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Contents

Front cover: The new URSI Board of Officers and the two Assistants Secretary General (ASG) : from left to right : C.M. Butler, F. Lefeuvre, W.R. Stone (ASG), H. Matsumoto, A.W. Wernik, P.H. Wittke, K. Schlegel (President), P. Lagasse, F. Olyslager (ASG). This picture was taken after the new Board meeting at the end of the XXVIIth General Assembly in Maastricht, The Netherlands.

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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

An Excellent General Assembly

The URSI XXVIIth General Assembly in Maastricht was an outstanding meeting. I hope you were able to attend. There was wide-spread agreement that the quality of the technical sessions was unusually high, and the hospitality of our Netherlands hosts was excellent. Special thanks go to the Organizing Committee, led by Frans Sluijter, Gert Brussaard (the Associate Scientific Program Coordinator), and Leon Kamp. A special salute must also go to Martin Hall, the Scientific Program Coordinator, whose efforts were outstanding.

This issue is being put together immediately after the General Assembly, on a very tight schedule. A General Assembly is really two equally important meetings, held simultaneously: the technical meeting, and the many business and committee meetings in which the business of our Union is carried out. That means that a tremendous amount of both technical and administrative work is done in a very short time at a General Assembly. Some information about what happened at the General Assembly is included in this issue; more will follow in the next issue. The Council voted to accept the proposal of India to hold the XXVIIIth General Assembly in New Delhi in October of 2005: this should be a new and exciting venue.

What's in this Issue

The technical papers in this issue have a common theme: propagation effects in wireless and mobile communications. Increasing the capacity of cellular communications is critical for economic and quality-of-service reasons, and it is certainly a primary goal of most current wireless communications research. One of the most promising ways to do this is to take advantage of the propagation channel, using so-called smart antennas. These antennas take advantage of the fact that signals often take multiple and different routes from the transmitter to the receiver. Andreas Molisch provides a tutorial on this subject in his paper, "Modeling of Directional Wireless Propagation Channels." This was the Commission C Tutorial Lecture, presented at the Maastricht General Assembly. It provides a very fine introduction to the subject, and highlights the directions of current research and development in this important field.

Yoshio Karasawa's paper, on "Multipath Propagation Theory and Modeling in Wideband Mobile Radio...," addresses a more-specific aspect of the same general topic. He considers one particular type of propagation environment: the frequency-selective Nakagami-Rice fading environment. This is a very common environment for wideband mobile communication systems. A limiting factor for communications in such an environment is usually the inter-symbol interference: the interference of one digital symbol used to transmit information with adjacent (or nearby) symbols. He presents a tutorial on a method – the Equivalent Transmission-Path Model – for computing the limiting bit-error rate due to such interference in this type of propagation environment. In addition to presenting a very useful tool for analyzing the effect of such interference, the paper provides a readily understandable introduction to the science underlying such calculations. This paper was presented at the Asia-Pacific Radio Science Conference (AP-RASC'01), and was invited because it was identified by the program committee of that meeting as one of the meeting's outstanding papers.

Jim Lin's "Radio-Frequency Radiation Safety and Health" column is also related to the theme of wireless communication. It considers the health and safety aspects of wireless communication base stations. This is a topic that has been receiving more and more publicity in recent months. With base stations becoming ubiquitous in urban areas, it is a topic of broad interest and importance.

This issue of the *Bulletin* also contains the reports from the URSI Commissions. Read these: most of the scientific work of URSI is done through its Commissions. There is news from the Poland Member Committee. The resolutions passed at the Maastricht General Assembly are also in this issue, and some of these involve changes that I think are exciting news for the future of URSI. The newly elected officers of URSI are also announced in this issue. Congratulations to Kristian Schlegel, our new President; to Chalmers Butler and François Lefeuvre, our new Vice Presidents; to Andy Wernik and Paul Wittke, our second-term Vice Presidents; and to Paul Lagasse, our Secretary General, on their elections. Congratulations go, too, to A.P. Mitra, on his election as Honorary President. I also want to express my personal, very special thanks to Hiroshi Matsumoto, now our Past President, for his excellent leadership, and particularly for the help he has given to me and to URSI publications.

Changes to URSI Publications

At the Maastricht General Assembly, the Council approved recommendations of the Standing Publications Committee that will lead to a number of important changes in URSI publications. Perhaps most exciting, the reviews previously published in a separate book, the *Review of Radio Science*, will now be published in the *Radio Science Bulletin*. This will be done over a three-year period. The goal is to have the first of the reviews appear in the December, 2003, issue of the *Bulletin*. The last of the current triennium's reviews will then appear in 2006, the year following the next General Assembly, at which point the cycle will repeat. Commission editors will be appointed as in the past (and those that have already been appointed are listed under Associate Editors in the front of this issue). They will coordinate the identification of the review topics by the Commissions, the inviting of authors for the reviews, and peer-reviewing of the reviews, all as previously done for the *Review*. They will also be responsible for soliciting additional technical papers within the areas of their Commissions for the *Bulletin*. This is part of the on-going effort to bring you a *Bulletin* that has significant, high-quality, interesting, useful, timely technical content. Publishing the reviews in the *Bulletin* will also substantially widen the distribution of the reviews, and should allow them to be more timely. It eliminates the problem of trying to bring the approximately 40 works of about 100 authors together at the same time on a very tight schedule, in order to have a book available for the General Assembly. This had become an ever-increasing challenge in producing the book version of the *Review*.

Since the *Bulletin* has been indexed by INSPEC since 1995, this will also provide indexing to the reviews, as it does for all of the technical papers in the *Bulletin*.

The Council also approved making the *Radio Science Bulletin* available – without charge –on the Web. This will take some time to implement, but we will certainly let you know when it is available. The paper version of the *Bulletin* will still be available (don't worry: I prefer to read it in paper, myself!). However, making the paper version optional for those who prefer Web-based delivery will hopefully reduce the number of copies that are needlessly mailed. We will also provide a Web-based archive of back issues of the *Bulletin* (from the time it becomes available on the Web). The plan includes distributing the previous triennium's issues on CD-ROM at each General Assembly.

Opportunities

If you were at the Maastricht General Assembly, you received a copy of the *Review of Radio Science, 1999-2002*, on a fully-text-searchable CD-ROM, as part of your registration. If you weren't there, and/or if you would like a printed copy of the 977-page book including the CD-ROM, you can now order a copy through IEEE Press/John Wiley (ISBN: 0-471-26866-6): visit the Web site at http://www.wiley.com/cda/product/0,,0471268666,00.html. The list price is US$125.00, and a 15% discount is available for those using Promotion Code #18493 and an IEEE member number when ordering. The book contains 38 peer-reviewed reviews on topics (and by authors) chosen by the URSI Commissions as the most significant for the current triennium.

The *Bulletin* is still looking for interesting papers on topics of broad interest to URSI. If you have something you would like to share, please send it to me. If you heard an appropriate paper at the General Assembly, please either encourage the author to submit it to the *Bulletin*, or let me know about it.

Addendum

Brian Robinson, author of "Recollections of the URSI Tenth General Assembly, Sydney, Australia, 1952" (*The Radio Science Bulletin*, **300**, March, 2002, pp. 22-30) has received some additional information. Yela Stevanovich pointed out that the person on the left in Figure 10 (identified as "another delegate") is "...Mr. Jean Voge, who was President of URSI from 1975-78. Before he had been Chairman of the Commission on radio propagation in the troposphere." Jaap Baars pointed out that the 1966 URSI General Assembly was held in Munich, not Grenoble. He and the author thus determined that it was during the IAU meeting in Grenoble in 1976 that Brian Robinson became a member of IUCAF.

Multipath Propagation Theory and Modeling in Wideband Mobile Radio: The "ETP Model", Connecting 'Propagation" and "Systems"

Y. Karasawa

Abstract

A very simple, general scheme for calculating the irreducible bit-error rate (BER) – namely, the BER floor – due to inter-symbol interference (ISI) in frequency-selective Nakagami-Rice fading environments has been developed. The scheme, which we call the Equivalent Transmission-Path (ETP) model, makes a general connection between "wave propagation" and "digital transmission characteristics." In this paper we present a consistent calculation formula for the BER due to ISI, by re-examining the information in our previous papers on the ETP model. Moreover, we demonstrate an application of the ETP model to the indoor propagation environment.

1. Introduction

Modeling of Nakagami-Rice fading, or so-called Ricean fading, is expected to play an important role in the design of wideband and high-capacity mobile systems. Examples include indoor wireless communication systems, short-range wireless access systems, and mobile satellite systems (MSS), which can enrich personal communications. The model of Nakagami-Rice fading, which appears in line-of-sight radio communications environments, is more general than that of Rayleigh fading. In fact, Rayleigh fading is a special case of Nakagami-Rice fading. The propagation environments are shown in Figure 1.

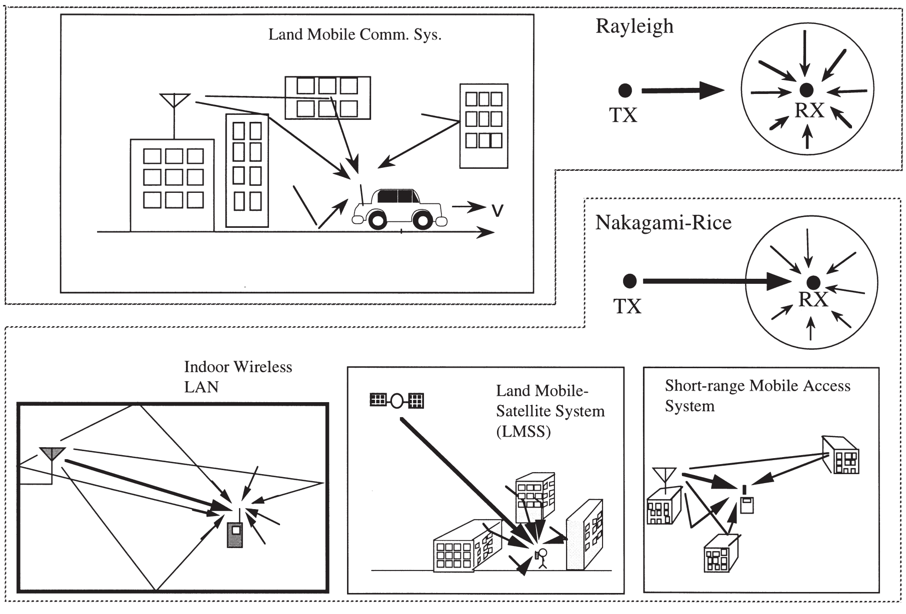

Figure 1. Multipath fading environments (Rayleigh fading and Nakagami-Rice fading).

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[Editor's note: This paper is invited.]

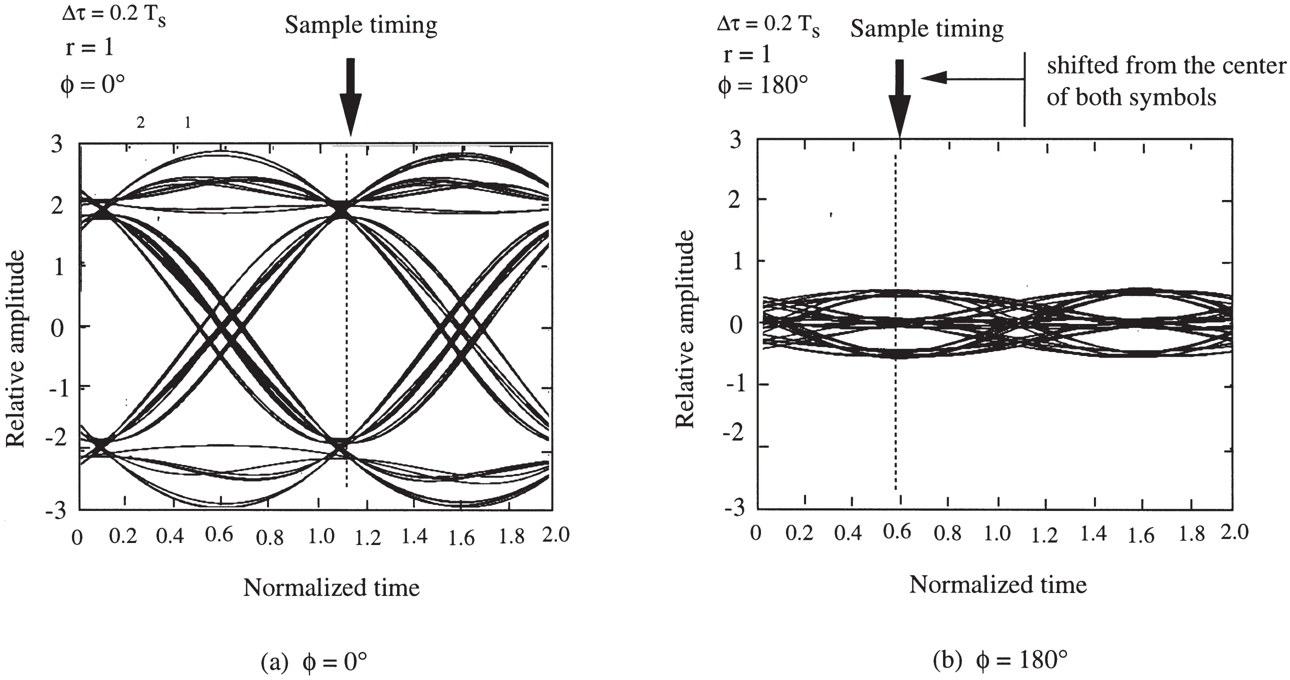


Figure 2. The eye patterns of the received signal for $r=1$ and $\Delta\tau = 0.2T_s$: (a) $\phi = 0°$; (b) $\phi = 180°$.

Based on a series of numerical analyses using computer simulations and theoretical considerations, we have proposed a simplified propagation model for assessing wideband digital transmission characteristics in frequency-selective Nakagami-Rice fading environments [1-4]. We have called this the Equivalent Transmission-Path (ETP) model. Moreover, we have used this model to derive a straightforward calculation formula for error-occurrence characteristics due to inter-symbol interference (ISI) in frequency-selective Nakagami-Rice fading environments.

