanding. The drawback is that the core principles are not always obvious, being stated and explained in the middle of the description.

The participation of significant actors in the modern radar community, either in the redaction or in the reviewing and editing of the book, ensures that most aspects of radar systems are effectively dealt with. Topics range from phenomenology to a detailed description of subsystems – transmitters, receivers, exciters, antennas – and from radar signal processing to radar systems, with a wealth of examples (although obviously mostly based on US systems). A standard drawback of books with multiple authors is not always avoided here: cross-referencing is not strong enough, each author making use of his or her own set of basic references, rather than referring to those of coauthors. The reader is very seldom referred to another chapter, whereas many overlaps between chapters do exist – which would be fine, if they were properly cross-referenced! Obviously, a radar beginner should not be required to get several introductory books of 900 pages.

The index is an important tool for such a huge reference book (few readers will read from the first chapter to the last, as this reviewer did – and enjoyed doing!). However, this is not always the case. For example, looking for ambiguity removal, which is at the core of many radar systems' data exploitation and waveform management, is not obvious. This topic could eventually be found in the Doppler-processing Chapter.

Despite the huge overall dimensions of the book, there are still some remaining blind spots:

- Target imaging is badly missing in the chapter dealing with RCS, where target images are shown and described – including such artifacts as air-intake multipath – without any description of the underlying imaging principle. Radar holography could be explained in a paragraph, which would also have well-complemented the SAR imaging chapter.

- Clutter characteristics are not very detailed (curiously enough for this team of authors from Georgia Tech, which have a renowned expertise in that area), especially concerning surface-clutter spectra (ground and sea), and the effects of multipath and shadowing. Similarly, airborne clutter distribution and its characteristics, and associated target extraction, are not very well covered.

- Polarization is mentioned in a very cursory way, without any detailed physical description to help the reader to understand the use (weather radar) and limitations (for target classification). Basic physical phenomena, signal decomposition, and essential clutter and target characteristics should be provided in such a detailed introductory course.

Considering the applicability of using this book as a textbook in universities and training schools, the answer is largely positive – and this will indeed be the preferred textbook of this reviewer for the years to come. The explanations from high level to details, the vast corpus of references, the high readability of the text, the fine balance between intuitive description and precise analytical formulations, are very significant assets for that use. However, some of the critical areas that are known as chronic weak points for students are not perfectly covered here:

A detailed physical explanation of the important issue of Doppler, as a phase shift from pulse to pulse, would have been appreciated in Chapter 1, since it is difficult to grasp for students and essential in signal processing. The definition of radar cross section (Chapter 2) should mention the isotropic diffraction assumption, not always easy to grasp for students. there is a very abrupt introduction of synchronous detection (Chapter 3), and I and Q channels. This issue, often poorly understood by students, should be very clearly described (perhaps in an appendix, since it is not specific to radar applications).

The paragraph on basic reflection physics (Chapter 6) should also roughly describe the available modeling techniques, from Rayleigh to asymptotic methods, to help the reader in grasping the underlying physics: diffraction, creeping waves, resonance, etc. In this paragraph, the description of polarization effects is also very limited. There is no description of circular compared to linear polarization, the effects on drops, edges, surface waves, etc. In Chapter 15, the key notion of integration gain is not clearly defined: is it the gain in signal-to-noise ratio, or the gain required for a certain detection quality (P_d , P_{fa}) level? This is essential for a good understanding of power budgets, and difficult to grasp for beginners. Moreover, if it is indeed defined as signal-to-noise ratio improvement, coherent and non-coherent integration are strictly equivalent: summing N independent samples improves the signal-to-noise ratio by a factor of N, whatever the underlying distribution. In Chapter 15, the description of detection issues on Gaussian probabilities is very misleading, since in practice, the quantities submitted to threshold are positive quantities! Why not use the correct probabilities and curves, as in the following chapter? The whole detailed discussion with exact numerical values is pointless, since radar never detects without some kind of envelope detection.

In Chapter 17, rather than the autoregressive model, which has specificities making it touchy to use by beginners, it would have been useful to mention here Capon or MVDR spectral analysis, which can be used very easily, and can generally be used preferably to the standard DFT!

Chapter 18, on radar measurement (range, angle, etc.) is essentially an accumulation of non-demonstrated formulas, roughly equivalent for different specific cases. For such a book dealing with principles, it would be more useful to give demonstrations of the basic principles and formulas. This is especially true for the very frustrating description of monopulse. There is no explanation of the necessity of Δ channel (maximization of $\left|\sum(\theta)\right|^2$), or of the equivalence between phase and amplitude monopulse, or of the underlying phenomenology: alignment along the wavefront. The same is true for the multiple-targets situation, where only a very specific example is given, rather than a general view. This chapter clearly does not address the same objectives as the rest of the book. This specific aspect of monopulse, also addressed in a very cursory way in Chapter 9 on antennas, though certainly important for the students and for many engineers, is definitely a weak point in this book.

In Chapter 20, it should be clearly mentioned – and emphasized – that RCS is proportional to the square of the ambiguity function $\left|A(t, f_d)\right|$, meaning that the sidelobe requirements are in terms of $|A|^2$: there is a very frequent confusion looming there.

Conversely, some approaches will certainly be appreciated by beginners, and some experts. In Chapter 2, a nice example of system analysis is given for the influence of antenna beam squint on power budget: lengthy, but efficient. The clear description of data cubes in Chapter 8 is welcome here, and will certainly prove useful for many students. Chapters 11, 13, and 14 include very well designed high-level descriptions of signal-processing matters: the clarity of these chapters is certainly a strong point of this book. In Chapter 16, a careful use of baseline examples is a nice way to help the beginner in grasping the importance of false alarms. Mentioning clutter-fill pulses, in Chapter 17, is certainly helpful for many beginners. It is also a good idea to mention pulse-pair processing, basic in many weather radars.

A very nice feature of this book is also the presence of a whole range of problems at the end of each chapter, with varying degrees of difficulty. This is obviously the best way to check the correct understanding of the main issues, and will be a valuable help for the reader – and for the teachers alike.

Overall, this is the best available book I know for starting to learn and design modern radar systems. It is very carefully edited, with a diversity of approaches (high and low level), and detailed discussions and problems. The general objective of providing a comprehensive textbook of choice for modern students and engineers is achieved, even though a few specific improvements can still be identified for future editions.

Reviewed by

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Conferences

CONFERENCE REPORTS

COSPAR 2012 General Assembly

Mysore, India, 14 - 22 July 2012

The 39th Scientific Assembly of the Committee on Space Research (COSPAR) has been held at the Infosys Campus, Global Education Centre-2 (GEC-2) in Mysore, Karnataka India on July 14-22, 2012. The Scientific Program on behalf of international community was coordinated by Prof. U.R. Rao (India).

The organized Scientific Events covered the topics related to eight Scientific Commissions of present COSPAR Scientific Structure and joint sessions between Commissions, as well. At the same time, six tutorial lectures and four general and public lectures were given.

Report on activities since the 38th COSPAR Scientific Assembly has been presented (Council39_2.1). Current membership of National Scientific Institutions is 46. International Scientific Unions is 13. Associated Supporters 8 and Associates 7964. Membership changes since 2010: two new adhering national scientific institution members are Korean Astronomy and Space Science Institute and University Putra Malaysia and three new Associated Supporters are China Academy of Launch Vesicle Technology (CALT), China Academy of Space Technology (CAST) and Orbital Sciences Corporation (USA). The number of Associates represents a significant jump of approximately 1353 (20%) over the figure presented at the Bremen Assembly. Personal contact with new potential associated supporters were derived.

During this this Assembly 3489 abstracts were submitted (2615 number of authors, abstracts rejected 63, abstracts withdrawn 118, number of core program scientific events 115). Finally with the papers submitted in the last moment is 3504 and only less than half of them were selected to be posters. The number of papers is slightly less than in Bremen (4488) and Montreal (3780).

Over 1500 pre-registered participants. Financial support per person has been given up to 496 applicants, while in 2010 it was 548. Number of grants awarded was 238, 197 in 2010, 163 in 2008, and 139 in 2006. Total funding per participant was 131.525 Eur plus plane tickets while in Bremen it was 141 EUR. 84 exhibitors. 78 press. 1000 attendance for public lectures. 73 countries were represented.

Publications Committee (Council39_13.1) stress that: Space Research Today with its publications 3 times a year is serving its purpose well for the communications between COSPAR members, COSPAR journal Advances in Space Research impact factor is increasing steady and now has higher than ever before impact factor – 1.178. During last 4 years 791 papers has been published in regular issues and 212 special issues including COSPAR Colloquia. Project under consideration: A new “Short Communications” category with faster turnaround (Council_39_13.1).

Capacity building

4 workshops12÷15 Brazil (Council39_4.1), India (Council39_4.2), Argentina (Council39_4.3), South Africa (Council39_4.4). Fellowship program successful now become permanent. Capacity Building Fellowship program was established by the Bureau in March 2008. A total of about 20 fellowships have been attributed, half of them since 2010.Collaborative agreement signed with WMO Space program.

Outreach

UNESCO Paris, January 2010 in closure of the IYA: “Ocean and our climate seen from space”, Paris, April 2012. The Bureau has decided that COSPAR would organize similar events spanning all COSPAR disciplines, in non-Assembly years. But they will not be continued on a regular basis, but rather organized in favorable contexts such as that offered by the IYA.

COSPAR organized, co-sponsored, or represented at numerous meetings as, COSPAR Symposium on Planetary protection and Space Exploration, at the STS of COPUOS in Austria, Workshop “International Earth-based Research program as a Stepping Stone for Global Space Exploration in USA, Symposium on new Technologies for Future Space Astronomy Missions in South Africa, IRSI/COSPAR Workshop on The International Reference Ionosphere in South Africa and COSPAR Colloquium on Protecting the Earth and Planetary Protection Policy in Austria. COSPAR co-sponsored 12 meetings and 19 meetings with COSPAR participation.

Following a proposal discussed in Bremen to organize z new series of meetings in countries with new or medium sized space program, after consultation the results has been presented in March 2011. "Planetary Systems of our Sun and other stars and the Future of Space Astronomy was selected for the first Symposium. Proposals from Poland, Thailand and expressed interest from Spain and Malaysia. Bangkok 2013 has been selected.

Concerning the Secretariat a new officer Dr. (Ms.) Venence Journe has been appointed.

Financial reports (documents Council39_2A.1 and document Council39_3A.2) including draft budgets for 2013 and 2014 have been approved by Council with requirement of taking into account changes agreed during the meeting or resulting from the financial transactions of this meeting and Execution of the 2010 and 2011 budgets, as well. Audit report on the 2011 Financial Statement was received on January 26, 2012 (Council39_3B.1) attesting the correctness and truthfulness for the year 2011. Revenues and Expenditures show loss of 58 821 loss. It was recommended that the Bureau endorses the first draft of the budget as a reasonable approach to the financial affairs for this year. The Finance Committee notices that the new initiatives appearing for the first time in the budget of 2012 and 2013 i.e. the support to the PPP Website, and the preparation for the first COSPAR Symposium in a non-Assembly years, these reserves are in excess of the amount that would be sufficient to provide a healthy reserve to weather difficult financial periods. Therefore, the Finance Committee suggests the Bureau to consider additional initiatives or more generous arrangements for the new Symposia or future Assemblies, for instance by providing more financial aid to needy participant. Finally the COSPAR Council agrees that the Bureau be authorized to set the amounts of national contributions for 2014 and 2015, there being no Council meeting in 2013.

COSPAR 2014 – Moscow (Council39_5.1) with its draft draft budget for next 40th COSPAR meeting which income to be received is 896 600 Eur. Two propositions for 2016 were presented: Turkey (Istanbul) and Italy (final decision made just before the meeting – Rome). According to ballot COSPAR 2016 will be in Turkey. Voices 43:13. Submitted proposals for 2018 – Australia, 2020 – Mexico.

Revision of COSPAR by-laws has been presented; explanatory notes (Council39_6.1), Terms of reference of the Working Group on the revision of COSPAR By-Laws (Council39_6.4) and correspondence with Executive Board of ICSU about finally approved proposed revision (Council39_6.5).

Reports from business meetings of every commissions (A, B, C, D, E, F, G, PCB, PE, PPP, PRBEM, PSB1, PSD1, PSW) have been approved (Council39_15.XX).

Special recommendations from panels on Radiation Belt Environment Modelling (Council39_14.1) and on Space Weather (Council39_14.2) have been presented.

113 proposals for COSPAR Assembly in Moscow are presented: 12 in C (including IRI) and 3 in SW Space Weather).

Traditionally, in the frame of COSPAR Meeting two **short courses** (Meta-materials and Applications and MIMO Propagation Channels) were provided.

COSPAR **Interdisciplinary Lectures**:
- The New Face of the Moon
- The Very Early Universe
- Dynamics of the Global Sun from Interior to Outer Atmosphere
- Origin and Signatures of Life
- The Gamma-ray Universe through Fermi
- Long-term Aerosol and Cloud Observations from Space for Climate Studies

COSPAR **Working Group**: Future of Space Astronomy Report - A Space Astronomy Global Road Map for the Next Decades

COSPAR **Public Lecture** : Exoplanets

Report on C4.1 "Global and Regional Representation of Ionospheric Peak Parameters for Space Weather Applications

Mysore, India, 14 - 22 July 2012

The session on "Global and Regional Representation of Ionospheric Peak parameters for Space Weather Applications" was held during the 39th COSPAR Scientific Assembly, which took place in Mysore, India, from July 14 to 22, 2012. It was organized by the COSPAR/URSI Working Group on the International Reference Ionosphere, and was held on Sunday and Monday of the conference week. The session was divided into six subsections, entitled "Topside and TEC in IRI," "F Peak Modeling," "Variation During Ionospheric Storms," "Representing Solar Minimum Conditions," "Improving IRI," and "New Inputs for IRI." [IRI is the International Reference Ionosphere.] The session was well attended (40-60). It consisted of 27 talks and two posters, with presenters from Austria, Czech Republic, India, Iran, Italy, Japan, Poland, Russia, South Africa, Uganda, Ukraine, and USA. A business meeting of the IRI

Working Group was held on the day after the session, and was attended by 18 participants.

Topside and TEC

Work continues on the Vary-Chap model for the topside electron-density profile. Latest results were presented by Reinisch et al. (University of Massachusetts, Lowell, USA), based on ISIS topside-sounder data. Several papers presented comparisons of IRI-TEC predictions with GPS-TEC measurements from the Indian subcontinent. Of special interest were the comparative studies in the equatorial anomaly region. These found good agreement, with the exception of the sunrise time period (Surat station: Karia et al., S V National Institute of Technology; Palehua station: Devi et al., Mar Thoma College, Kerala). A study with Korean GPS-TEC data showed that the winter anomaly appears in the GPS TEC only during the solar-maximum period, in contrast to the IRI estimations in which it shows up regardless of the solar activity. Kakinami et al. (Hokkaido University, Japan) constructed empirical models of the topside electron density and temperature measurements by the DEMETER satellite. However, they also pointed out that DEMETER densities were systematically lower and temperatures higher than measurements by other satellites, and also than IRI predictions. They recommended using relative variations, instead of absolute values. Truhlik et al. (Institute of Atmospheric Physics, Czech Republic) discussed ways to improve the current IRI ion-composition and electron-temperature models in the topside ionosphere, based on newer data and with special regard to low solar activity and to the extension to the plasmasphere.

F Peak Parameters

Ratovsky et al. (Institute of Solar-Terrestrial Physics, Irkutsk, Russia) presented local empirical models for the peak parameters foF2 and hmF2, based on validated ionogram data recorded by Digisondes in Norilsk, Irkutsk, and Hainan (China). Nagatsuma et al. (National Institute of Information and Communications Technology, Japan) described the status and data of the NICT network of ionosondes (Wakkanai; Kokubunji; Yamagawa; Okinawa; and the South-East Asia Low-Latitude IOnospheric Network, SEALION). These data, extending from low to middle latitudes with a multi-year data record, are a valuable data source for improvements of the F peak models for IRI. Ionospheric behavior during the storm-recovery phase was discussed by Buresova et al. (Institute of Atmospheric Physics, Czech Republic). This was compared with the predictions by IRI and other models, pointing to significant deficiencies, particularly for the peak height, hmF2. McKinnell et al. (South Africa National Space Agency, South Africa) reported on the continued efforts by her group on the planned inclusion of their neural-network models for the F peak parameters in IRI. COSMIC and GPS data were used by Irina Zakharenkova (IZMIRAN, Kaliningrad, Russia) to study the global variations of the F peak parameters and the plasmaspheric electron content, with special emphasis on time periods and regions where shortcomings of the IRI model are found. The performance of the IRI model during the recent highly unusual solar minimum was discussed in several presentations during this session. Araujo-Pradere et al. (University of Colorado, USA; presented by Fuller-Rowell) showed that IRI overestimated the F peak density and height, as well as the TEC, during this very low and extended minimum. Bilitza et al. (George Mason University, USA) presented comparisons with ionosonde and C/NOFS measurements, and investigated the possible causes and remedies for the overestimation by IRI.