In this tutorial paper, a consistent calculation formula for predicting the BER due to ISI is presented, by reconfiguring our papers published so far on the ETP model from a practical viewpoint. In addition, an application of this model to indoor propagation is demonstrated.

2. Occurrence of Bit Errors due to ISI

Before introducing the ETP model, let us review the occurrence of bit errors due to inter-symbol interference (ISI), under the frequency-selective fading condition [5]. The following time-invariant two-wave condition, which is the simplest case producing frequency-selective fading, is considered first.

$$h(\tau) = a_1\delta(\tau) + a_2(\tau - \Delta\tau) \quad (1a)$$

$$= a_1\left[\delta(\tau) + re^{j\phi}\delta(\tau - \Delta\tau)\right], \quad (1b)$$

where h is the impulse response, τ is the delay, a_i ($i = 1, 2$) is the complex envelope of the ith wave, δ is the delta function, and $\Delta\tau$ is the delay difference between the preceding wave and the delayed wave. In Equation (1b), r is the amplitude ratio, defined as $|a_2/a_1|$, and ϕ is the phase difference between the two waves. Throughout this paper, our main concern is for $\Delta\tau$ within the range of the symbol-duration time, T_s, namely, $\Delta\tau < T_s$. When dealing with errors due to ISI, the parameters r and ϕ are more essential than a_1 and a_2, because irreducible errors due to ISI become independent of the amplitude of each wave.

Figure 2 shows the eye pattern of the received signal for $r = 1$ and $\Delta\tau = 0.2T_s$, for $\phi = 0°$ and $\phi = 180°$. We can easily understand that only the case of Figure 2b causes errors due to ISI. This means that the error-occurrence condition depends not only on $\Delta\tau$, but also on r and ϕ. This raises the question, "What is the condition where the error occurs?" The answer is given in Figure 3. This figure shows that the error-occurrence area for CQPSK (quadrature phase shift keying with coherent detection) is a function of r and ϕ while $\Delta\tau = 0.2T_s$. Different patterns can be seen for each modulation/demodulation scheme. We call this figure a BER map.

3. Basic Expression for Multipath Environments

It is assumed that the time-variation speed of the channel is sufficiently slower than the data-transmission speed. In other words, the multipath-fading environment remains constant during the data-symbol period. Under this condition, an instantaneous multipath environment at a given position and at a given time, t, can be expressed in terms of the slowly time-varying impulse response [6, 7]. This is given by

$$h(\tau, t) = \sum_{i=0}^{\infty} a_i(t)\delta\left[\tau - \tau_i(t)\right] \quad (2)$$

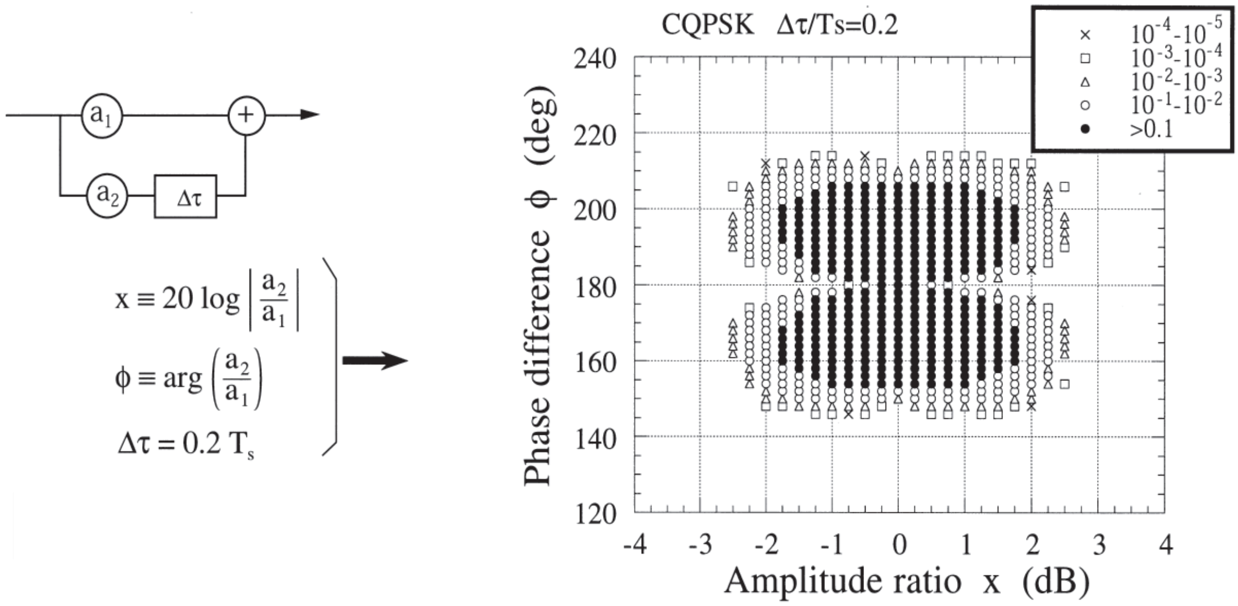


Figure 3. The error-occurrence area for $\Delta\tau = 0.2T_s$ in CQPSK (hereafter, we call this a BER map).

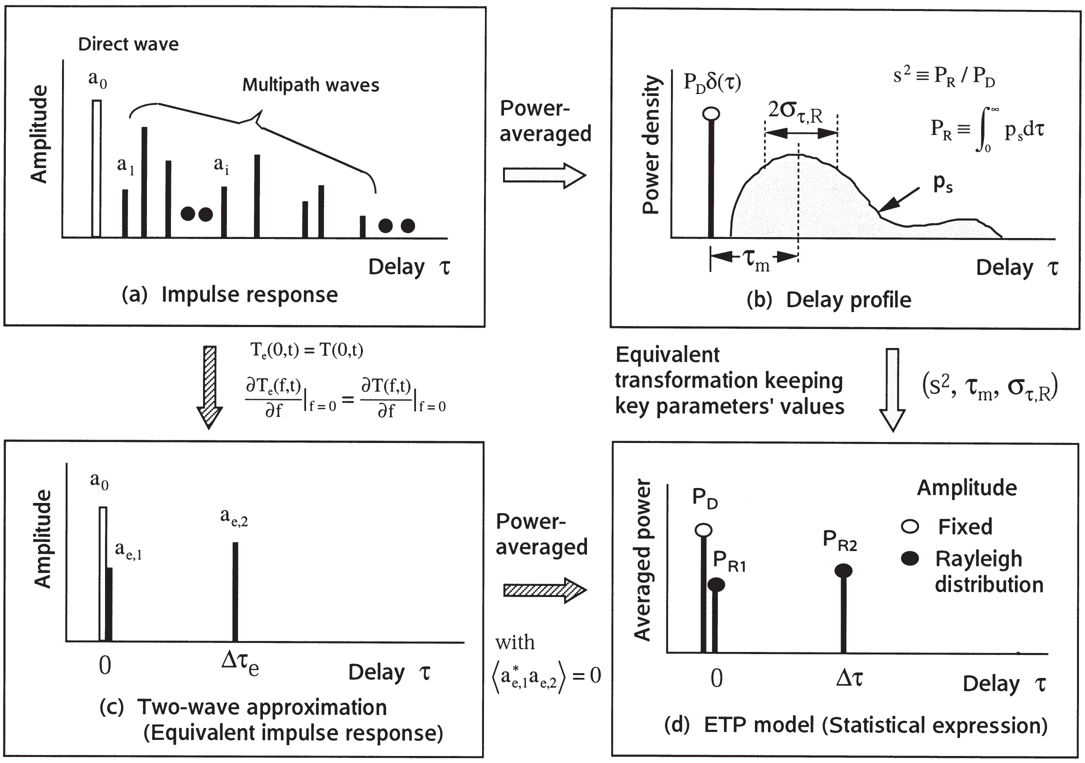


Figure 4. Various expressions of the Nakagami-Rice fading environment (instantaneous versus statistical).

where a_i is the complex amplitude of the ith incident wave in the multipath waves. For modeling, we assign the direct wave path to be $i = 0$ with $\tau_0 = 0$. The impulse response is shown in Figure 4a. For the case of Rayleigh fading, a_0 must be 0 when modeling.

The transfer function, which is another expression of the instantaneous fading condition, is obtained by Fourier transform of the impulse response. It is given by

$$T(f,t) = \int_0^{\infty} h(\tau,t)\exp(-j2\pi f\tau)\,d\tau \tag{3}$$

$$= \sum_{i=0}^{\infty} a_i(t)\exp\left[-j2\pi f\tau_i(t)\right]$$

In the mobile radio-propagation environment, it seems acceptable to assume that the propagation mechanism follows the nature of a WSSUS (wide-sense stationary, uncorrelated scattering) channel [6], excluding the direct-wave path. The power-delay profile, which is a statistical expression of the multipath environment in the time-delay domain, is given by

$$p(\tau) = \left\langle h^*(\tau,t)h(\tau,t)\right\rangle \tag{4}$$

$$= P_D\delta(\tau-\tau_0) + p_s(\tau)$$

where $\langle g\rangle$ means the ensemble average (or the time-domain average, if the process is ergodic), P_D is the direct wave power, and p_s is the averaged power density of multipath waves. The delay profile given in Equation (4) is an idealized profile, from the viewpoint of propagation modeling, while a measurable profile is a continuous function, due to the averaging effect of a receiver filter. The total multipath power is given by

$$P_R = \int_0^{\infty} p_s(\tau)\,d\tau \cdot \tag{5}$$

Figure 4b shows a delay profile for Nakagami-Rice fading. In this figure, the following three key parameters (which will be explained in a later section) are given:

1. s^2: The ratio of the mean multipath power (P_R) to the direct wave power (P_D) [$= P_R/P_D$].
2. τ_m: The mean delay of multipath waves relative to the delay of the direct wave.
3. $\sigma_{\tau,R}$: The delay spread of multipath waves (excluding the direct wave)

τ_m and $\sigma_{\tau,R}$ are given respectively by

$$\tau_m = \frac{1}{P_R}\int_0^{\infty} \tau p_s(\tau)\,d\tau \tag{6}$$

$$\sigma_{\tau,R} = \sqrt{\frac{1}{P_R}\int_0^{\infty} (\tau-\tau_m)^2\, p_s(\tau)\,d\tau} \tag{7}$$

The overall delay spread, including the direct wave, can be calculated using the above three parameters [1]. This is given by

$$\sigma_\tau = \sqrt{\left\langle \tau^2\right\rangle - \left\langle \tau\right\rangle^2}$$

$$= \sqrt{\frac{s^2}{1+s^2}\left(\tau_m^2+\sigma_{\tau,R}^2\right) - \left(\frac{s^2}{1+s^2}\tau_m\right)^2}$$

$$= \sqrt{\frac{s^2}{1+s^2}\left(\frac{\tau_m^2}{1+s^2}+\sigma_{\tau,R}^2\right)} \tag{8}$$

In order to show an example, let us analyze the wideband digital transmission characteristics in indoor environments for a wireless LAN. Figure 5a shows the multipath profile of a rectangular-type indoor environment, where the transmitter (TX) point and the receiver (RX) point are, respectively, set at (x, y, z) coordinates of (2, 8, 2) and (13, 2, 1), in a room of (15, 10, 3) meters. The three-dimensional path profile was obtained by a ray-tracing scheme based on the image method [8-12]. Figure 5b shows the impulse response with a reflection coefficient, γ, of 0.7 (a probable value for plasterboard with attached rock wool, in the case of an oblique angle of incidence [13]) for every wall. Figures 6a-6c show examples of the spatial distribution of error occurrence for CQPSK with data-transmission bit rates of 2, 5, and 10 Mbps, at a frequency of 5 GHz [12]. In the figure, points where the BER exceeds 10^{-1} are marked by large dots, and points where the BER exceeds 10^{-3} are marked by smaller dots. The data shown in Figures 6a-6c were obtained by computer simulation, based on ray tracing and CQPSK data transmission. The data shown in Figures 6d-6f will be mentioned in a later section.