General

The IRI Working Group submitted a proposal for a session during the 2014 COSPAR General Assembly in Moscow, Russia, entitled “Improved Representation of the Ionosphere in Real-Time and Retrospective Mode.” The 2013 IRI Workshop will be held at the University of Warmia and Mazury in Olzstyn, Poland, from June 24 to 28. The Main Organizer is Andrzej Krankowski, and the special topic will be GNSS inputs for IRI. Selected papers from the 2009 IRI Workshop in Kagoshima, Japan, have been published in two dedicated issues of *Earth, Planets, and Space*. Papers from the 2010 IRI session during the COSPAR General Assembly in Bremen, Germany, will soon be published in a special issue of *Advances in Space Research*. Another special IRI issue of *ASR* with papers from the 2011 IRI Workshop in Hermnaus, South Africa, is now in the reviewing stage.

The IRI business meeting on July 17 was attended by 15 Participants. Several improvements to the IRI model were discussed, based on the presentations at this meeting and prior workshops. A primary focus was the height of the F peak, hmF2, which in IRI is represented through its relationship to the propagation factor M(3000)F2. New models were proposed by Altadill et al. (Ebro, Spain) and by Gulyaeva et al. (IZMIRAN, Russia), and will be included as new options in the next version of IRI-2012. It was also found that the current hmF2-M(3000)F2 model predicted unrealistically low values during the extreme 2008/2009 solar minimum, because data for such conditions were not available when the model was developed. Efforts are underway to improve the model for very low solar activities. It was also pointed out that ITU and HF users of IRI are still very interested in a representation of not only hmF2 but also M(3000)F2, because it can be directly applied to some of their applications. John Bosco Habarulema (Uganda) was proposed and accepted as a new member for the IRI Working Group. He has worked extensively on TEC- and IRI-related research, and was one of the organizers of the 2011 IRI Workshop in Hermanus. He was co-Editor of the *ASR* issue with papers from the Hermanus meeting. His main field of interest is in improving the predictability of TEC using neural networks under all conditions, and as this is of increasing interest to the IRI group, will bring this expertise to the group. There are no plans for a dedicated issue with papers from this meeting. Papers can be either submitted as standard *ASR* papers or can be considered for our next special issue, which is planned for the papers from the 2013 IRI Workshop. This workshop will be held at the University of Warmia and Mazury in Olsztyn, Poland, from June 24 to 28, 2013 (MSO: Andrzej Krankowski). The IRI homepage is at http://IRI.gsfc.nasa.gov/.

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Radio 2012

Wolmar, Flic en Flac, Mauritius, 24 - 27 September 2012

Honourable Tassarajen Pillay Chedembrum, Minister of Information and Communication Technology, officially opened the inaugural Radio and Antenna Days of the Indian Ocean (RADIO 2012) that was held at the Sugar Beach Resort, Wolmar, Flic en Flac, from 24th to 27th September 2012. The organizing committee of this international conference consists of researchers from the University of Mauritius and University of Technology, Mauritius, and is chaired by Prof. Vikass Monebhurrun from SUPELEC (Ecole Supérieure d'Electricité), France.

RADIO is the first of a series of conferences that will be organized in the Indian Ocean region. For this first edition, RADIO 2012 brought together about 70 international experts from 17 countries namely Belgium, Canada, China, Finland, France, Germany, India, Malaysia, Mauritius, Reunion Island, Russia, Singapore, South Africa, South Korea, Sweden, United Kingdom and USA. The conference featured several sessions on state-of-the-art research themes including antenna design, wireless applications and metamaterials as well as two full day workshops. One workshop was dedicated to radio astronomy, a field in which Mauritius has recently gained international recognition by forming part of the consortium which will be hosting the Square Kilometre Array (SKA), one of the world's largest radio telescope and one of the biggest scientific projects ever. Another workshop was devoted to the growing issue of human exposure to electromagnetic fields from base station antennas and mobile phones.

Keynote speeches were delivered by Prof. S. Ananthakrishan from Pune University, India, Dr. M. Gaylard from Hart RAO Observatory, South Africa and Prof. M. Tentzeris, from Georgia Tech, USA. Prof. S. Ananthakrishan discussed about the importance of experimental skill development among science students. He indicated that a major problem faced by science faculty in India at post-graduate level is the near absence of conceptual abilities in students. Dr. M. Gaylard provided an overview of the SKA radio telescope project, highlighting that this project provides a new science and developmental opportunity for African countries and neighbouring islands of the Indian Ocean. Prof. M. Tentzeris introduced nanotechnology and inkjet-printed flexible electronics and sensors fabricated on paper, plastic and other polymer substrates as a sustainable ultra-low-cost solution for low-power applications.

The first day of the conference was essentially dedicated to discussions on antenna design and wireless applications. There were several contributions by students on novel antenna designs for wideband and ultra-wide band applications. During the second day, the discussions were focused on wireless power transfer and material modeling. The pros and cons of both inductive and capacitive power transfer methods were discussed. The session on material modeling covered ferromagnetic materials as well as metamaterials. A short poster session was also organized during the afternoon coffee break.

The workshop on radio astronomy organized during the third day provided a platform for presentations about some already built as well as future radio telescopes from around the world: Arecibo Radio Telescope in Puerto Rico, Giant Metrewave Radio Telescope (GMRT) in India, Chinese Spectral Radioheliograph (CSRH), Five-hundred-meter Aperture Spherical radio Telescope (FAST) in China and Square Kilometre Array (SKA). The major groups in this workshop came from China and India. The Chinese scientists described the new radio solar spectroheliograph array being set up in Inner Mangolia, about 400 kms north of Beijing and the Chinese Mega-science project, the Giant 500 m aperture single dish radio telescope being set up in Guizhou province in China. It will be the largest single dish radio telescope in the world. The Indian scientists and engineers described their well-established GMRT and its upgrade plans. Currently, GMRT is one of the most sensitive low frequency (< 1500 MHz) radio telescopes in the world. It was stated that its upgrade will make it a very competitive instrument at least till SKA Phase I is completed. The Ooty Radio Telescope working at 327 MHz since 1970's has also been fully refurbished and has a new and powerful digital backend. South African scientists and engineers described their plan to set up a new pan African Very-Long-Baseline Interferometry (VLBI) network including a radio dish in the Island of Mauritius. The group from the Mauritius Radio Telescope (MRT) operating at 150 MHz will participate in the South African VLBI activity and also become partners in the VLBI project. There was an invited talk on the Galactic continuum Transit survey using the Arecibo L-band Feed Array (ALFA), which will cover 13000 square degree of the sky. This will be a major observational astronomy contribution for imaging the polarized radiation from the Milky Way.

The workshop on human exposure to electromagnetic fields organized during the last day of the conference consisted of presentations about some recent biological studies and discussions on the means to evaluate compliance of both local and whole body exposure with regard to current limits. A first study from India showed that the 10 GHz field has an injurious effect on the fertility potential of male exposed rats. Another study from the same country showed that chronic, intermittent amplitude modulated RF (73.5 MHz) exposure to the peripubertal rat increases the emotional component of phasic pain over a basal eaualgesic state, while late response to tonic pain decreased. The case of an accidental exposure to high-levels of RF radiation (85-100 MHz) during work on a transmission mast in Finland was reported. The results of an international survey of mobile phone users' knowledge of specific absorption rate (SAR) were presented. They show that there is generally a low level of concern about possible health risks from using mobile phones and widespread misunderstanding of SAR. Case studies from India where the government is currently developing RF exposure limits and standards were presented. Since all marketed mobile phones are expected to be SAR compliant (e.g. less than 2 W/kg in Europe), the meaning and display of the relative SAR values of mobile phones measured in laboratory conditions were debated since they do not reflect the real life exposure scenarii.

Before the closing ceremony of the conference, prizes and certificates were awarded to young scientists and students. Three young scientists benefited from partial financial support from Union Radio Scientifique Internationale (URSI) to attend RADIO 2012. First and second best paper prizes were awarded to two students.

Following the success of RADIO 2012 and numerous requests from foreign delegates, the local organizing committee is considering the organization of the next edition of the conference again in Mauritius in 2014.

Vikass MONEBHURRUN
General Chair, RADIO Conference

CONFERENCE ANNOUNCEMENTS

COSPAR 2014

Moscow, Russia, 2 - 10 August 2014

Topics

Approximately 120 meetings covering the fields of COSPAR Scientific Commissions (SC) and Panels:

- SC A: The Earth's Surface, Meteorology and Climate
- SC B: The Earth-Moon System, Planets, and Small Bodies of the Solar System
- SC C: The Upper Atmospheres of the Earth and Planets Including Reference Atmospheres
- SC D: Space Plasmas in the Solar System, Including Planetary Magnetospheres
- SC E: Research in Astrophysics from Space
- SC F: Life Sciences as Related to Space
- SC G: Materials Sciences in Space
- SC H: Fundamental Physics in Space
- Panel on Satellite Dynamics (PSD)
- Panel on Scientific Ballooning (PSB)
- Panel on Potentially Environmentally Detrimental Activities in Space (PEDAS)
- Panel on Radiation Belt Environment Modelling (PRBEM)
- Panel on Space Weather (PSW)
- Panel on Planetary Protection (PPP)
- Panel on Capacity Building (PCB)
- Panel on Education (PE)
- Panel on Exploration (PEX)
- Special events: interdisciplinary lectures, round table, etc.

Scientific Program Chair

Prof. M.I. Panasyuk, Moscow State University

Abstract Deadline

Mid-February 2014 : Selected papers published in *Advances in Space Research*, a fully refereed journal with no deadlines open to all submissions in relevant fields

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URSI CONFERENCE CALENDAR

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

January 2013

MECON-2013 - Mobile Communication and Embedded System International Conference
Noida, India, 17-18 January 2013
Contact: Dr. (Mrs.) Balvinder Shukla, Acting Vice Chancellor, AUUP & Director General, ASET, Amity University Uttar Pradesh, Noida - 201 303, INDIA, Phone: +91 120-4392672, Fax: +91 120-439232

March 2013

META'13 - Fourth International Conference on Metamaterials, Photonic Crystals and Plasmonics
Sharjah, Dubai, UAE, 19-22 March 2013
Contact: Said ZOUHDI, Professor, Paris-Sud University, Head of International Relations (Polytech Paris-Sud), Fax: +33 1 69 41 99 58 (Polytech), E-mail said.zouhdi@supelec.fr http://metaconferences.org/ocs/index.php/META13/META13

AES 2013 - Second Advanced Eletromagnetics Symposium
Sharjah, Dubai, UAE, 19-22 March 2013
Contact: Said ZOUHDI, Professor, Paris-Sud University, Head of International Relations (Polytech Paris-Sud), Fax: +33 1 69 41 99 58 (Polytech), E-mail said.zouhdi@supelec.fr http://mysymposia.org/index.php/AES13/AES13

April 2013

EUCAP 2013 - The Seventh European Conference on Antennas and Propagation
Gothenburg, Sweden, 8-12 April 2013
Contact: Eucap2013@realize-events.de, Jennifer at +49-89-660799-420 and registration@eucap2013.org
http://www.eucap2013.org/

URSI-F-TS - URSI Commission F Triennial Open Symposium on Radiowave Propagation and Remote Sensing
Ottawa, ON, Canada, 30 April - 3 May 2013
Contact: Radio Propagation: Dr R.J. BULTITUDE, Communications Research Centre, Satellite Comm. & Radio Propagation, 3701 Carling Avenue, Ottawa, ON K2H-8S2, Canada, E-mail : robert_bultitude@ursi-f-ts.com ; Remote Sensing: Brian_Brisco@ursi-f-ts.com

May 2013

EMTS 2013 - URSI Commission B International Symposium on Electromagnetic Theory
Hiroshima, Japan, 20-23 May 2013
Contact : Prof. G. Manara, Dept. of Information Engineering, University of Pisa, Italy, E-mail g.manara@iet.unipi.it, Website : http://ursi-emts2013.org

June 2013

RAST 2013 - New ways of Accessing Space for the Benefit of Society
Istanbul, Turkey, 12-14 June 2013
Contact : RAST2013 Secretariat, Turkish Air Force Academy (Hava Harp Okulu), Yesilyurt, Istanbul, Turkey, Fax : +90 212 6628551, E-mail : rast2013@rast.org.tr, http://www.rast.org.tr

July 2013

IconSpace 2013 - 2013 International Conference on Space and Communication
Malacca, Malaysia, 1-3 July 2013
Contact: iconspace@ukm.my
http://www.ukm.my/iconspace2011/

Beacon Satellite Meeting
Bath, Uk, 8-12 July 2013
Contact: Ms. Patrica Doherty, Boston University School of Management, 595 Commonwealth Avenue, Boston, MA 02215, USA, E-mail : pdoherty@bu.edu, Website : http://www.bc.edu/research/isr/ibss.html

August 2013

HF 13- The Tenth Nordic HF Conference HF 13 with Longwave Symposium LW 13
Faro, Sweden (Baltic Sea), 12-14 August 2013
Contact: Carl-Henrik Walde, HF 13 chair, info@walde.se
http://www.nordichf.org/index.htm?index2.htm&2

ISRSSP 201 - Third International Symposium on Radio Systems and Space Plasma
Sofia, Bulgaria, 28-30 August 2013
Contact: IICREST c/o B. Shishkov (ICTRS 2013 Event); P.O. Box 104; 1618 Sofia; Bulgaria, E-mail: bshishkov@math.bas.bg
http://www.isrssp.org/

September 2013

EMC Europe 2013 Brugge
Brugge, Belgium, 02-06 September 2013
Contact: Davy Pissoort, Head FMEC, Zeedijk 101, B8400 Oostende, Belgium, Fax: +32 59 56 90 01, E-mail: davy.pissoort@khbo.be, http://www.emceurope2013.eu

AP-RASC 2013 - AsiaPacific Radio Science Conference
Tapei, China SRS, 3-7 September 2013
Contact : Prof. K. Kobayashi, Chair, AP-RASC International Advisory Board, Fax: +886 2 23632090, E-mail: ctshih@tl.ntu.edu.tw, Website : http://aprasc13.ntu.tw

ICEAA-APWC-EMS conferences
Torino, Italy, 9-13 September 2013
Contacts: Prof. W.A. Davis, EMS Chair wadavis@vt.edu and Prof. Y. Koyama, EMS Vice-Chair koyama@nict.go.jp, http://www.iceaa.net

October 2013

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

January 2014

VERSIM-6 - Sixth VERSIM Workshop
Dunedin, New Zealand, 20-23 January 2014
Contact: Prof Craig J. Rodger, Department of Physics, University of Otago, PO Box 56, Dunedin 9016, NEW ZEALAND, Fax: +64 3 479 0964, E-mail: crodger@physics.otago.ac.nz

August 2014

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

September 2014

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

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

International Geophysical Calendar 2013

	S	M	T	W	T	F	S
JANUARY			1	2	3	4	5
	6	7	8	9	10	11 N	12
	13	14	15*+	16+	17+	18+	19+
	20+	21+	22+	23+	24+	25+	26+
	27F+	28+	29+	30+	31+	1+	2+
FEBRUARY	3+	4+	5+	6+	7+	8+	9+
	10N+	11+	12*+	13+	14+	15+	16+
	17	18	19	20	21	22	23
	24	25F	26	27	28	1	2
MARCH	3	4	5	6	7	8	9
	10	11N	12*	13	14	15	16
	17	18	19	20	21	22	23
	24	25	26	27F	28	29	30
	31	1	2	3	4	5	6
APRIL	7	8	9	10N*	11*	12	13
	14	15	16+	17+	18+	19+	20
	21	22	23	24	25F	26	27
	28	29	30	1	2	3	4
MAY	5	6	7	8	9	10N	11
	12	13	14	15	16	17	18
	19	20	21	22	23	24	25F
	26	27	28	29	30	31	1
	2	3	4	5	6	7	8N
JUNE	9	10	11*	12	13	14	15
	16	17	18	19	20	21	22
	23F	24	25	26	27	28	29
	30						
	S	M	T	W	T	F	S

S	M	T	W	T	F	S	
	1	2	3	4	5	6	JULY
7	8N+	9*+	10*+	11+	12+	13	
14	15	16	17	18	19	20	
21	22F	23	24	25	26	27	
28	29	30	31	1	2	3	AUGUST
4	5	6N*	7*	8	9	10	
11	12	13	14	15	16	17	
18	19	20	21F	22	23	24	
25	26	27	28	29	30	31	
1	2	3	4*	5N*	6	7	SEPTEMBER
8	9	10	11	12	13	14	
15	16	17	18	19F	20	21	
22	23	24	25	26	27	28	
29	30	1	2	3	4	5N	OCTOBER
6	7	8*	9*	10	11	12	
13	14	15	16	17	18F	19	
20	21	22	23	24	25	26	
27	28	29	30	31	1	2	NOVEMBER
3N	4+	5+	6+	7+	8	9	
10	11	12	13	14	15	16	
17F	18	19	20	21	22	23	
24	25	26	27	28	29	30	
1	2	3N*	4*	5	6	7	DECEMBER
8	9	10	11	12	13	14	
15	16	17F	18	19	20	21	
22	23	24	25	26	27	28	
29	30	31	1N	2	3	4	2014 JANUARY
5	6	7	8	9	10	11	
12	13	14	15	16F	17	18	
19	20	21	22	23	24	25	
26	27	28	29*	30N*	31		
S	M	T	W	T	F	S	

15 Regular World Day (RWD)

16 Priority Regular World Day (PRWD)

13 Quarterly World Day (QWD) also a PRWD and RWD

2 Regular Geophysical Day (RGD)

11 12 World Geophysical Interval (WGI)

\+ Incoherent Scatter Coordinated Observation Day (The period Jan 15-Feb 15 is a StratWarm Alert Interval with a fallback interval of Feb 7-12.)