4. Equivalent Transformation of Impulse Response

To maintain the characteristics of frequency selectivity, at least two waves are necessary, as shown in Figure 4c. The impulse response and frequency transfer function of the two-wave model are given, respectively, by

$$h_c(\tau,t) = \left[a_0 + a_{c,1}(t)\right]\delta(\tau) + a_{c,2}(t)\delta(\tau-\Delta\tau_c) \tag{9}$$

$$T_c(f,t) = a_0 + a_{c,1}(t) + a_{c,2}(t)\exp(-j2\pi f\Delta\tau_c) \tag{10}$$

In order to keep the equivalence for assessing digital-transmission characteristics, we can connect the two transfer functions by the following conditions [2]:

$$T_e(0,t) = T(0,t) \quad (11)$$

$$\left.\frac{\partial T_e(f,t)}{\partial f}\right|_{f=0} = \left.\frac{\partial T(f,t)}{\partial f}\right|_{f=0} \quad (12)$$

By the above equations, the path amplitude and its frequency dependence at $f = 0$ (namely, at the carrier frequency for the RF signal) are set to be equal to each other. These conditions lead to

$$a_{e,1}(t) = \sum_{i=1}^{\infty} a_i(t) - \frac{\sum_{i=1}^{\infty} a_i(t)\tau_i(t)}{\Delta\tau_e} \quad (13)$$

$$a_{e,2}(t) = \frac{\sum_{i=1}^{\infty} a_i(t)\tau_i(t)}{\Delta\tau_e} \quad (14)$$

No strict condition is imposed to determine the value of $\Delta\tau_e$, if the following condition is satisfied. From our examination by computer simulations [1, 12], and as will be seen in Figure 8, the condition for the application of this method is as follows:

$$\tau_m \le 0.3T_s \text{ and } \sigma_{\tau,R} \le 0.3T_s \quad (15)$$

For the ray-tracing case, the mean delay, τ_m, and the delay spread of multipath waves, $\sigma_{\tau,R}$, can be roughly estimated by

$$\tau_m \approx \frac{\sum_{i=1}^{\infty} \tau_i |a_i|^2}{\sum_{i=1}^{\infty} |a_i|^2} \quad (16)$$

$$\sigma_{\tau,R} \approx \sqrt{\frac{\sum_{i=1}^{\infty} (\tau_i - \tau_m)^2 |a_i|^2}{\sum_{i=1}^{\infty} |a_i|^2}} \quad (17)$$

Under this condition, the BER, P_e, can be estimated from the BER map of $\Delta\tau_{map}$, E, by

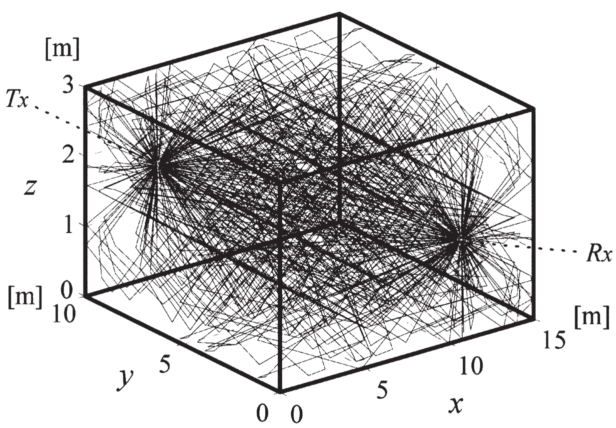
$$P_e = E(r, \phi; \Delta\tau_e), \quad (18)$$

where

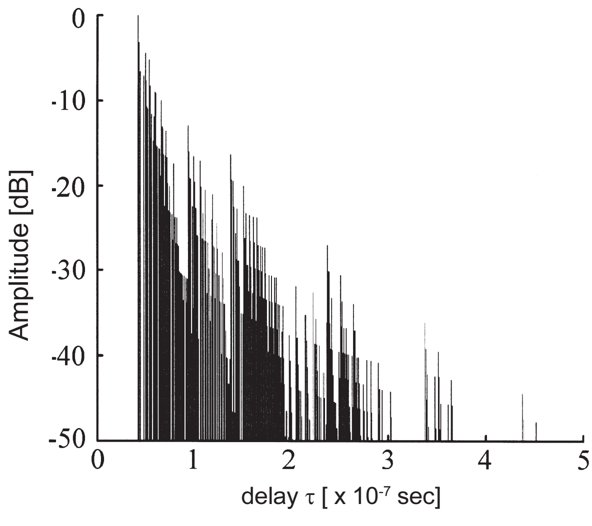
$$r = \left| a_{e,2} / (a_0 + a_{e,1}) \right|, \phi = \arg\left[a_{e,2} / (a_0 + a_{e,1}) \right] \quad (19)$$

$$\Delta\tau_e = \Delta\tau_{map}. \quad (20)$$

Although any kind of BER map, ranging from $\Delta\tau_{map} = 0.1T_s$ to $0.6T_s$, gives almost the same estimate of BER due to ISI, the use of $\Delta\tau_{map} = 0.2T_s$ (which is shown in Figure 3) is suggested [12].



(a) Ray-tracing profile



(b) Impulse response

Figure 5. The indoor propagation environment: (a) A ray-tracing profile; (b) The impulse response.

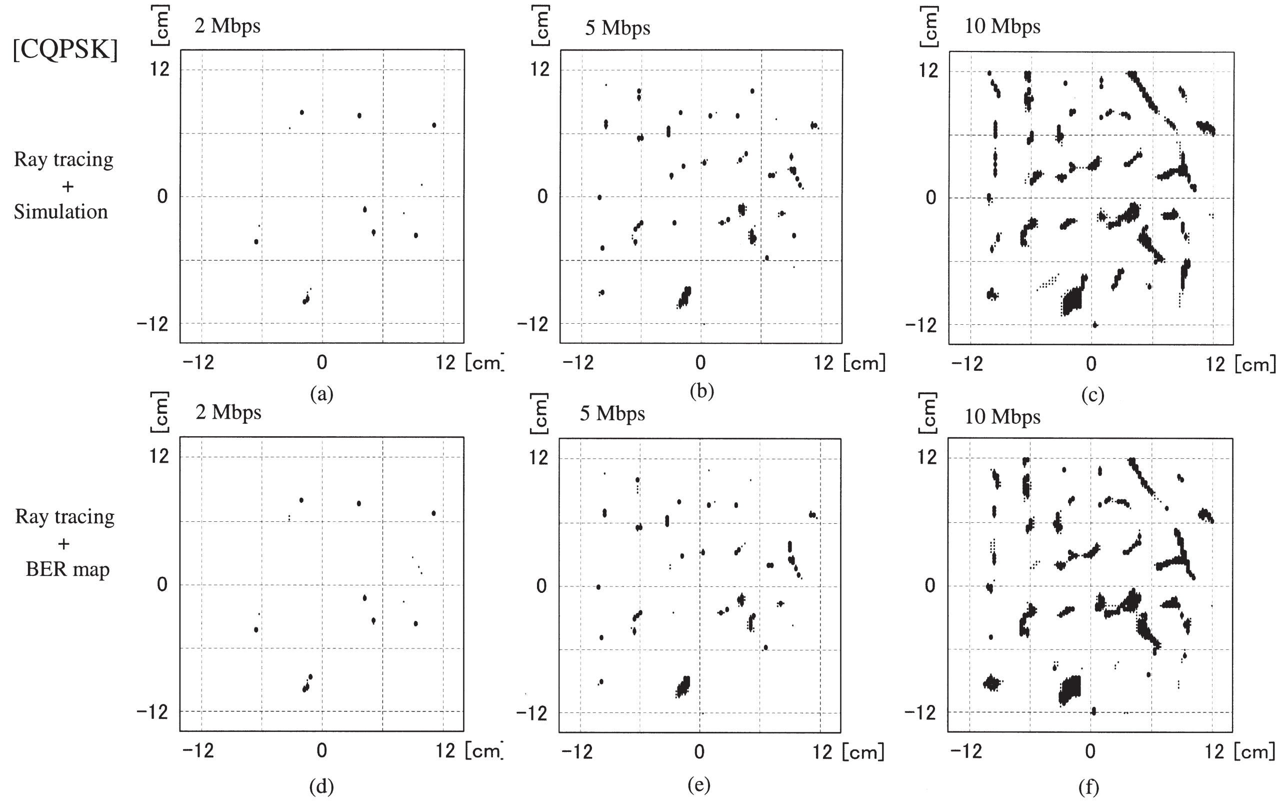


Figure 6. A spatial map of error occurrence for CQPSK with data rates of 2, 5, and 10 Mbps. The upper maps are for the Ray tracing + digital transmission simulation method, while the lower maps are for the Ray tracing + BER method. Points where the BER exceeds 10^{-1} are marked by large dots, and points where the BER exceeds 10^{-3} are marked by smaller dots.

Figures 6d-6f show the spatial distribution of error occurrence for CQPSK, calculated using the above method, namely, (1) obtaining the impulse response by means of ray tracing (see Figure 5); and (2) calculating the BER from Equations (18) and (19), with a BER map, E. We call this method "Ray tracing + BER map." Figures 6d-6f, respectively, correspond to the cases of Figures 6a-6c, calculated based on (1) ray tracing, and (2) rigorous digital-transmission simulation in the multipath environment determined by the ray tracing. We call this method "Ray tracing + Simulation." The averaged BER and the location percentage of error occurrence – namely, the error-occurrence rate (EOR) in the four-wavelength-square area (24 cm × 24 cm) for CQPSK – are compared in Figure 7 (the black dots and the white dots). As seen in Figures 6 and 7, the results of our proposed scheme agree extremely well with the computer simulation. The

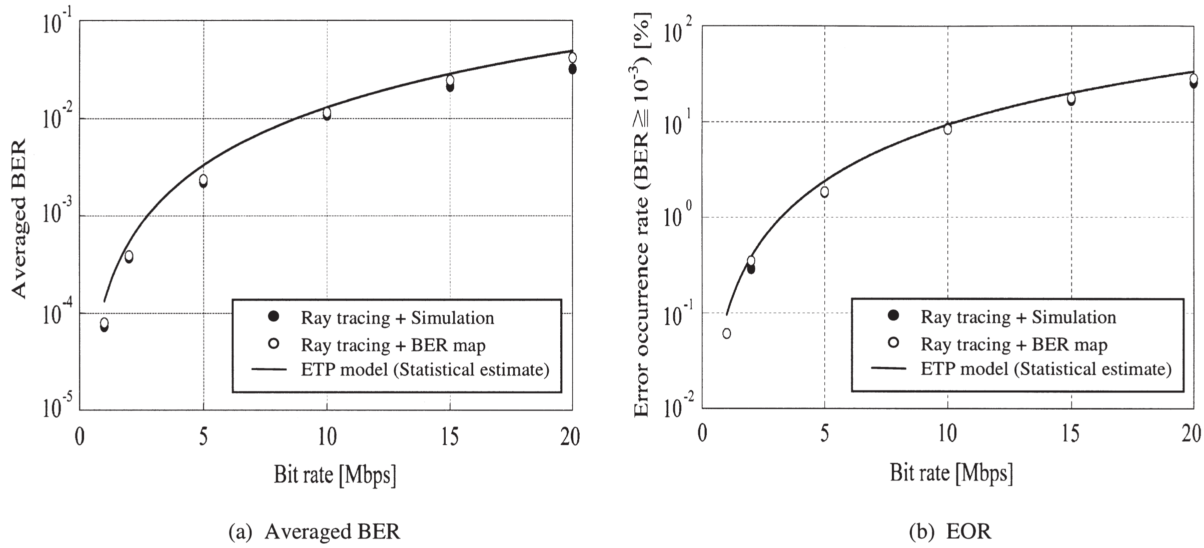


Figure 7. A comparison of the averaged BER (a) and the EOR (b) for three methods. Results given by the ETP model (a statistical simulation), discussed later in the text, are also shown.

computational time to draw one map, shown in Figures 6a, 6b, or 6c, was more than five hours on a personal computer, excluding the common part of the ray tracing, while the proposed method took only three minutes. The calculation speed of the proposed method is 100 times faster. In Figure 7, a statistical estimate using the ETP model is shown by solid curves. This will be discussed later.

5. Equivalent Transformation of Delay Profile: ETP Model

Next, we will develop a statistical two-wave model for the prediction of the statistical properties of digital-transmission characteristics, namely, the averaged BER under a time-varying multipath fading condition. As stated above, for the approximation of an impulse response, the value of $\Delta\tau_e$ can be set to $\Delta\tau_e = \Delta\tau_{map}$. For statistical modeling in terms of a delay profile, on the other hand, it seems better to select the value of $\Delta\tau_e$ to be where the fluctuations between $a_{e,1}$ and $a_{e,2}$ become independent. By adopting this condition, the modeling is drastically easier. Here, let us determine the value of $\Delta\tau_e$. Using Equations (13) and (14), the correlation coefficient is given by [2]

$$\rho_a = \left\langle a_{c,1}^* a_{c,2} \right\rangle \Big/ \sqrt{\left\langle a_{c,1}^* a_{c,1} \right\rangle \left\langle a_{c,2}^* a_{c,2} \right\rangle}$$

.

$$= \frac{\tau_m \Delta\tau_c - \tau_m^2 - \sigma_{\tau,R}^2}{\sqrt{\left(\Delta\tau_c^2 - 2\tau_m \Delta\tau_c + \tau_m^2 + \sigma_{\tau,R}^2\right)\left(\tau_m^2 + \sigma_{\tau,R}^2\right)}} \qquad (21)$$

Independence of $a_{e,1}$ and $a_{e,2}$ requires the correlation coefficient to be zero; therefore, in Equation (21), we must impose the following relation:

$$\Delta\tau_e\Big|_{\rho_a=0} \equiv \Delta\tau = \left(\tau_m^2 + \sigma_{\tau,R}^2\right)\Big/\tau_m \qquad (22)$$

where $\Delta\tau$ is the value of $\Delta\tau_e$ corresponding to $\rho_a = 0$. In this condition, the mean powers of $a_{e,1}$ and $a_{e,2}$, are respectively given by [2]

$$P_{R1} = \left\langle a_{e,1}^* a_{e,1} \right\rangle\Big|_{\rho_a=0} = \frac{s^2 \sigma_{\tau,R}^2}{\tau_m^2 + \sigma_{\tau,R}^2} P_D \qquad (23)$$

$$P_{R2} = \left\langle a_{e,2}^* a_{e,2} \right\rangle\Big|_{\rho_a=0} = \frac{s^2 \tau_m^2}{\tau_m^2 + \sigma_{\tau,R}^2} P_D \qquad (24)$$

The statistical two-wave environment determined by Equations (22)-(24) can also be designated by the fading parameters corresponding to s^2, τ_m, and $\sigma_{\tau,R}$. If we let the parameters be s_e^2, $\tau_{m,e}$, and $\sigma_{\tau,R,e}$, then they are given by

$$s_e^2 = \frac{P_{R1} + P_{R2}}{P_D} = s^2 \qquad (25)$$

$$\tau_{m,e} = \frac{P_{R2}\Delta\tau}{P_{R1} + P_{R2}} = \tau_m \qquad (26)$$

$$\sigma_{\tau,R,e} = \frac{\sqrt{P_{R1}P_{R2}}}{P_{R1} + P_{R2}} \Delta\tau = \sigma_{\tau,R} \qquad (27)$$

In Figure 4d, the statistical two-wave model is characterized by the equivalent transformation of the delay profile, maintaining the values of the three fading parameters: s^2, τ_m, and $\sigma_{\tau,R}$. We call these three fading parameters "the key parameters," and the statistical two-wave model is "the equivalent transmission-path (ETP) model."

The relationship of model expressions for the Nakagami-Rice fading environment, in terms of "instantaneous versus statistical" and "multipath versus two-wave approximated," is summarized in Figure 4.