N NEW MOON F FULL MOON

10 Days of Solar Eclipse: May 10 annular & Nov 3 hybrid

10 11 Airglow and Aurora Period

15* Dark Moon Geophysical Day (DMGD)

This Calendar continues the series begun for the IGY years 1957-58, and is issued annually to recommend dates for solar and geophysical observations, which cannot be carried out continuously. Thus, the amount of observational data in existence tends to be larger on Calendar days. The recommendations on data reduction and especially the flow of data to World Data Centers (WDCs) in many instances emphasize Calendar days. The Calendar is prepared by the International Space Environment Service (ISES) with the advice of spokesmen for the various scientific disciplines. For some programs, greater detail concerning recommendations appears from time to time published in IAGA News, IUGG Chronicle, URSI Information Bulletin and other scientific journals or newsletters.

The Calendar provides links to many international programs, giving an opportunity for scientists to become involved with data monitoring and research efforts. International scientists are encouraged to contact the key people and join the worldwide community effort to understand the Sun-Earth environment.

The definitions of the designated days remain as described on previous Calendars. Universal Time (UT) is the standard time for all world days. Regular Geophysical Days (RGD) are each Wednesday. Regular World Days (RWD) are three consecutive days each month (always Tuesday, Wednesday and Thursday near the middle of the month). Priority Regular World Days (PRWD) are the RWD which fall on Wednesdays. Quarterly World Days (QWD) are one day each quarter and are the PRWD which fall in the World Geophysical Intervals (WGI). The WGI are fourteen consecutive days in each season, beginning on Monday of the selected month, and normally shift from year to year. In 2013 the WGI are February, May, August, and November. The 2013 FINAL Calendar is available in PDF format.

2013 Solar Eclipses:

The year 2013 has one annular and one hybrid eclipse.

a. 10 May 2013, annular solar eclipse, magnitude 0.954, maximum duration 06m03s, in Australia (Western Australia, Northern Territory, northern Queensland), Papua New Guinea's eastern tip, Solomon Islands, Pacific Ocean, Kiribati (5m44s of annularity); partial phases visible throughout Australia, in the northern island of New Zealand and the western half of its South Island, in most of Indonesia, southern Philippines, Papua New Guinea, in Fiji, Tuvalu, American Samoa, Cook Islands, French Polynesia, U.S. (Hawaii; 44% in Honolulu)

b. 3 November 2013, total solar eclipse with annularity at its beginning, magnitude 1.016, maximum duration 01m40s, eclipse visible in the Atlantic Ocean, with partial phases visible at sunrise throughout eastern North America (U.S. east of Ohio to Georgia; Canada from Quebec to the east); Bermuda, South America (southern Columbia, eastern Venezuela, Guyana, Suriname, northeastern Brazil), Europe (Spain, Portugal, Greece), all of Africa except Cape Town region; and at sunset in the middle-East (western Turkey, Syria, Iraq, Saudi Arabia, Israel, Yemen, Gulf States). (Totality: Atlantic Ocean through Gabon, Congo, Democratic Republic o the Congo, Uganda, Kenya); annularity: Ethiopia, ending at sunset in western Somalia)

Information from Jay M. Pasachoff, Williams College (Williamstown, Massachusetts), Chair, International Astronomical Union's Working Group on Eclipses, based on information and maps provided by Fred Espenak and Xavier Jubier.

Eclipse References:

- Fred Espenak, Fifty Year Canon of Solar Eclipses: 1986-2035, NASA Reference Publication 1178 Revised, July 1987.
- Leon Golub and Jay M. Pasachoff, The Solar Corona, Cambridge University Press, 1998.
- Jay M. Pasachoff and Alex Filippenko, The Cosmos: Astronomy in the New Millennium, Brooks/Cole Publishers, 2002, 2004 and 2006.
- Leon Golub and Jay M. Pasachoff,Nearest Star: The Exciting Science of Our Sun, Harvard University Press, 2001.
- Jay M. Pasachoff, The Complete Idiot's Guide to the Sun, Alpha Books, 2003.

2013 Meteor Showers

(Selected from data compiled by Alastair McBeath for the International Meteor Organization Shower Calendar.):

a. Meteor outbursts are unusual showers (often of short duration) from the crossing of relatively recent comet ejecta. Dates are for the year 2013: June 11, 08:28 UT, γ-Delphinids

b. Annual meteor showers liable to have geophysical effects: Dates (based on UT in year 2013) are:

- Dec 28-Jan 12, peak Jan 03 13h25m, Quadrantids (QUA)
- Apr 16-Apr 25, peak Apr 22 11h40m, Lyrids (LYR)
- Apr 19-May 28, peak May 06 01h15m, η-Aquariids (ETA)
- May 22-Jul 02, peak Jun 07 12h, Daytime Arietids (Ari)
- May 20-Jul 05, peak Jun 09 11h, Daytime ζ-Perseids (Zeta Per)
- Jun 05-Jul 17, peak Jun 28 10h, Daytime β-Taurids (Beta Tau)
- Jul 12-Aug 23, peak Jul 30, Southern δ-Aquariids (SDA)
- Jul 17-Aug 24, peak Aug 12 18h15m to 20h45m, Perseids (PER)
- Sep 09-Oct 09, peak Sep 27 11h, Daytime Sextantids (Sex)
- Oct 02-Nov 07, peak Oct 21, Orionids (ORI)
- Nov 06-Nov 30, peak Nov 17 15h55m, Leonids (LEO)
- Dec 07-Dec 17, peak Dec 13 13h15m - Dec 14 10h30m, Geminids (GEM)
- Dec 17-Dec 26, peak Dec 22 14h15m, Ursids (URS)

c. Annual meteor showers which may have geophysical effects: Dates (based on UT in year 2013) are:

- Apr 15-Apr 28, peak April 23 16h45m, η-Puppids(PPU)

- Jun 22-Jul 02, peak June 27 09h15m, June Bootids (JBO)
- Aug 28-Sep 05, peak Sep 1 01h35m, α-Aurigids (AUR)
- Sep 05-Sep 21, peak Sep 9 14h50m - 15h30m, September ε-Perseids(SPE)
- Oct 06-Oct 10, peak Oct 8 17h25m, Draconids (DRA)
- Nov 15-Nov 25, peak Nov 21 16h15m, α-Monocerotids (AMO)

Meteor Shower Websites:
- Shower activity near-real time reports -- International Meteor Organization
- Meteor shower activity forecast from your own location -- Meteor Shower Flux Estimator
- Shower names and data -- IAU Meteor Data Center
- Announcements and reports of meteor outbursts -- IAU Minor Planet Center
- Shower outburst activity forecast -- Institut de Mecanique celeste et de calcul des ephemerides

References:
Peter Jenniskens, Meteor showers and their parent comets. Cambridge University Press, 2006, 790 pp.

Real Time Space Weather and Earth Effects
The occurrence of unusual solar or geophysical conditions is announced or forecast by ISES through various types of geophysical "Alerts" (which are widely distributed via the internet on a current schedule). Stratospheric warmings (STRATWARM) were also designated for many years. The meteorological telecommunications network coordinated by the World Meteorological Organization (WMO) carries these worldwide Alerts once daily soon after 0400 UT. For definitions of Alerts see ISES URSIgram Codes. For many years Retrospective World Intervals were selected and announced by MONSEE (Monitoring of the Sun-Earth Environment) and elsewhere to provide additional analyzed data for particular events studied in the ICSU Scientific Committee on Solar-Terrestrial Physics (SCOSTEP) programs.

RECOMMENDED SCIENTIFIC PROGRAMS (FINAL EDITION)
(The following material was reviewed in 2012 by spokesmen of IAU, IAGA, WMO and URSI as suitable for coordinated geophysical programs in 2013.)

Airglow and Aurora Phenomena
Airglow and auroral observatories operate with their full capacity around the New Moon periods. However, for progress in understanding the mechanism of many phenomena, such as low latitude aurora, the coordinated use of all available techniques, optical and radio, from the ground and in space is required. Thus, for the airglow and aurora 7-day periods on the Calendar, ionosonde, incoherent scatter, special satellite or balloon observations, etc., are especially encouraged. Periods of approximately one weeks' duration centered on the New Moon are proposed for high resolution of ionospheric, auroral and magnetospheric observations at high latitudes during northern winter.

Atmospheric Electricity
Non-continuous measurements and data reduction for continuous measurements of atmospheric electric current density, field, conductivities, space charges, ion number densities, ionosphere potentials, condensation nuclei, etc.; both at ground as well as with radiosondes, aircraft, rockets; should be done with first priority on the RGD each Wednesday, beginning on 2 January 2013 at 0000 UT, 09 January at 0600 UT, 16 January at 1200 UT, 23 January at 1800 UT, etc. (beginning hour shifts six hours each week, but is always on Wednesday). Minimum program is at the same time on PRWD beginning with 16 January at 1200 UT. Data reduction for continuous measurements should be extended, if possible, to cover at least the full RGD including, in addition, at least 6 hours prior to indicated beginning time. Measurements prohibited by bad weather should be done 24 hours later. Results on sferics and ELF are wanted with first priority for the same hours, short-period measurements centered around minutes 35-50 of the hours indicated. Priority Weeks are the weeks that contain a PRWD; minimum priority weeks are the ones with a QWD. The World Data Centre for Atmospheric Electricity, 7 Karbysheva, St. Petersburg 194018, USSR, is the collection point for data and information on measurements.

Geomagnetic Phenomena
It has always been a leading principle for geomagnetic observatories that operations should be as continuous as possible and the great majority of stations undertake the same program without regard to the Calendar.

Stations equipped for making magnetic observations, but which cannot carry out such observations and reductions on a continuous schedule are encouraged to carry out such work at least on RWD (and during times of MAGSTORM Alert).

Ionospheric Phenomena
Special attention is continuing on particular events that cannot be forecast in advance with reasonable certainty. These will be identified by Retrospective World Intervals. The importance of obtaining full observational coverage is therefore stressed even if it is only possible to analyze the detailed data for the chosen events. In the case of vertical incidence sounding, the need to obtain quarter-hourly ionograms at as many stations as possible is particularly stressed and takes priority over recommendation (a) below when both are not practical.

For **the vertical incidence (VI) sounding program**, the summary recommendations are:

a) All stations should make soundings on the hour and every quarter hour;
b) On RWDs, ionogram soundings should be made at least every quarter hour and preferably every five minutes or more frequently, particularly at high latitudes;

c. All stations are encouraged to make f-plots on RWDs; f-plots should be made for high latitude stations, and for so-called "representative" stations at lower latitudes for all days (i.e., including RWDs and WGIs) (Continuous records of ionospheric parameters are acceptable in place of f-plots at temperate and low latitude stations);
d. Copies of all ionogram scaled parameters, in digital form if possible, be sent to WDCs;
e. Stations in the eclipse zone and its conjugate area should take continuous observations on solar eclipse days and special observations on adjacent days. See also recommendations under Airglow and Aurora Phenomena.

For the 2013 incoherent scatter observation program, every effort should be made to obtain measurements at least on the Incoherent Scatter Coordinated Observation Days, and intensive series should be attempted whenever possible in WGIs, on Dark Moon Geophysical Days (DMGD) or the Airglow and Aurora Periods. The need for collateral VI observations with not more than quarter-hourly spacing at least during all observation periods is stressed.

Special programs include:

- **Sudden Stratospheric Warming** (StratWarm): Dynamics, electrodynamics, temperature and electron density in the lower and upper thermosphere and ionosphere during a sudden stratospheric warming event.
  Key objectives are: to extend studies of stratospheric warming effects to the lower and upper thermosphere and investigate coupling with the ionosphere, to document variations in multiple thermospheric and ionospheric parameters in response to different stratospheric sudden warming events, to capture and document ionospheric response to stratospheric sudden warmings during the rising solar activity, to measure electric field, neutral wind, electron and ion temperatures and electron density in the ionosphere and lower and upper thermosphere before and during sudden stratospheric warming, to compare variations in ionospheric and thermospheric parameters observed during SSW to average wintertime behavior of ionosphere and thermosphere, to compare variations in temperatures and winds to mesospheric response as given by MF and meteor radars and lidars, to examine mechanisms responsible for variations in lower and upper thermospheric dynamics, temperatures, electric field, and ionospheric electron density and investigate to what degree they can be related to sudden stratospheric warming
  Background condition: The observations need to be made before and during the sudden stratospheric warming. A 10-day campaign is requested.
  Primary parameters to measure: LTCS mode - electron and ion temperatures from lowest possible altitudes throughout the F region, zonal and meridional components of the neutral wind in the lower thermosphere (95-140km), ExB drift, F-region meridional wind. Temporal resolution can be sacrificed and data integration period increased in order to obtain data at lower altitudes.
  Need for simultaneous data: The idea is to measure how variations in temperatures, electric field and winds associated with sudden stratospheric warming change with latitude and altitude and relate to variations in electron density.
  Principle investigator: Larisa P. Goncharenko, lpg@haystack.mit.edu, MIT Haystack Observatory, Westford, MA 01886, USA. Larisa is responsible for issuing the alert. She anticipates a few days' notice.
  Co-investigators: Jorge Chau (Jicamarca Radio Observatory, Peru), Hanli Liu (NCAR, USA), Peter Hoffmann (Institute for Atmospheric Physics, Germany).
- **E-region E field:** Latitudinal variation of the vertical electric field in the E region
  Key objectives: To measure the vertical and geomagnetic zonal ion drifts in the E and F regions, to study the height variation of the E-region electric field and its relationship to the F-region electric field
  Background Conditions: Ideally two days each during geomagnetically quiet and active periods.
  Primary Parameters to Measure: Vertical profiles of vertical ion drifts and geomagnetic zonal ion drift primarily during daytime. No beam swinging unless necessary to obtain the two components in the geomagnetic zonal plane. For single feed, swing in the geomagnetic zonal plane if possible.
  Secondary Parameters to Measure: Electron density, electron and ion temperatures.
  Principle Investigator: Qihou Zhou, zhouq@muohio.edu, Tel: +1-513-529-0743 Electrical and Computer Engineering Dept., Miami University, Oxford, OH 45056, USA. Qihou will coordinate the observations and discuss with each ISR site to ensure that optimal modes will be used.
- **Synoptic**: Experiments are intended to emphasize wide coverage of the F region, with some augmented coverage of the topside or E region to fill in areas of the data bases that have relatively little data
  Contacts: Jan Sojka, janjsojka@usu.edu; Mary McCready, mary.mccready@sri.com
- **AO** -- Arecibo Observatory
- **JRO** -- Jicamarca Radio Observatory.
- **Special programs**: Mary McCready, Center for Geospace Studies, SRI International, 333 Ravenswood Avenue, Menlo Park, CA 94025, USA; tel:+1-650-859-5084; Fax:+1-650-322-2318; email: mary.mccready@sri.com, chair of URSI ISWG Commission G. See the 2013 Incoherent Scatter Coordinated Observation Days (URSI-ISWG) webpage for complete 2013 definitions.
- For the **ionospheric drift** or wind measurement by the various radio techniques, observations are recommended to be concentrated on the weeks including RWDs.
- For **travelling ionosphere disturbances**, propose special periods for coordinated measurements of gravity waves induced by magnetospheric activity, probably on selected PRWDs and RWDs.
- For the **ionospheric absorption program** half-hourly observations are made at least on all RWDs and

half-hourly tabulations sent to WDCs. Observations should be continuous on solar eclipse days for stations in the eclipse zone and in its conjugate area. Special efforts should be made to obtain daily absorption measurements at temperate latitude stations during the period of Absorption Winter Anomaly, particularly on days of abnormally high or abnormally low absorption (approximately October-March, Northern Hemisphere; April-September, Southern Hemisphere).

- For **back-scatter and forward scatter programs**, observations should be made and analyzed at least on all RWDs.
- For **synoptic observations** of mesospheric (D region) electron densities, several groups have agreed on using the RGD for the hours around noon.
- For **ELF noise** measurements of earth-ionosphere cavity resonances any special effort should be concentrated during WGIs.

It is recommended that more intensive observations in all programs be considered on days of unusual meteor activity.

Meteorology

Particular efforts should be made to carry out an intensified program on the RGD -- each Wednesday, UT. A desirable goal would be the scheduling of meteorological rocketsondes, ozone sondes and radiometer sondes on these days, together with maximum-altitude rawinsonde ascents at both 0000 and 1200 UT.

During **WGI and STRATWARM** Alert Intervals, intensified programs are also desirable, preferably by the implementation of RGD-type programs (see above) on Mondays and Fridays, as well as on Wednesdays.

Global Atmosphere Watch (GAW)

The World Meteorological Organization (WMO) Global Atmosphere Watch (GAW) integrates many monitoring and research activities involving measurement of atmospheric composition, and serves as an early warning system to detect further changes in atmospheric concentrations of greenhouse gases, changes in the ozone layer and in the long range transport of pollutants, including acidity and toxicity of rain as well as of atmospheric burden of aerosols (dirt and dust particles). Contact WMO, 7 bis avenue de la Paix, P.O. Box 2300, CH-1211 Geneva 2, Switzerland or wmo@wmo.int.