In the statistical two-wave model, which is the ETP model, the preceding wave consists of a constant-wave (namely, the direct wave) component and a Rayleigh-wave component, while the delayed wave is a Rayleigh-wave component. Consequently, the probability density function (PDF) of the amplitude of the preceding wave follows a Nakagami-Rice distribution, and the PDF of the delayed wave follows a

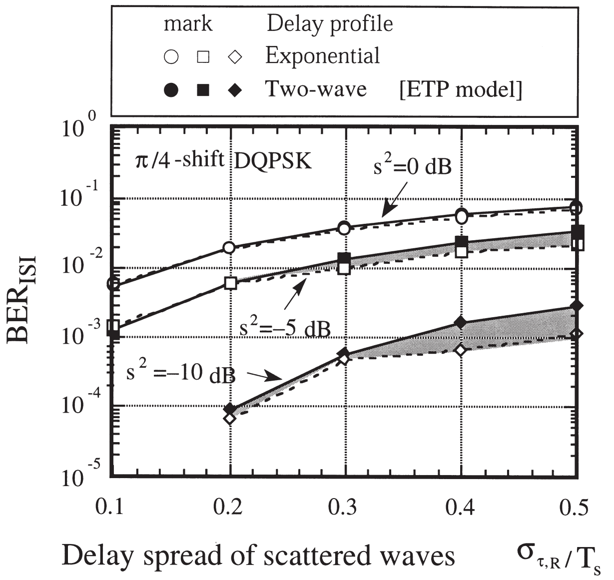


Figure 8. A comparison of the BER due to ISI for two different delay profiles, for the identification of the applicable range of delay spread.

Rayleigh distribution. They are given, respectively, by

$$f_1(r_1;m,\sigma_1)=\frac{r_1}{\sigma_1^2}\exp\left(-\frac{m^2+r_1^2}{2\sigma_1^2}\right)\mathrm{I}_0\left(\frac{mr_1}{\sigma_1^2}\right) \quad (28)$$

$$f_2(r_2;\sigma_2)=\frac{r_2}{\sigma_2^2}\exp\left(-\frac{r_2^2}{2\sigma_2^2}\right) \quad (29)$$

where I_0 is the modified Bessel function of order zero, and the parameters m, σ_1, and σ_2 have the following relationship:

$$P_D=m^2;\quad P_{R1}=2\sigma_1^2;\quad P_{R2}=2\sigma_2^2\cdot \quad (30)$$

Since we chose $\Delta\tau$ so as to be independent for fluctuations of the two Rayleigh waves, the joint PDF for r and ϕ is given by [1]

$$f_{r\phi}(r,\phi;m,\sigma_1,\sigma_2;\Delta\tau)=\frac{\sigma_1^2\sigma_2^2 r}{\pi\left(\sigma_1^2r^2+\sigma_2^2\right)^2}$$

$$\exp\left(-\frac{m^2}{2\sigma_1^2}\right)F\left[2,1;\frac{m^2\sigma_2^2}{2\sigma_1^2\left(\sigma_1^2r^2+\sigma_2^2\right)}\right]$$

$$=\frac{1}{2\pi}\int_0^\infty f_1(z)\,f_2(zr)\,zdz \quad (31)$$

where $F(\alpha,\gamma;z)$ is the confluent hypergeometric function (or Kummer function), for which $\alpha=2$ and $\gamma=1$, given by

$$F(\alpha,\gamma;z)\Big|_{\substack{\alpha=2\\ \gamma=1}}=\sum_{n=0}^{\infty}\frac{(n+1)z^n}{n!} \quad (32)$$

Although the PDF must be given as a function of r and ϕ, the formula actually does not include the variable ϕ, because ϕ follows a uniform distribution.

By replacing the two-wave parameters, m, σ_1, and σ_2 (or P_D, P_{R1}, and P_{R2}) in Equation (31) by the three key parameters, s^2, τ_m, and $\sigma_{\tau,R}$, using the relations in Equations (22)-(27), the joint PDF can be expressed as a function of the key parameters. The PDF is

$$f_{r\phi}\left(r;s^2,\tau_m,\sigma_{\tau,R};\Delta\tau\right)$$

$$=\frac{1}{\pi}\frac{\sigma_{\tau,R}^2\tau_m^2 r}{\left(\sigma_{\tau,R}^2r^2+\tau_m^2\right)^2}\exp\left(-\frac{\tau_m^2+\sigma_{\tau,R}^2}{s^2\sigma_{\tau,R}^2}\right)$$

$$F\left[2,1:\frac{\tau_m^2\left(\tau_m^2+\sigma_{\tau,R}^2\right)}{s^2\sigma_{\tau,R}^2\left(\sigma_{\tau,R}^2r^2+\tau_m^2\right)}\right] \quad (33)$$

In the case of Rayleigh fading (namely, s^2 ? 1), the formula is simplified to

$$f_{r\phi}(r;\infty,\tau_m,\sigma_\tau;\Delta\tau)=\frac{1}{\pi}\frac{\sigma_\tau^2\tau_m^2 r}{\left(\sigma_\tau^2r^2+\tau_m^2\right)^2} \quad (34a)$$

$$=\frac{1}{\pi}\frac{r}{\left(r^2+1\right)^2}\ \text{(when setting } \tau_m=\sigma_{\tau,R}\text{).} \quad (34b)$$

Now we are ready to formulate the prediction of BER due to ISI in Rayleigh and Nakagami-Rice fading environments.

6. Formulation of BER due to ISI

The averaged BER due to ISI under a frequency-selective fading condition can be calculated by the following basic equation [1]:

$$BER_{ISI}\left(s^2,\tau_m,\sigma_{\tau,R}\right)$$

$$=\int_0^\infty\int_0^{2\pi} f_{r\phi}\left(r;s^2,\tau_m,\sigma_{\tau,R};\Delta\tau\right)E(r,\phi;\Delta\tau)\,d\phi dr \quad (35)$$

where $\Delta\tau$ is given in Equation (22), and E is the specific BER floor of the two-wave model – namely, the BER map – as a function of r and ϕ with a parameter of $\Delta\tau$. Since, as seen in Figure 3, every map is logarithmically symmetrical for $r=1$ (that is, the same value of BER is obtained at $r=r_0$ and $r=1/r_0$), it seems more convenient to use the logarithmic variable in dB, $x\,(=20\log r)$, rather than r, itself. The PDF, $f_{x\phi}(x)$, converted from $f_{r\phi}(r)$, is given by

$$f_{x\phi}(x)=\frac{1}{b}\exp\left(\frac{x}{b}\right)f_{r\phi}\left[\exp\left(\frac{x}{b}\right)\right],$$

$$\left[b\equiv 20\log_{10}(e)\right] \quad (36)$$

By using the above formula, the BER due to ISI, corresponding to Equation (35), can be rewritten with a simplified summation formula as follows:

$$BER_{ISI}\left(s^2,\tau_m,\sigma_{\tau,R}\right)$$

$$=\Delta x\Delta\phi\sum_x\left[f_{x\phi}(x)\sum_\phi E(x,\phi)\right] \quad (37)$$

where Δx (in dB) and $\Delta\phi$ (in radians) are the step sizes of the BER map in x and ϕ such that the calculated values converge sufficiently. Testing showed that a Δx of 0.25 dB and a $\Delta\phi$ of $2\pi/180$ rad (which corresponds to two degrees) are sufficient for QPSK and 16QAM (quadrature amplitude modulation) with $\Delta\tau > 0.1T_s$, while other cases, such as BPSK (binary phase shift keying) or QPSK with $\Delta\tau > 0.1T_s$ need finer step sizes.

Furthermore, to pursue more convenient use, a calculation scheme using only one BER map for each modulation/demodulation scheme is available. To realize this, we utilize the similarity of the BER pattern on the BER map for different $\Delta\tau$ values that are smaller than $0.6T_s$. The following formula can be obtained without loosing prediction accuracy [3]:

$$BER_{ISI} = \left(s^2, \tau_m, \sigma_{\tau,R}\right):$$

$$= \eta^2 \Delta x \Delta\phi \sum_x \left[f_{x\phi}(\eta x) \sum_\phi E(x,\phi) \right] \tag{38}$$

with a scaling factor, η, of

$$\eta = \frac{\sigma_{\tau,R}^2 + \tau_m^2}{\tau_m} \frac{1}{\Delta\tau_{map}} \tag{39}$$

For the Rayleigh-fading environment, when using Equation (34b) for $f_{r\phi}$, the scaling factor is given by

$$\eta = 2\sigma_\tau / \Delta\tau_{map} . \tag{40}$$

The use of $\Delta\tau_{map} = 0.2T_s$ is suggested, although noticeable differences are not detected when using a map with a $\Delta\tau_{map}$ of less than about $0.4T_s$ [3].

When the effect of thermal noise is not negligible, the following approximation can be made [3]:

$$BER\left(s^2, \tau_m, \sigma_{\tau,R}, E_b/N_0\right)$$

$$= BER_{ISI}\left(s^2, \tau_m, \sigma_{\tau,R}\right) + BER_{TN}\left(E_b/N_0\right) \tag{41}$$

where BER_{TN} is the BER due to thermal noise, and E_b/N_0 is a signal-to-noise ratio parameter, defined by the power for one-bit transmission divided by the noise power density.

For systems where each user terminal moves fast, the long-term-averaged BER in a time domain seems to be a reasonable measure for digital-transmission quality assessment. On the other hand, for systems where the user terminal is at a fixed position, such as in a wireless LAN, the percentage of locations where outage (namely, unacceptable error rate) occurs seems to be a more practical measure, instead of the averaged BER. Throughout this paper, we have called the measure the EOR (error occurrence rate). In this case, the "error occurrence" means that the signal quality specified by the BER comes down to the predetermined threshold value.

The EOR can be calculated by replacing E with P in Equation (38):

$$EOR_{ISI}\left(s^2, \tau_m, \sigma_{\tau,R}\right)$$

$$= \eta^2 \Delta x \Delta\phi \sum_x \left[f_{x\phi}(\eta x) \sum_\phi P(x,\phi) \right] \tag{42}$$

with

$$P(x,\phi) = \begin{matrix} 1 \text{ for } E(x,\phi) \ge E_0 \\ 0 \text{ for } E(x,\phi) \le E_0 \end{matrix} \tag{43}$$

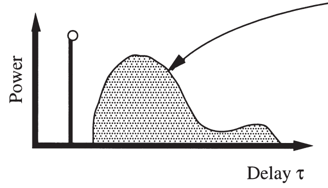
where E_0 is the threshold BER for the error occurrence, such as 10^{-3}.

7. Prediction Accuracy and Applicable Parameter Range

To identify the applicable range of parameter values, we performed a computer simulation to compare the results for the two different delay profiles. One is the two-wave model, corresponding to the ETP model, and the other is the exponential delay-profile model. Figure 8 shows the results of comparison. From the figure, the ETP model has high prediction accuracy for multipath environments where τ_m and $\sigma_{\tau,R}$ are less than $0.3T_s$, and when s^2 is above 0 dB ($=1$) – that is, near the Rayleigh fading environment – this limit extends to $0.5T_s$. This is one reason why we restrict the application limit by Equation (15). Within this range, we evaluated the dependence of BER_{ISI} on the delay-profile shape, by assuming the various types of delay profile shown in Figure 9. In this figure, numbers such as "1," "2," and "4" at the top of each impulse state the relative averaged power. The absolute averaged power and the delay (τ_A, τ_B,...), which represent the fading environments, are given in the table in Figure 9. For comparison, eight cases, each of which had eight profiles, were considered. Figure 10 shows the results of the comparison. As can be seen from this figure, there seemed to be no profile dependence on BER_{ISI} when the set of key parameter values was the same. Moreover, the theoretical estimates based on the ETP model, drawn with dotted lines, corresponded fairly well with the results of the simulation. Figure 11 compares the "calculated" versus the

Eight sets of key parameters' values

Case	s^2	τ_m/T_s	$\sigma_{\tau,R}/T_s$	Symbol
1	∞	–	0.1	○
2	∞	–	0.2	●
3	2.0	0.1	0.1	□
4	2.0	0.2	0.2	■
5	1.0	0.1	0.1	△
6	1.0	0.2	0.2	▲
7	0.5	0.1	0.1	◇
8	0.5	0.2	0.2	◆



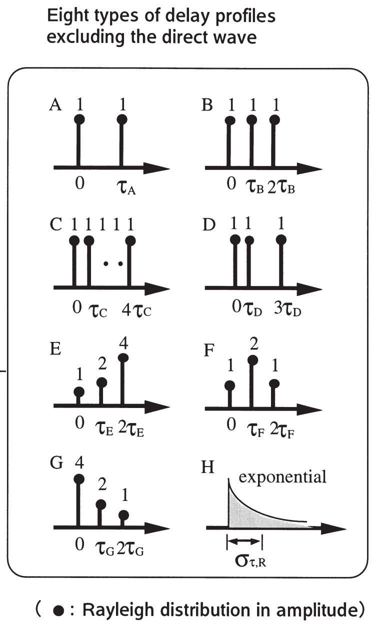


Figure 9. The delay profiles of scattered waves for the simulation. In the simulation, a constant wave was added to each profile (see lower left) at the place that satisfied the set parameter values in the table (upper left).

"simulated" BER_{ISI} for the various environments given in Figure 9 for CBPSK, CQPSK, and $\pi/4$-DQPSK ($\pi/4$-shift QPSK with differential detection). Figure 7 also shows statistical estimates, drawn with solid curves, corresponding to the cases mentioned in the previous section (namely, the "Ray tracing + Simulation" and "Ray tracing + BER map"). From these figures, we can see an excellent correspondence between the statistical and simulated results for various kinds of fading environments and modulation schemes.

Moreover, as for BER due to ISI and thermal noise mixed concurrently, values calculated by Equation (38) correspond well with simulated values, which are given in Figure 12.

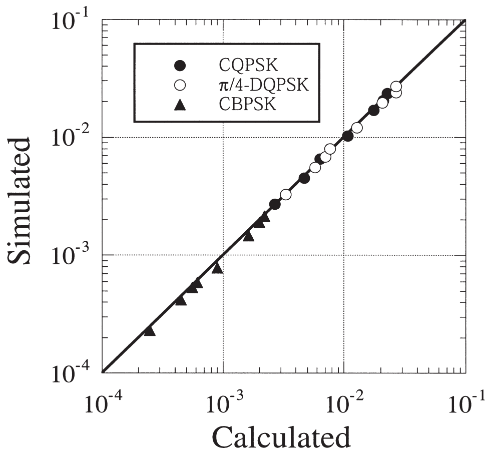


Figure 11. A comparison between a simulated BER floor and a calculated BER floor, based on the ETP model, for various modulation systems.