Solar Phenomena

Observatories making specialized studies of solar phenomena, particularly using new or complex techniques, such that continuous observation or reporting is impractical, are requested to make special efforts to provide to WDCs data for solar eclipse days, RWDs and during PROTON/ FLARE ALERTS. The attention of those recording solar noise spectra, solar magnetic fields and doing specialized optical studies is particularly drawn to this recommendation.

Climate and Weather of the Sun-Earth System (CAWSES) II

Program within the SCOSTEP (Scientific Committee on Solar-Terrestrial Physics): 2009-2013. Aim is to significantly enhance our understanding of the space environment and its impacts on life and society. The main functions of CAWSES are to help coordinate international activities in observations, modeling, and applications crucial to achieving this understanding, to involve scientists in both developed and developing countries, and to provide educational opportunities for students of all levels. Contact is Prof. Marianna Shepherd (mshepher@yorku.ca), SCOSTEP Scientific Secretary. Co-chairs are Joseph M. Davila (GSFC/NASA, USA) and Toshitaka Tsuda (RISH/Kyoto University, Japan).

Program theme groups and theme group leaders are:

- Task1: What is the solar influence on climate? Annika Seppälä (Finland), Katja Mathes (Germany)
- Task2: How will geospace respond to a changing climate? Dan Marsh (USA), Jan Lastovička (Czech Republic)
- Task3: How does short-term solar variability affect the geospace environment?
  Joseph Borovsky (USA), Kazunary Shibata (Japan)
- Task 4: What is the geospace response to variable inputs from the lower atmosphere
  Jens Oberheide (USA), Kazuo Shiokawa (Japan)
- Capacity building
  Nat Gopalswamy, Franz-Josef Lübken, Marianna Shepherd
- Informatics and eScience
  Peter Fox, Barbara Thompson, Kozyra

See the CAWSES II website for more information.

ILWS (International Living With a Star) International effort to stimulate, strengthen, and coordinate space research to understand the governing processes of the connected Sun-Earth System as an integrated entity. Contact info@ilwsonline.org

ISWI (International Space Weather Initiative) a program of international cooperation to advance space weather science by a combination of instrument deployment, analysis and interpretation of space weather data from the deployed instruments in conjunction with space data, and communicate the results to the public and students. ISWI is a follow-up activity to the successful IHY 2007, but focusing exclusively on space weather. The goal of the ISWI is to develop the scientific insight necessary to understand the science, and to reconstruct and forecast near-Earth space weather. This includes instrumentation, data analysis, modeling, education, training, and public outreach. Contact J. Davila at Joseph.M.Davila@nasa.gov

Space Research, Interplanetary Phenomena, Cosmic Rays, Aeronomy.

Experimenters should take into account that observational efforts in other disciplines tend to be intensified on the days marked on the Calendar, and schedule balloon and rocket experiments accordingly if there are no other geophysical reasons for choice. In particular it is desirable to make rocket measurements of ionospheric characteristics on the same day at as many locations as possible; where feasible, experimenters should endeavor to launch rockets to monitor at least normal conditions on the Quarterly World Days (QWDs) or on RWDs, since these are also days when there will be maximum support from ground observations. Also, special efforts should be made to assure recording of telemetry on QWDs and Airglow and Aurora Periods of experiments on satellites and of experiments on spacecraft in orbit around the Sun.

Meteor showers

Of particular interest are both predicted and unexpected showers from the encounter with recent dust ejecta of comets (meteor outbursts). The period of activity, level of activity, and magnitude distributions need to be determined in order to provide ground truth for comet dust ejection and meteoroid stream dynamics models. Individual orbits of meteoroids can also provide insight into the ejection circumstances. If a new (1-2 hour duration) shower is observed due to the crossing of the 1-revolution dust trail of a (yet unknown) Earth threatening long-period comet, observers should pay particular attention to a correct determination of the radiant and time of peak activity in order to facilitate predictions of future encounters. Observations of meteor outbursts should be reported to the I.A.U. Minor Planet Center (mpc@cfa.harvard.edu) and International Meteor Organization (visual@imo.net). The activity curve, mean orbit, and particle size distribution of minor annual showers need to be characterised in order to understand their relationship to the dormant comets among near-Earth objects. Annual shower observations should be reported to national meteor organizations, or directly to the International Meteor Organization. Meteoroid orbits are collected by the IAU Meteor Data Center.

The International Space Environment Service (ISES) is a permanent scientific service of the International Union of Radio Science (URSI), with the participation of the International Astronomical Union and the International Union of Geodesy and Geophysics. ISES adheres to the Federation of Astronomical and Geophysical Data Analysis Services (FAGS), now a part of the new World Data System (WDS), of the International Council of Scientific Unions (ICSU). ISES coordinates the international aspects of the world days program and rapid data interchange.

This Calendar for 2013 has been drawn up by R. A. D. Fiori and H.E. Coffey, of the ISES Steering Committee, in association with spokesmen for the various scientific disciplines in SCOSTEP, IAGA and URSI and other ICSU organizations. Similar Calendars are issued annually beginning with the IGY, 1957-58, and are published in various widely available scientific publications. PDF versions of the past calendars are available online.

Published for the International Council of Scientific Unions and with financial assistance of UNESCO for many years.

Copies are available upon request to ISES Director, Dr. Terry Onsager, NOAA Space Weather Prediction Center, 325 Broadway, Boulder, CO, 80305, USA, telephone +1-303-497-5713, FAX +1-303-497-3645, e-mail Terry.Onsager@noaa.gov, or ISES Secretary for World Days, Dr. Robyn Fiori, Geomagnetic Laboratory, Natural Resources Canada, 2617 Anderson Road, Ottawa, Ontario, Canada, K1A 0E7, telephone +1-613-837-5137, FAX +1-613-824-9803, e-mail rfiori@NRCan.gc.ca. Beginning with the 2008 Calendar, all calendars are available only in digital form.

The website for the International Geophysical Calendar, including recent versions, can be found here.

CALL FOR PAPERS

ICEAA - IEEE APWC - EMS

September 9 - 13, 2013 Torino, Italy

http://www.iceaa.net

ICEAA 2013
International Conference on Electromagnetics in Advanced Applications

IEEE APWC 2013
IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications

The fifteenth edition of the *International Conference on Electromagnetics in Advanced Applications* (ICEAA 2013) is supported by the Politecnico di Torino, by the Istituto Superiore Mario Boella and by the Torino Wireless Foundation, with the principal technical cosponsorship of the IEEE Antennas and Propagation Society and the technical cosponsorship of the International Union of Radio Science (URSI). It is coupled to the third edition of the *IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications* (APWC 2013), and to the first edition of the *Electromagnetic Metrology Symposium* (EMS 2013) organized by Commission A of URSI in cooperation with ICEAA (see separate CFP). The three conferences consist of invited and contributed papers, and share a common organization, registration fee, submission site, workshops and short courses, banquet, and social events. The proceedings of the conferences will be published on IEEE Xplore.

Suggested Topics for ICEAA

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

Suggested Topics for APWC

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

Information for Authors

Authors must submit a full-page abstract electronically by March 1, 2013. Authors of accepted contributions must submit the full paper, executed copyright form and registration electronically by June 7, 2013. Instructions are found on the website. Each registered author may present no more than two papers. All papers must be presented by one of the authors. Please refer to the website for details.

Deadlines

Abstract submission	March 1, 2013
Notification of acceptance	April 12, 2013
Full paper and presenter registration	June 7, 2013

Inquiries

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Prof. Piergiorgio L. E. Uslenghi
Chair of Scientific Committee
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University of Illinois at Chicago
851 South Morgan Street
Chicago, Illinois 60607-7053, USA
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Electromagnetic Metrology Symposium

Organized by Commission A of the International Union of Radio Science

In coordination with the International Conference on Electromagnetics in Advanced Applications (ICEAA 2013) and the IEEE Topical Conference on Antennas and Propagation in Wireless Communications (IEEE APWC 2013)

September 9 – 13, 2013 **Torino, Italy**

This first Electromagnetic Metrology Symposium (EMS 2013) is organized by Commission A of the International Union of Radio Science (URSI) in coordination with the ICEAA and IEEE APWC Conferences. The three conferences will be held concurrently at the Torino Incontra Conference Center in Torino, Italy from Monday, September 9 through Friday, September 13, 2013. The three conferences share a common organization, registration fee, submission site, welcoming reception, coffee and lunch breaks, banquet, and social program. Detailed information is found on the conferences website: http://www.iceaa.net/ . EMS 2013 will consist of invited and contributed papers, workshops and short courses, and business sessions.

Suggested Topics for EMS

Metrology, measurements and standards in all areas of radio science, including:
Microwave to submillimeter measurements/standards
Quantum metrology and fundamental concepts
Time and frequency
EMC and EM pollution
Noise
Materials
Bioeffects and medical applications
Antennas
EM field metrology
Impulse radar
Planar structures and microstrip circuits
Interconnects and packaging

Information for Authors

Authors must submit a full-page abstract electronically by March 1, 2013. Authors of accepted contributions must register electronically by June 7, 2013. Instructions can be found on the website. Each registered author may present no more than two papers. All papers must be presented by one of the authors. Authors who want their paper to be published on IEEE Xplore should follow the instructions on the website. Selected authors of EMS will be invited to submit a full-length paper for possible publication in the URSI Radio Science Bulletin.

Deadlines	Abstract submission	March 1, 2013
	Notification of acceptance	April 12, 2013
	Presenter registration	June 7, 2013

EMS Contacts
Prof. William A. Davis, EMS Chair wadavis@vt.edu
Prof. Yasuhiro Koyama, EMS Vice-Chair koyama@nict.go.jp

Inquiries
Prof. Roberto D. Graglia, Chair of Organizing Committee roberto.graglia@polito.it
Prof. Piergiorgio L. E. Uslenghi, Chair of Scientific Committee uslenghi@uic.edu

AP-RASC' 13

2013 Asia-Pacific Radio Science Conference

Howard International House, Taipei, Taiwan, September 3-7, 2013

Call for Papers

Website: http://aprasc13.ntu.edu.tw

The "Asia-Pacific Radio Science Conference" (AP-RASC) is the Asia-Pacific regional URSI conference held between the URSI General Assemblies and Scientific Symposia. The objective of the AP-RASC is to review current research trends, present new discoveries, and make plans for future research and special projects in all areas of radio science, especially where international cooperation is desirable, and a particular emphasis is placed on promoting various research activities in the Asia-Pacific area.

Topics

- Electromagnetic Metrology
- Fields and Waves
- Radio Communication and Signal Processing Systems
- Electronics and Photonics
- Electromagnetic Environment and Interference
- Wave Propagation and Remote Sensing
- Ionospheric Radio and Propagation
- Waves in Plasmas
- Radio Astronomy
- Electromagnetics in Biology and Medicine

Young Scientist Programs

As in the URSI General Assemblies and Scientific Symposia, the following two programs are planned for young scientists:

- Student Paper Competition (SPC)
- Young Scientist Award (YSA)

Details on the Programs and the Application Guidelines are posted on the Conference website.

Special Issues

- AP-RASC'13 Special Issue will be published in "Radio Science".
- AP-RASC'13 Special Issue for Student Paper Competition will be published in "URSI Radio Science Bulletin".

Sponsored by

International Union of Radio Science (URSI)
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In Cooperation with

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Tel: +886-2-23628136 Ext. 49
Fax: +886-2-23632090

Important Dates

Submission Deadline of One-Page Abstracts:
Feb. 28, 2013
Acceptance Notification:
April 30, 2013

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CALL FOR PAPERS
URSI COMMISSION F TRIENNIAL
OPEN SYMPOSIUM
ON
RADIOWAVE PROPAGATION
& REMOTE SENSING
U.R.S.I.
Ottawa, Canada
April 30-May 3, 2013
(Ottawa Convention Centre)
Solicited and unsolicited papers will be presented in an equal number of sessions on Radiowave Propagation and on Remote Sensing, including:
Passive and Active Microwave Remote Sensing
Atmospheric, Ocean and Land Sensing
Propagation and Scattering in Random Media
Earth-Space Propagation
Fixed Link Terrestrial Propagation
Radio Propagation Pertinent to Personal, Indoor and Mobile, Communications, including Military Com. & Sensor Networks
Dynamic and Physical Modelling of Radio Links
Abstract/Manuscript Submission
Submission: Oct 1, 2012-March 1, 2013
One page abstracts can be submitted at www.URSI-F-TS.com
Acceptance:
Notification of acceptance within two weeks following abstract submission
Archiving:
Abstracts will be available for downloading 1 week prior to symposium
Five page manuscripts can optionally be submitted for refereeing and possible archiving with IEEE Xplore up until two weeks following the symposium
Events:
Plenary and expert presentations, poster sessions, a visit to a local laboratory, and many networking opportunities.
Joint Sessions with IEEE RadarCon 2013 are under discussion.
Contacts:
Radio_Propagation@ursi-f-ts.com
Remote_Sensing@ursi-f-ts.com
Check out some of Ottawa's attractions including the Canadian Tulip Festival at http://www.ottawatourism.ca/spring/

Journées scientifiques

L'électromagnétisme, 150-1[1]

Une science en pleine action !

Les 26 et 27 mars 2013,
Cnam, 292 rue Saint-Martin, Paris 3ème, France

Les Journées Scientifiques 2013 d'URSI-France, placées sous le haut patronage de l'Académie des sciences, auront pour thème « L'électromagnétisme, 150-1 : une science en pleine action ». Ces journées se tiendront au Conservatoire national des arts et métiers (Cnam) à Paris les 26 et 27 mars 2013. La date limite de soumission est le **25 janvier 2013**.

L'électromagnétisme, qui sera mis à l'honneur en 2014 pour les 150 ans de la publication du mémoire de James Clerk Maxwell, est une science en pleine vitalité dont la fécondité est attestée par la démonstration théorique et expérimentale récente de nouveaux concepts. S'appuyant sur l'outil mathématique autant que sur la puissance de l'ordinateur, la résolution des équations de Maxwell dans des milieux microscopiques ou macroscopiques souvent complexes offre des perspectives de développements scientifiques aussi bien qu'applicatifs très prometteurs pour le futur.

L'instrumentation, les télécommunications, l'observation spatiale, l'énergie voire la santé constituent quelques exemples parmi les domaines scientifiques ou économiques bénéficiant largement de ces avancées dans le domaine des radiosciences et de l'optique.

Dans ce contexte favorable, les journées scientifiques 2013 d'URSI-France feront le point et apporteront un éclairage sur quelques thèmes d'actualité en électromagnétisme, parmi lesquels :

- **Les rayonnements électromagnétiques et les interactions avec la matière ;**
- **La propagation des ondes électromagnétiques dans les milieux inhomogènes et les plasmas ;**
- **La montée en fréquence : des térahertz à l'optique ;**
- **La télédétection de la Terre et de l'univers en mode passif ;**
- **Les matériaux périodiques et pseudopériodiques et leurs applications en micro-ondes et en optique ;**
- **La modélisation électromagnétique de systèmes complexes ;**
- **L'impact de la propagation des ondes sur la ressource spectrale ;**
- **L'enseignement de l'électromagnétisme.**

[1] Le 27 octobre 1864, James Clerk Maxwell adressait à la Royal Society un mémoire de 54 pages intitulé « *A Dynamical Theory of the Electromagnetic Field* » à la fois dense et d'une grande clarté. Il présentera ce papier et ses équations devant la Royal Society 6 semaines plus tard, le 8 décembre.

The "Scientific Days" of URSI-France 2013, placed under the high patronage of the french Academy of sciences, will this year be organized around the theme: "Electromagnetism, 150-1: a science in full motion". These scientific days will be hosted by the "Conservatoire national des arts et métiers (Cnam)" in Paris on March 26-27, 2013. The submission deadline is on **January 25, 2013**.

Electromagnetism, which will be honoured in 2014 at the occasion of the publication of his famous book by James Clerk Maxwell, is a very lively science, whose fruitfulness is ascertained by the recent theoretical and experimental demonstration of new concepts. Based on the mathematical tool as well as on the power of today's computers, the resolution of Maxwell's equations in often complex microscopic or macroscopic media offers important perspectives of scientific and applied developments that are quite promising for the future.

Measuring instruments, telecommunications, space observation, energy, even health, do constitute some examples among the various scientific or economic areas broadly profiting by this progress in the field of radiosciences and of optics.

In this favorable context, the Scientific Days 2013 of URSI-France will update and provide a synthetic view on some topical subjects in electromagnetism, among which:

- **Electromagnetic radiations and their interactions with matter;**
- **Propagation of eectromagnetic waves in inhomogeneous media and plasmas;**
- **The frequency rise: from terahertz to optics;**
- **Teledetection of the Earth and the Universe in passive mode;**
- **Periodic and pseudoperiodic materials and applications in microwaves and optics;**
- **Electromagnetic modeling of complex systems and media;**
- **Impact of wave propagation phenomena on the spectral resource;**
- **Education of electromagnetism.**

[1] On October 27, 1864, James Clerk Maxwell sent to the Royal Society a 54 pages book entitled « *A Dynamical Theory of the Electromagnetic Field* », which was both very dense and of a great clarity. He presented this document and its equations in front of the Royal Society 6 weeks later, on December 8.

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Note: an alphabetical index of names with coordinates and page references is given on pages 61-76.

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