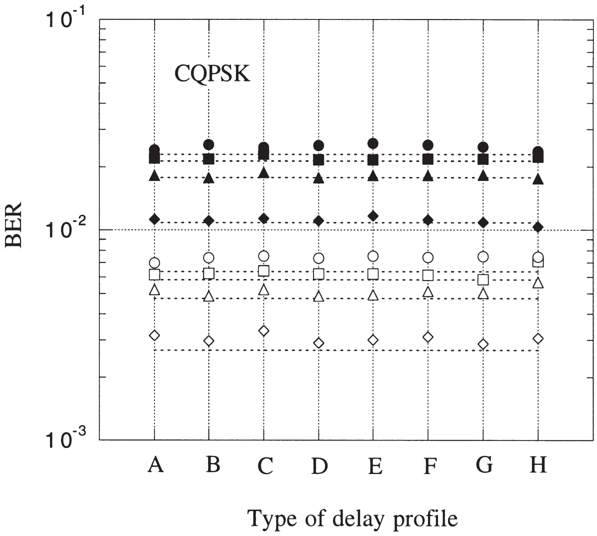


Figure 10. The dependence of the BER on the delay-profile shape. Each mark corresponds to that in the table in Figure 9. The dotted lines are theoretical estimates based on the ETP model, discussed later in the text.

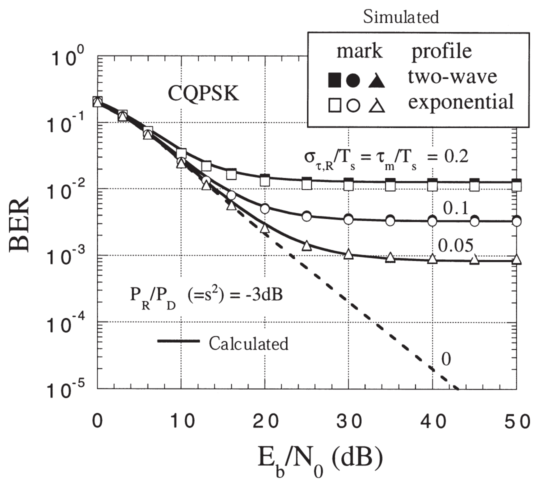


Figure 12. Overall estimates of the BER floor coexisting with thermal noise.

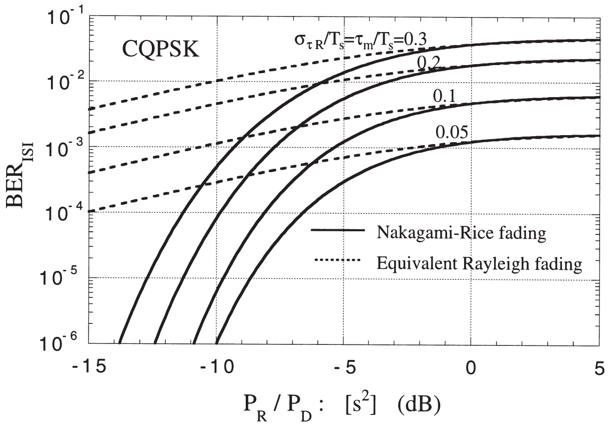


Figure 13. The BER floor characteristics of CQPSK as a function of $s^2(P_R/P_D)$ for $\sigma_{\tau,R}/T_s=\tau_m/T_s=0.05$ to 0.3, based on the ETP model (solid lines).

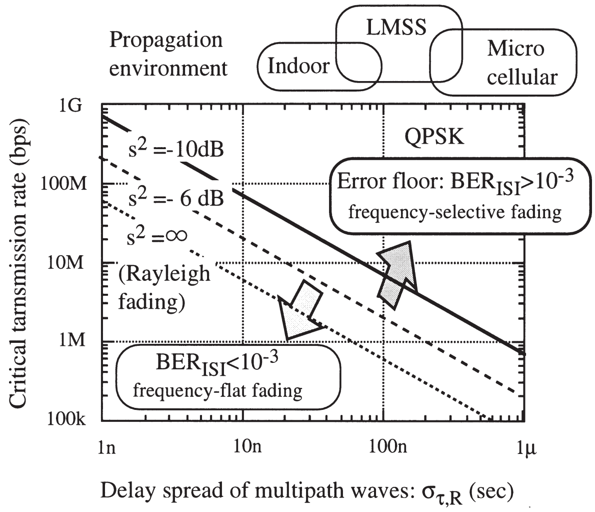


Figure 14. The critical transmission bit rate for various propagation environments.

In Figure 13, the solid lines show the calculated BER_{ISI} as a function of s^2, when $\sigma_{\tau,R}=\tau_m=0.05T_s$, $0.1T_s$, $0.2T_s$, and $0.3T_s$ for CQPSK. In this figure, the results calculated using the single parameter of σ_τ in Equation (8) (that is, the equivalent Rayleigh-fading approximation) are shown by dotted lines. As for a comparison between Nakagami-Rice fading and equivalent Rayleigh fading with the same delay profile, the difference becomes very small for s^2 above 0 dB. On the other hand, in conditions with smaller values of s^2, such that $s^2<-2$ dB, considerable differences can be seen between the two. In the Nakagami-Rice fading model shown in Figure 13 (solid line), a very accurate estimate can be expected in a line-of-sight fading environment, as well as in a Rayleigh fading environment.

It can be concluded that the ETP model is a simple, accurate, and powerful tool for analyzing digital-transmission characteristics in a line-of-sight fading environment, as well as in a Rayleigh fading environment.

Finally, the critical transmission bit rate for QPSK – which is defined as the bit rate where the BER degrades by 10^{-3} – is shown in Figure 14 as a function of the delay spread ($\sigma_{\tau,R}$) and the multipath power ratio (s^2), for various propagation environments. This might be helpful when judging whether special countermeasures for wideband digital transmission – such as an equalizer, or a multi-carrier transmission scheme – are necessary.

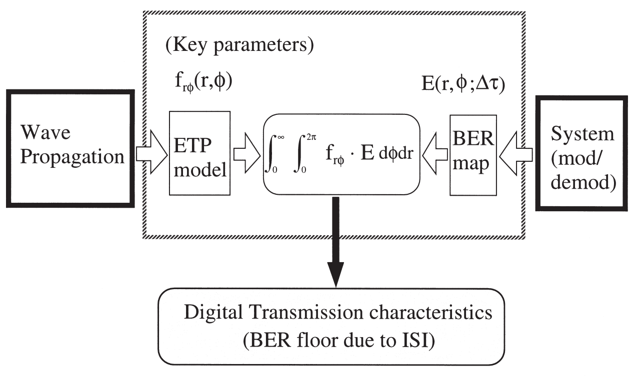


Figure 15. The relationship between "wave propagation" and "systems" in BER_{ISI} estimation.

8. Conclusion

A very simple but general scheme for calculating the irreducible bit-error rate (the BER floor), due to inter-symbol interference (ISI), in frequency-selective Nakagami-Rice fading environments has been reviewed. The scheme, which we call the equivalent transmission-path model (ETP model), connects wave propagation with digital transmission characteristics in a general manner. The role of this model is summarized in Figure 15.

In this paper, after reconfiguring our papers on the ETP model, we presented a consistent calculation formula for the BER due to ISI. In order to show application examples, we analyzed wideband digital transmission characteristics in terms of averaged BER and EOR (specifically, the percentage of locations where the BER exceeds a threshold value), in the case of an indoor propagation environment. The ETP model is expected to be a powerful tool for the analysis of OFDM (orthogonal frequency-division multiplexing) transmission characteristics, where the delay spreading exceeds the guard interval. We will carry out this analysis in the next step.

9. References

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Modeling of Directional Wireless Propagation Channels

Andreas F. Molisch

Abstract

We consider models for the wireless propagation channel that are applicable to systems with multiple (smart) antennas. Such channel models need to implicitly or explicitly include information about the direction-of-arrival (DOA) and direction-of-departure (DOD) of the multipath components. We first review site-specific models, based on measurement results or ray tracing. We then describe geometry-based and correlation-based stochastic models. The COST259 Directional Channel Model (DCM), which is being established as the standard spatial-channel model, receives special attention. We also discuss double-directional channel models, which are important for systems with smart antennas at both ends of the link (multiple-input/multiple-output systems).

1. Introduction

Increasing the capacity and data rate is the most important goal of wireless-systems research. As second-generation systems are bursting at their seams, and providers have paid a king's ransom for spectrum for third-generation systems, increasing the capacity (and thus, revenue) above values that are obtainable with current technology has become vital. The most promising way to obtain this is the use of smart antennas, which exploit the fact that signals take different routes from transmitter to receiver [1-3].

Smart antennas consist of multiple antenna elements, and sophisticated signal processing to exploit the information available at the different antenna elements. A wealth of different processing algorithms is available in the literature, ranging from simple switched-beam algorithms (e.g., [4]) to interference-suppressing diversity combining [5], to blind processing of the information (e.g., [6]). Furthermore, it has been shown that the use of multiple antennas at both transmitter and receiver (multiple-input/multiple-output systems, MIMO) can enhance the capacity even further [5, 7, 8].

In order to assess the benefits and possible problems of all these algorithms, realistic models of the wireless propagation channel are required. Since smart antennas make use of the spatial (directional) information, those models have to include the DOAs (directions of arrival) and DODs (directions of departure) of the multipath components. For this reason, the earlier established models (see, e.g., [9]) cannot be used. Thus, a new family of models has been developed, especially since the mid-1990s (for earlier reviews, see [10, 11]). These models are called "directional" or "spatial" channel models. Much progress has been made in recent years, both with respect to creating generic channel models that allow an accurate and efficient simulation procedure, and with respect parameterizing those channel models with the help of measurement results.

The rest of the paper is organized as follows. We start out with the basic methods of describing the directional mobile radio channel, including directional and double-directional impulse responses. Next, we deal with site-specific modeling, both by means of measurement results and by ray-tracing (computer-simulation) techniques. We then proceed to describe the geometry-based modeling approaches and their parameterization. The purely stochastic models constitute the next section. For the comparison of different smart-antenna algorithms, standardized channel models are vital. Section 6 describes such a model, the COST259 Directional Channel Model. Finally, we discuss aspects of double-directional channel modeling, which is vital for MIMO systems. A summary wraps up this paper. Due to space restrictions, we only briefly touch upon many rather involved subjects. The interested reader is referred to the cited literature for further information.

2. Description Methods for Directional Propagation Channels

Before going into the various modeling methods, we first have to establish what the quantities are that we want to model. The most fundamental description of the propagation channel is the double-directional impulse response[1], which consists of a sum of contributions from multipath components (MPCs):

$$h\left(\vec{r}_T,\vec{r}_R,\tau,\Omega,\Psi\right)=\sum_{l=1}^{L(\vec{r})} h_l\left(\vec{r}_T,\vec{r}_R,\tau,\Omega,\Psi\right).$$

The impulse response depends on the locations of the transmitter, $\vec{r}_T$, and the receiver, $\vec{r}_R$, the delay, τ, the direction-of-departure (DOD), Ω, and the direction-of-arrival (DOA), Ψ. $h\left(\vec{r}_T,\vec{r}_R,\tau,\Omega,\Psi\right)$ is the contribution of the *l*th

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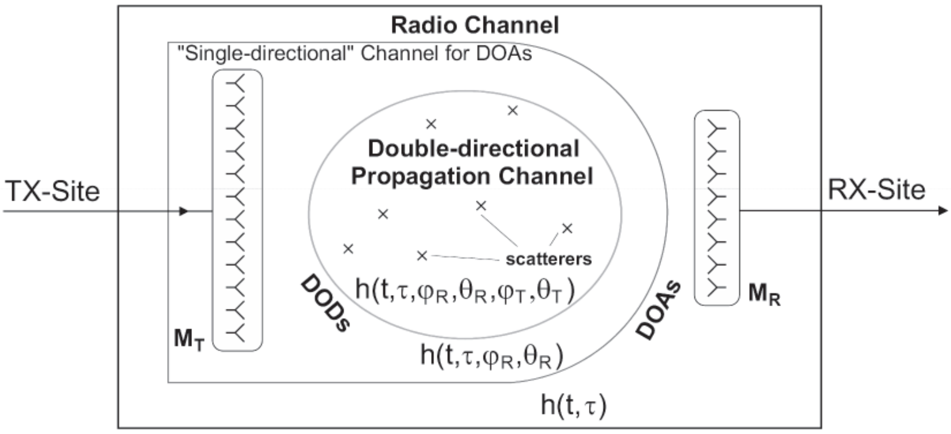

Figure 1. The non-directional, single-directional, and double-directional mobile radio channel (from [54]).

wave, which can be written as

$$h(\vec{r}_T, \vec{r}_R, \tau, \Omega, \Psi)$$

$$= a_l e^{j\varphi_l} \delta(\tau - \tau_l) \delta(\Omega - \Omega_l) \delta(\Psi - \Psi_l)$$

Note that the absolute amplitude, a, and the DOA and the DOD depend slowly (over several wavelengths) on the position, while the phase, φ, varies quickly2.

The single-directional impulse response can be obtained by integrating the double-directional impulse response (weighted by the transmitting antenna pattern) over the DODs. Integrating the single-directional impulse response (weighted by the receiving antenna pattern) over the DOAs results in the conventional impulse response (see Figure 1).

Another representation of directional channels gives the impulse response of the channel at the elements of an antenna array. Thus, the impulse response becomes a matrix, if we have arrays at both link ends, and a vector, for an array at one link end. We denote the transmitting and receiving element coordinates as $\vec{r}_T^{(1)}, \vec{r}_T^{(2)}, ..., \vec{r}_T^{(N_T)}$ and $\vec{r}_R^{(1)}, \vec{r}_R^{(2)}, ..., \vec{r}_R^{(N_R)}$, respectively. The impulse response from the ith transmitting to the jth receiving element3 then becomes (under the assumption of plane, narrowband waves):

$$h_{i,j} = h\left[\vec{r}_T^{(i)}, \vec{r}_R^{(j)}\right]$$

$$= \sum_l h_l \left[\vec{r}_T^{(0)}, \vec{r}_R^{(0)}, \tau, \Omega_l, \Psi_l\right] G_T(\Omega_l) G_R(\Psi_l)$$

$$\exp\left[j\left\langle \vec{k}(\Omega_l)\vec{r}_T^{(i)}\right\rangle\right] \exp\left[j\left\langle \vec{k}(\Psi_l)\vec{r}_R^{(i)}\right\rangle\right]$$

where G_T and G_R are the patterns of the transmitting and receiving antenna elements, respectively, and k is the unit wave vector in the direction of the lth DOD or DOA. We thus see that it is always possible to obtain the impulse-response matrix from a double-directional impulse response (and the knowledge of antenna positions and patterns), while the converse is not true.

3. Deterministic Models

The most realistic deterministic models are based on measurement results. We thus first review the available directional measurement techniques, and then discuss different evaluation techniques. Some channel-modeling approaches only need the impulse responses, h_{ij}, at different positions (antenna elements), which usually can be obtained directly from a measurement run. Other models require the directional information of all multipath components. We will discuss how this information can be extracted from measurement results.

For non-directional wideband channels, measurement devices ("channel sounders" [9]), based on different principles (network analyzer, correlator, sliding correlator), are available. These devices can be used as a basis for constructing directional-channel sounders. The simplest way is to combine such a device with a directional (e.g., horn) antenna [13]. A stepping motor is used to point the antenna toward different directions, and the impulse response is recorded for each direction. The drawbacks of this method are the long measurement time, and the fact that the resolution is limited by the beamwidth of the directional antenna.

Alternatively, directional information can be obtained from an antenna array (Figure 2). In a "physical array" arrangement, we have one "normal" channel sounder connected to each antenna element, so that the impulse responses at the different elements h_{1j} can be measured simultaneously [14]. In a "multiplexed array" arrangement, there are several antenna elements connected to a single sounder via a fast RF switch [15]. We thus first measure the impulse response at the first antenna element, $h_{1,1}$, then connect the switch to the second element, measure $h_{1,2}$, and so on. Finally, in a "virtual array" arrangement, there is only a single antenna element, which is moved mechanically from one position to the next, measuring the h_{1j} [16]. A basic assumption for the evaluation is that the environment does not change during the measurement procedure. "Virtual arrays" (which require a few seconds or even minutes for one measurement run) can thus only be used in static environments: this precludes scenarios where cars or moving persons are significant scatterers. On the other hand, they avoid all problems with mutual coupling between antenna elements. In non-static environments, multiplexed arrays are usually the best compromise between measurement speed and hardware effort.

For geometry-based approaches, the directions-of-arrival (DOAs) of the multipath components (MPCs) have to be extracted from the impulse responses. The simplest approach is a spatial Fourier analysis; however, the resolution is usually very poor. For this reason, high-resolution parametric approaches should be used. The most popular ones are MUSIC [17], ESPRIT [18, 19], SAGE [20], and the minimum-variance method [21]. These algorithms have an estimation accuracy of the order of one degree. We stress, however, that they might sometimes lead to numerical problems, and some of them are limited in the number, L, of MPCs, h_l, that can be estimated.

The measuring of double-directional (MIMO) channels is even more complicated. We need to send signals that are orthogonal either in time [22] (i.e., sending first only from the first antenna, then only from the second,...), frequency (transmission of offset carriers from the different antennas), or code [23] (e.g., transmission of different Walsh-Hadamard sequences from the different antennas), from the transmitting antennas. In any case, each receiving antenna has to sort out which contribution stems from which transmitting-antenna elements. Theoretically, the measurement accuracy and susceptibility to noise do not depend on whether the transmitted signals are orthogonal in time, frequency, or code (assuming all other parameters, such as measurement bandwidth, are equal). However, some practical aspects differ: for example, the required interpolation between subsequent measurements in a time-varying (but still identifiable) channel differs, as does the calibration and the influence of mutual coupling. Also, note that in MIMO channel measurements, the requirement that the channel does not change significantly during the measurement period is even more stringent than for single-directional measurements. For example, it is clear that if the transmitted signals are orthogonal in time, the measurement duration is N_T times larger than for single-directional measurements.

The extraction of DOAs and DODs from the measurement results follows essentially the same techniques as the extraction of DOAs from measurements with one array. Again, we can use Fourier techniques or high-resolution techniques to obtain the DOAs and DODs. There is, however, one interesting twist: it is not sufficient to determine DOAs and DODs separately. Rather, we have to answer the question: "If we transmit into a certain direction, then from which directions will the MPCs arrive at the receiver?" In other words, we have to solve a two-dimensional – and not two one-dimensional – extraction problems. Methods to deal with this problem are discussed, e.g., in [24, 25].

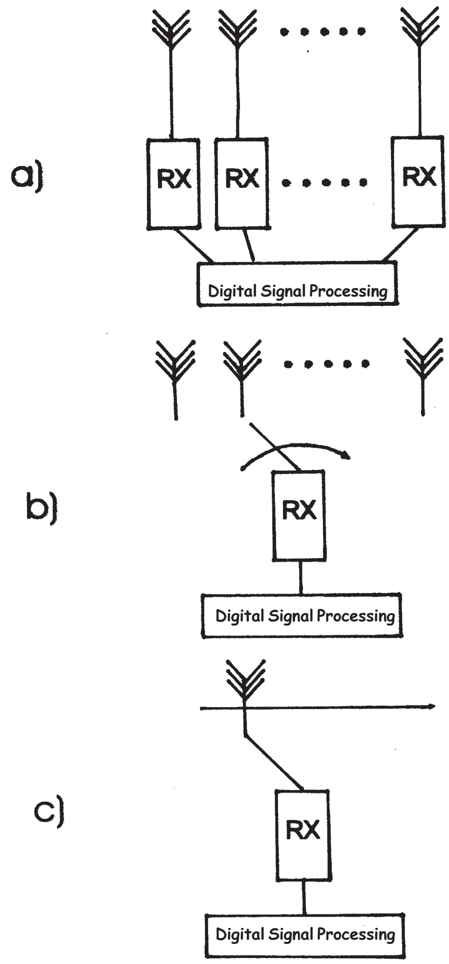

Figure 2. A directional channel sounder: (a) a multi-channel sounder, (b) a multiplexed sounder, and (c) a virtual array.

Finally, ray tracing or ray launching also provide site-specific information (see, e.g., [26]). Ray tracing uses a data bank, containing geographical and morphological data (for outdoor propagation) or building plans (for indoor propagation), to check which propagation paths are possible from transmitter to receiver, and how strong is the attenuation of the different propagation paths. Advanced models take into account not only specular-reflection processes of different orders, but also diffuse reflection and diffraction at corners. Since ray tracing follows each ray on its propagation paths, it gives the DOAs and DODs "for free." Most existing ray-tracing programs would just need a change in their interface to actually put out that information.

Deterministic models depend on the geography and morphology of the environment considered, and are thus mainly suitable for site-specific modeling. This type of modeling is used for the deployment of networks. On the downside, the models do not necessarily describe the behavior in a "typical" environment, as they are tied to a specific layout.

When comparing measurement results to ray tracing, we find that it is much more time-consuming and expensive to obtain a large number of measurement results than ray-tracing results. Not only is the recording of the $h_{i,j}$ by means

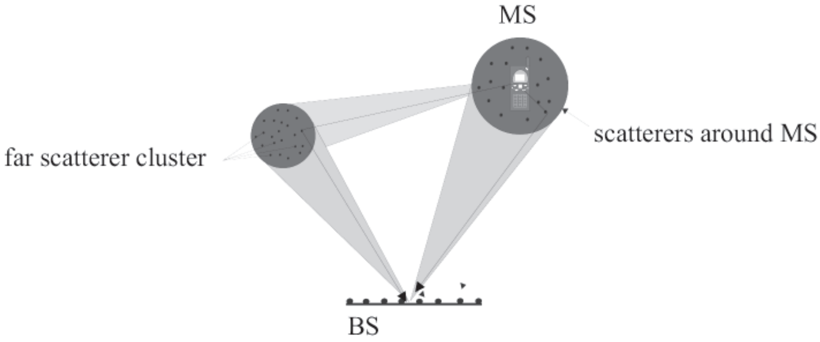

Figure 3. The principle of a geometry-based stochastic channel model (GSCM).

of the appropriate channel sounders very time consuming, but so is the extraction of the multipath parameters: the a_l, τ_l, Ω_l, and Ψ_l. On the other hand, all concerns about accuracy and sensitivity to database errors of "standard" ray-tracing programs [27] are even more valid for directionally resolved impulse responses: directional characteristics can be severely distorted by estimation inaccuracies, even though their influence on the total received power may be small.

4. Geometry-Based Stochastic Models

4.1. General Considerations

In any geometrical model, the impulse response is related to the location of the scatterers. In a completely deterministic geometrical approach (for example, ray tracing), the location of the scatterers is prescribed deterministically from a database. In a geometry-based stochastic-channel model (GSCM), on the other hand, the location is chosen stochastically, following a certain probability density function. The actual impulse response is then found by a simplified ray-tracing procedure, assuming that only single-scattering processes occur (Figure 3). The "ray tracer" thus needs to follow only the path from the transmitter to the scatterer, and from there to the receiver. This path gives the runtime, the direction of departure from the transmitter, and the direction of arrival at the receiver. Additional phase shifts from the reflection process can be taken into account by ascribing, e.g., a random phase shift (in addition to the phase shifts due to the runtime) to each MPC. Each path is ascribed an attenuation of its own: usually proportional to a power law (e.g., d^{-4}).

The above approach has a series of advantages. It emulates physical reality, and thus reproduces many effects implicitly. The small-scale fading is created by the superposition of waves from individual scatterers. The delays and directions of the waves (from which the correlations between the $h_{i,j}$ follow) are also implicit in the scatterer location, and are thus reproduced automatically. It is also relatively easy to parameterize the model, as many of the large-scale parameters can be derived from physical considerations: for example, the delay and DOA of signals scattered by high-rise buildings ("far clusters," see below) follows immediately from the geographic position of the building, the base station (BS), and the mobile station (MS).

On the downside, the model (at least in its straightforward form) relies on the assumption of single scattering[4]. Furthermore, simulations take longer than do purely stochastic models, for the same accuracy [28].

4.2 Macrocells

The simplest GSCM is found by assuming that the scatterers are distributed uniformly in the whole plane. Contributions that come from far-away scatterers carry less power, as they propagate over a longer distance, *d*, and are thus attenuated more strongly (usually d^{-4}). This model has been introduced by Rappaport and co-workers. It is termed the Single-Bounce Geometrical Model (SBGM) [29], and has been used by several other groups to analyze smart antennas and MIMO systems, e.g., [30].

In macrocellular situations, scatterers tend to be concentrated around the mobile station, since it is at street level and thus surrounded by many scattering objects, while the base station is above the rooftops. This fact is reproduced by the model introduced by [31], which placed scatterers on a circle around the mobile station. This model was improved in [32], by choosing the scatterer location at random in a disk around the mobile station. [33] analyzed various other distributions of scatterers around the mobile station, and found that a one-sided Gaussian distribution (as a function of distance from the mobile station, and uniform as a function of azimuth) resulted in an approximately exponential power-delay profile, which is in good agreement with many measurement results.

Measurement campaigns have shown that propagation via far-away scatterers, like high-rise buildings or mountains, is also an important mechanism. This fact was accounted for in [34] by placing clusters of far scatterers at random locations in the cell. That approach was later refined in the COST 259 channel model, which will be described in more detail in Section 6.

4.3 Micro- and Picocells

In microcells, the propagation mechanisms are somewhat different, which also requires the geometrical models to be different. The base station is below rooftop height, so that propagation over the rooftops involves two diffraction processes, and is thus rather weak. Most of the power propagates by waves guided through the street canyons [35]. This also involves multiple-reflection and diffraction processes. Thus, a correct modeling of microcell propagation by single-reflection models is not easily possible. However, we will see below how this situation can be remedied, if we only wish to model the directions-of-arrival at one link end.

Similar considerations apply in picocells. For propagation within one large room, line-of-sight propagation and single-bounce reflections are the most important propagation mechanisms [36]. If the transmitter and receiver are in different rooms, then waves can either propagate through the walls, or they can leave the room (e.g., by a window or door opening), be guided through a corridor, and be diffracted into the room with the receiver [37]. For spatial channel modeling, it is important to note that these two different propagation mechanisms lead to different angular properties. Waves that are guided through corridors, and then diffracted into the room with the receiver, seem to be incident mainly from the door or window, while the waves propagating through the walls seem to come from the direction of the transmitter. Waves propagating through walls experience a much stronger attenuation for large distances than guided waves. Thus, the angular spectrum of the total arriving waves is a function of the distance, as well.

4.4 Equivalent Scatterers

We have mentioned above that most GSCMs are based on the assumption of single scattering. On the other hand, multiple reflections are dominant in micro- and picocells. This dilemma can be resolved by the concept of "equivalent scatterers." We can always place a scatterer at such a point that a certain delay and DOA at one link end is reproduced. In a microcell, for example, waves always arrive at the base station from the direction of the street canyon, although the delays might differ [38]. We thus have to place synthetic scatterers in the direction of the street canyon.

To give a more mathematical phrasing to the above considerations, the x and y coordinates of the scatterer location can be considered to be one pair of variables, while the delay and DOA form another[5]. It is always possible to do a mathematical transformation between those two. If the angular-delay power spectrum and the scatterer distribution are considered, then we have correspondence between two pairs of random variables. In this case, not the sample values themselves but rather the statistical properties are transformed – which is what we are interested in, anyway. More details about the transforms can be found in [39, 40].

5. Stochastic Models

Purely stochastic models for mobile propagation channels have been in widespread use, both for the narrowband field strength [41] and the wideband behavior [42]. For the field strength, the statistics of the complex amplitude are prescribed: usually as complex Gaussian, with a certain autocorrelation function or Doppler spectrum. For a wideband model, the delay axis is divided into delay bins, and the average power, power statistics, and autocorrelation function are prescribed for each bin. The best-known example for such a model is the COST207 wideband model, also known as the GSM model [44].

The generalization of this modeling approach to directional models is fairly straightforward: now we divide the *delay-angle plane* into bins, and prescribe the statistics of the arriving power in each such bin (Figure 4) [13]. Let us consider movement of the mobile station over an area that is large enough to give a number of different channel realizations, but small enough so that delays and DOAs do not change significantly. The distribution of the power over the delay-angle plane, averaged over this area, is called the ADPS (angular-delay power spectrum). The statistics of the field strengths arriving in each bin are usually complex Gaussian. A prescription of the ADPS and its autocorrelation function then characterizes the channel.

The stochastic model is very simple when considering movement of the mobile station over a small area, as described above. Generation of impulse responses from the ADPS is well known [28]. However, a purely stochastic description of large-scale effects, which reflects changes in DOAs of the multipath components, is much more complicated. The large-scale changes of the DOAs and delays of the arriving waves are correlated, so that a complete stochastic description requires a multi-dimensional probability density function. It is thus usually better described by geometrical means. A method for combining the two approaches is described in [43]: the ADPS is determined from geometrical considerations. From the ADPS, and the (usually Rayleigh) statistics of the amplitudes, stochastic realizations of the (instantaneous) directional impulse responses are created.

When comparing stochastic to deterministic models, we find that the former are better suited for system simulations. They can be described by a small set of parameters, which allows easy implementation by any interested party (instead of having to exchange large data files). Standardization and comparisons of results are thus more easily possible, and the parameters can be chosen to reflect typical impulse responses.

6. The COST259 Directional Channel Model

6.1 General Structure

The performance of algorithms for smart antennas can strongly depend on which channel model is used for the simulations. In order to obtain comparable results, a standard channel model is desirable. Recognizing that need, the European research initiative COST259 [45] formed a subgroup to devise a directional-channel model (DCM). This model was approved by the general assembly (which included representatives from most major European companies, network operators, and manufacturers), and has gained widespread acceptance. It is now used especially for the simulation of WCDMA systems (where it is being adopted by 3GPP), both for the simulation of directional effects, and for effects related to the large-scale behavior of the channel. The first version of the model is described in [46]; a final account is found in [12, 47, 48].

The COST259 DCM distinguishes three different layers (Figure 5):

1. At the top layer, there is a distinction between different *radio environments* (REs). An RE represents a certain

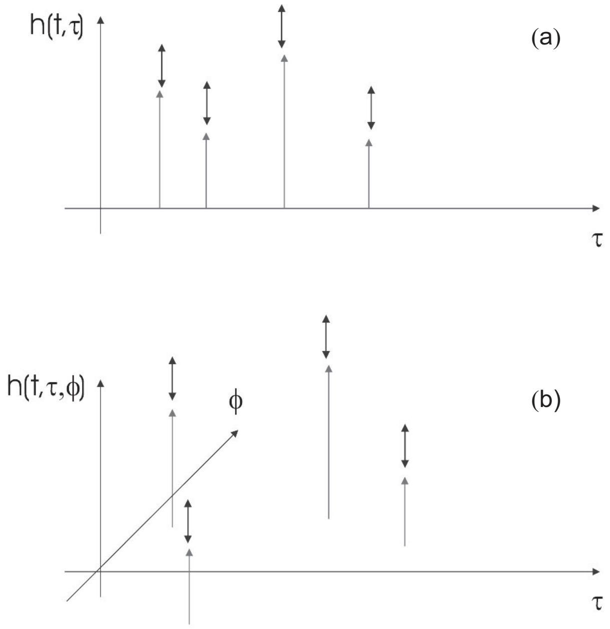

Figure 4. (a) The standard tap model for a wideband channel, and (b) the generalization to the directional case.

group of environments that have similar propagation characteristics, e.g., "Typical Urban." All in all, there are 13 REs: four macrocellular REs (i.e., base-station height above rooftop), four microcellular (outdoor, base-station height below rooftop) REs, and five picocellular (indoor) REs.

2. Large-scale effects describe the change of channel characteristics as the mobile station (MS) moves over large distances, e.g., 100 wavelengths or more. These effects include appearance/disappearance of far clusters, shadowing, changes in the directions-of-arrival, or changes in the delay spread. The large-scale effects are described by their probability density functions, the parameters of which differ for the different REs.
3. Small-scale fading is caused by interference of the multipath components. The statistics of the small-scale fading are determined by the large-scale effects.

The large-scale effects are described in a mixed-geometrical-stochastic fashion, applying the concept of scatterer clusters, as described in Section 4.2. At the beginning of a simulation, scatterer clusters (one local, around the mobile station, and several far scatterer clusters) are distributed at random (according to their probability density function) in the coverage area: this is the stochastic component. During the simulation, the delays and angles between the clusters are determined deterministically from their position and the positions of the base station and mobile station: this is the geometrical component. Each of the clusters has a small-scale averaged angular-delay power spectrum (ADPS), which is exponential in delay, and Laplacian in azimuth and elevation. Note that while the ADPS *of each cluster* is separable in delay and angle, the *total* ADPS is not.

The angularly resolved complex impulse responses are then obtained from the average ADPS, either directly (i.e., using a tap model, Section 5), or by mapping it onto a scatterer distribution and obtaining the impulse responses in a geometrical way (Section 4).

6.2 Micro- and Picocells

In macrocells, the placement of the clusters was at random, following a certain probability density function. In micro- and picocells, this placement is more deterministic, using the concept of "virtual cell deployment areas" (VCDAs). A VCDA is essentially a map of a virtual town or office building, with a route of the mobile station prescribed in it (see Figure 6). For any position of the mobile station, the cluster positions in delay and angle are thus known completely deterministically. This approach is somewhat similar to a ray-tracing approach, but differs in two important respects: the "city maps" need not reflect an actual city, and can thus be made more "typical" for many different cities. Furthermore, only the *cluster positions* are determined by ray tracing, while the behavior *within* one cluster is still treated stochastically.

7. MIMO Models

In recent years, MIMO (multiple-input/multiple-output) systems have attracted great interest, because they offer high information-theoretic capacities [5, 7]. Thus, a correct modeling of the MIMO channel has become of vital importance. The basic idea of MIMO systems is that each multipath component can carry a different data stream, if there are enough antennas at the transmitter and receiver. Thus, a "rich multipath environment" is an advantage – in contrast to conventional systems, where it is considered a drawback. Recent investigations have also shown that some specific propagation effects can decrease the information-theoretic capacities [49, 50]. It is thus very important to model those effects correctly.

There are two basic methods of modeling MIMO channels. In the "transfer matrix" approach, the statistical properties of the transfer functions from each transmitting to each receiving antenna, and the correlations between those transfer functions, are modeled. In the "double-directional" channel model, the statistics of the multipath components – including their delays, τ_l, the DODs, Ω_l, and the DOAs, Ψ_l – are modeled. In this section, we describe the two approaches, and discuss their advantages and drawbacks.

7.1 Modeling of the Transfer Matrix

For the flat-fading case, the channel for a MIMO system is described by the matrix *H*:

$$H = \begin{bmatrix} h_{11} & h_{12} & \dots & h_{1N_t} \\ h_{21} & & & \\ \dots & & & \\ h_{N_r1} & & & h_{N_rN_t} \end{bmatrix}.$$

The simplest, and most popular, model is to assume that each of the elements is complex Gaussian, and that all entries are uncorrelated [5, 7]. This corresponds to reality if there is no line-of-sight component and the antennas are "sufficiently" separated (the required amount of separation depends on the angular spread seen at the base station and mobile station).

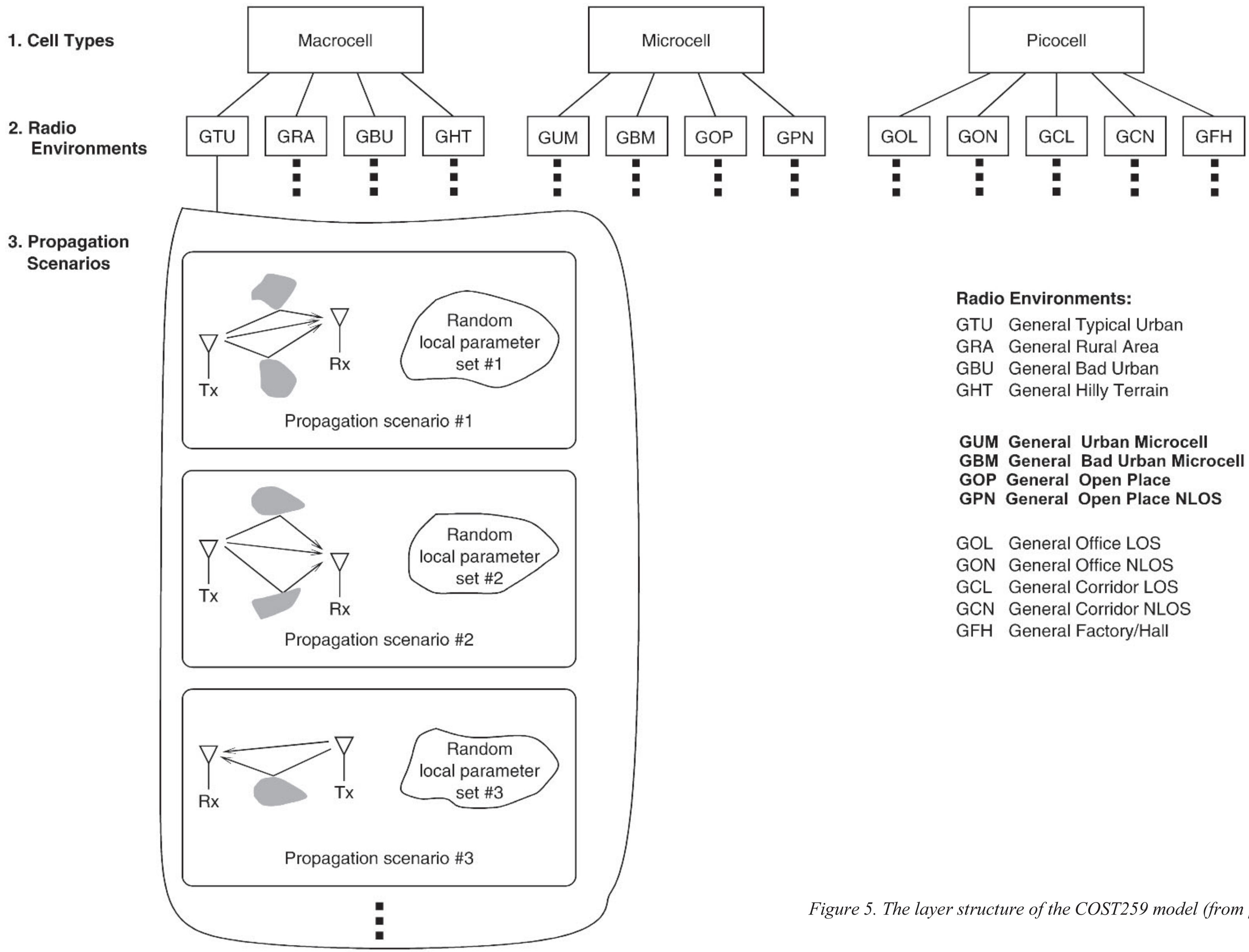

Figure 5. The layer structure of the COST259 model (from [12]).

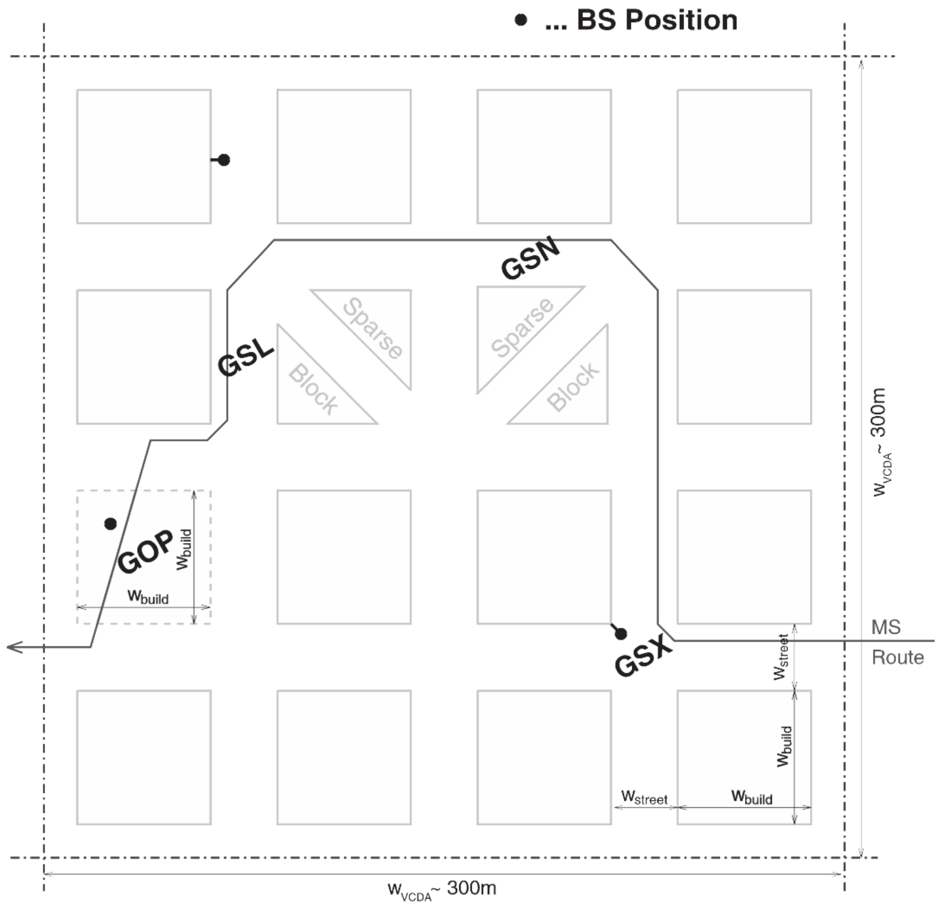

Figure 6. A map of the microcell Virtual Cell Deployment Area (VCDA) (from [48]).

The introduction of finite correlation is possible by multiplying a matrix of independent Gaussian entries with the square root of the correlation matrix. Correlation usually arises from a small angular spread of the DOAs or DODs [51]. It decreases the channel capacity, because there are fewer independent transmission paths. Line-of-sight is included by using a finite mean for the Gaussian entries. It usually decreases capacity, as well [49] .

One of the most important insights in MIMO channel modeling is that even if all entries of the transfer matrix are uncorrelated, the matrix can still be rank-deficient [50, 52]. This effect (known as the "pinhole" or "keyhole" effect) occurs when there are scatterers around the base station and the mobile station, with a "pinhole" between them (Figure 7). This pinhole could be a large stretch of empty space, a diffraction edge, or a corridor: any propagation effect that is described by a rank-deficient matrix of transfer functions from the scatterers around the base station to the scatterers around the mobile station. The rank deficiency of the pinhole causes a rank deficiency of the total transfer matrix. Still, the multipath components are incident at the base station and mobile station from all directions (because of the scatterers around the base station and mobile station), so that the fading at the different antenna elements is independent[6]. As the pinhole channel is rank-deficient, transmission of different data streams from different transmitting antennas (often known as BLAST [53]) is not possible. However, the channel still provides some diversity, so that the signal quality can be improved by multiple antennas.

An appropriate channel model thus decomposes the propagation from base station to mobile station into three parts (from base station to scatterers around the base station, propagation through the keyhole, and then from scatterers around the mobile station to the mobile station, itself). The model is parameterized in terms of the correlation matrices for the three processes.

7.2 Double-Directional Channel Models

The alternative to modeling the transfer matrix is to model the a_l , τ_l , Ω_l , and Ψ_l [54]. Such a channel model is more general, because it does not make any assumptions about the specific antenna configuration.

The simplest double-directional model is based on the assumption that DOAs and DODs are separable. In other words, we prescribe a certain angular spectrum at the base station and a spectrum at the mobile station, and the joint power spectrum is just the product of those two spectra. This approach has the great advantage of being simple, and the advantage that directional-channel models, like the COST259 DCM, can be reused immediately. The major disadvantage is that it does not correspond to physical reality (see Figure 8). If the transmitter sends of a beam in the direction of the receiver, the DOAs (at the receiver) will be different compared to the case where the transmitter illuminates a far scatterer cluster [55].

A second approach is the use of a geometrical model – usually with the assumption of single-scattering processes. In that case, the location of the scatterer determines the DOD

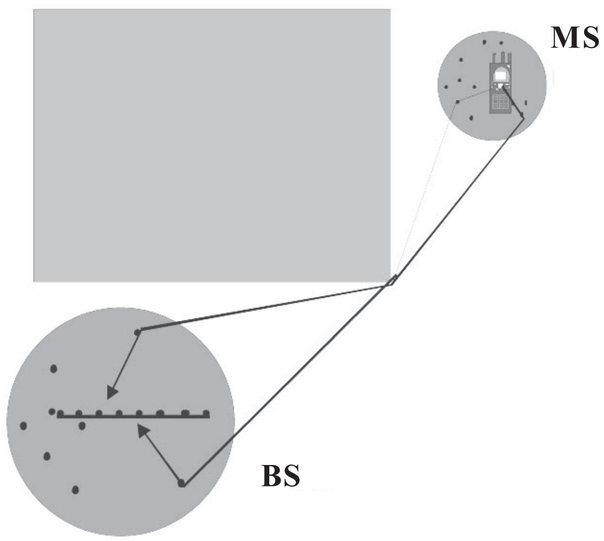

Figure 7. The keyhole effect by diffraction at an edge.

and the DOA. This model works for some macrocellular cases, but breaks down in microcellular cases where guiding of waves (i.e., multiple reflections) is an essential propagation mechanism [51, 56][7].

Recently, [57] has proposed a generic model that includes all the essential propagation effects. It is basically a geometrical approach, and reuses the clustering approach of COST259. However, it includes additional parameters that account for the guiding of waves, keyhole effects, and other effects. The model has a considerable number of parameters, the values of which in different radio environments have yet to be determined by measurement campaigns.

8. Summary and Conclusions

We have given an overview of different methods to model directional mobile propagation channels. We can basically distinguish among deterministic, purely stochastic, and geometry-based stochastic models. Deterministic models, which include measurement results and ray-tracing results, are best suited for site-specific modeling, e.g., in the deployment of networks with smart antennas. For the design and simulation of systems or algorithms, site-independent models are preferable. Purely stochastic models are most efficient for the simulation as the mobile station moves over a small distance, so that DOAs do not change. For large-scale effects, geometry-based models are preferable. This dual approach can also be used for the standard COST259 DCM.

Many of the considerations for directional-channel models also carry over to the MIMO channel modeling. The stochastic and geometry-based approaches become stochastic modeling of the transfer matrix and modeling of the multipath components, respectively. In many respects, MIMO channel modeling is now at a stage that directional channel modeling was five years ago: the basic propagation principles and generic modeling approaches have been

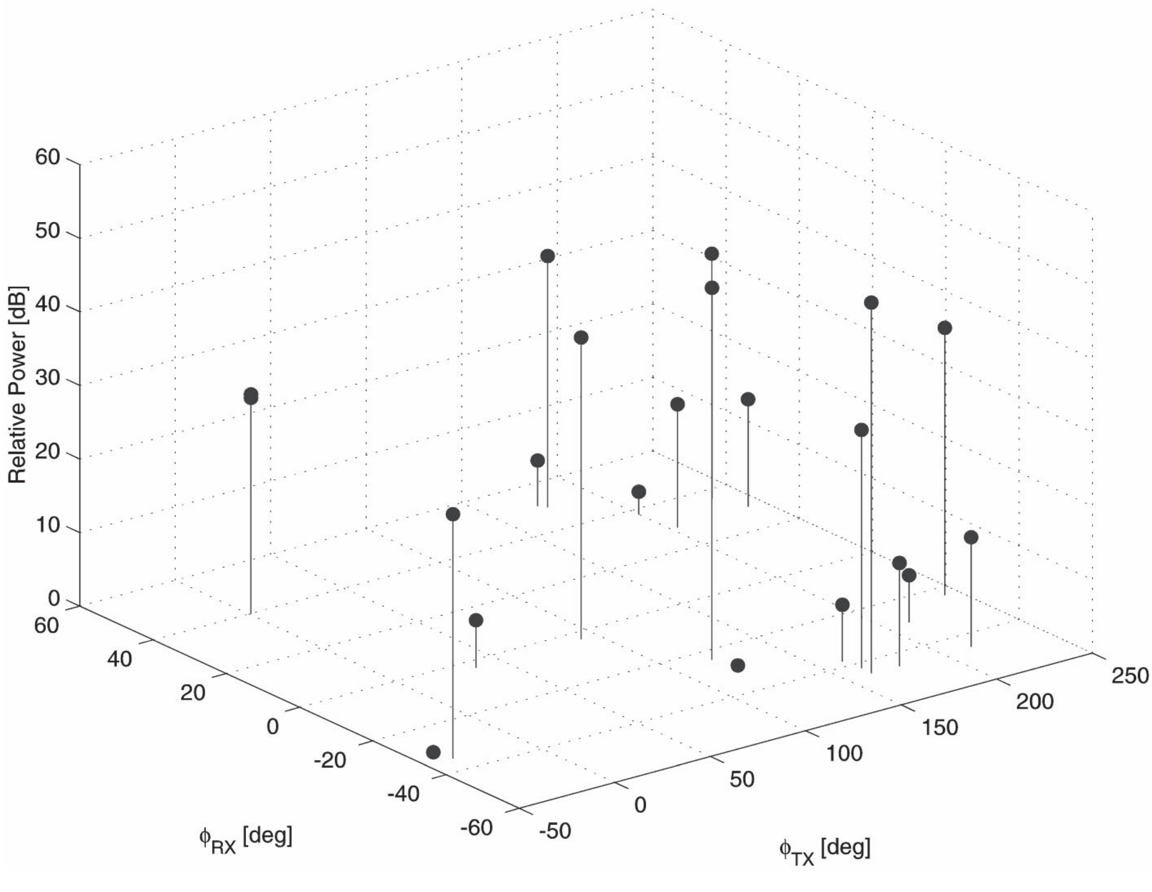

Figure 8. The received power, DOA, and DOD of the multipath components in a non-LOS microcellular environment (from [54]).

explored, but there is a desperate need for measurement results to parameterize these models.

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Footnote References

1 To be completely general, we would have to include a description of polarization, as well. To avoid the cumbersome matrix notation, we omit this case here, and refer the interested reader to [12].

2 To keep notation compact, we have not written these dependences on location explicitly in the above equation.

3 If we deal with an antenna array at only one link end, the impulse responses at the antenna elements constitute a vector (instead of a matrix). However, we still write the elements of this vector as h_{ij}, in order to avoid confusion with h_l, the contribution of the *l*th multipath component.

4 We will see below what measures can be taken to include multiple-scattering processes.

5 More generally, *x*, *y*, and *z* form a triplet, with delay, azimuth, and elevation forming the other triplet.

6 There are actually two (incompatible) definitions of “pinholes” in the literature. Some authors define a pinhole as *any* rank-deficient transfer matrix, irrespective of the correlation of the entries. Thus, an LOS connection would be a pinhole. Other authors define a pinhole as a rank-deficient transfer-function matrix with uncorrelated entries (where the “uncorrelatedness” is created by scattering around the base station and mobile station), so that a LOS connection would *not* be a pinhole. We use this latter definition.

7 We stress again that true ray tracing, with the inclusion of multiple reflections, gives the correct relationship between DOA and DOD (see also Section 3).

Continuation from page 15

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Triennial Reports Commissions

COMMISSION A

This report was prepared by Professor Elio Bava, Commission A Chair 1999-2002. Before reporting on the activity of this triennium, Commission A acknowledges the passing of its Past Chaiman Dr. Motohisa Kanda, occurred June 12, 2000. Officers and scientists who have appreciated him as an excellent research leader recall his dedication and his efforts to improve the activity of the Commission.

1. Chairpersons and other responsibilities

During this triennium the structure of Commission A has been:
Chairman: Prof. Elio Bava, Italy
Vice-Chairman: Dr. Quirino Balzano, USA
Review of Radio Science Editor: Prof. Salvatore Celozzi, Italy
Associate Editor of the Radio Science Bulletin: Dr. P. Banerjee, India

2. Review of Radio Science

Commission A: Electromagnetic Metrology edited by Salvatore Celozzi

Six Sub-Topics have been planned and contributed.

1. Sub-Topic: Characterization of non-linear active devices at microwaves.
   "Experimental Characterization of Non Linear Microwave Active Devices", Umberto Pisani, Andrea Ferrero, Gian Luigi Madonna, Politecnico di Torino, Turin, Italy
2. Sub-Topic: New techniques in frequency metrology
   "New developments in optical frequency standards and optical frequency synthesis", Jürgen Helmcke, Physikalisch-Technische Bundesanstalt, Braunschweig, Germany.
3. Sub-Topic: Bio-Electromagnetics
   "Dosimetry in the Human Head for Portable Telephones" Jianqing Wang and Osamu Fujiwara, Nagoya Institute of Technology, Nagoya, Japan.
4. Sub-Topic: Near-Field Coupling to Transmission Lines
   "Transient response for coupling of electromagnetic fields to transmission lines and crossing transmission lines", Yoshio Kami, W. Liu, and F. Xiao, The University of Electro-Communications, Tokyo, Japan.
5. Sub-Topic: EMC Test Facilities for Radiation Measurements
   "New EMC Test Facilities for Radiation Measurements" Heyno Garbe, University of Hanover, Hanover, Germany.
6. Sub-Topic: Broadband Microstrip Antennas
   "Analysis of microstrip antemmas by means of the regularization via Neumann series", Gaetano Panariello, F. Schettino, University of Cassino, Cassino, Italy; L. Verolino, University of Naples Federico II, Naples, Italy; R. Araneo and S. Celozzi, University of Rome"La Sapienza", Rome, Italy.

3. Scientific Program for the XXVIIth GA

Commission A contributed to the scientific program of the XXVIIth URSI GA a General Lecture, and a Tutorial Lecture, moreover has based its own program, concerned with fundamental metrology and high level applications of scientific measurements, on five Commission Sessions, six Joint Sessions headed by the same Commission, and six Joint Sessions headed by other Commissions.

4. Participation to scientific meetings

15th Meeting of the Consultative Committee for Time end Frequency (CCTF), 20-21 June 2001 (by Prof. S. Leschiutta and Dr. J McA Steel)

Members of the CIPM Committees are not individuals but the Laboratories that have expressed their intention to take part to the CC's activities; these Laboratories are designating their representatives for each session. At the moment the CCTF chair is Sigfrido Leschiutta of Politecnico di Torino/ Istituto Elettrotecnico Nazionale and Scientific Secretary is Felicitas Arias, chairwomen of the BIPM Time Section. The meeting was attended by thirty-eight people. Present were also some Observers and invited individuals, coming from Institutions not members of CCTF. Among the invited, the researchers of the BIPM Time Section. URSI was represented by J. Mc A. Steele.

At the outset the meeting stood in commemoration of Louis Essen who initiated the first operational caesium standard at NPL, Teddington in 1955 and the Chairman suggested that a suitable tribute to him be prepared in 2005 to mark 50 years of atomic timekeeping. [It may be appropriate also for URSI to celebrate this significant milestone which will coincide with the XXVIIIth General Assembly, given Essen's close association with the Union, having served as chairman of (the then) Commission 1 on Radio Standards and Measurements during two successive periods].

Primary frequency standards

Researches on primary frequency standards are performed in 14 laboratories, 13 of which are engaged on the construction of a caesium or a rubidium fountain with an increase of 3 with respect the previous period. Two of these fountains (NIST & PTB) were intercompared using TWSTFT ; the device at PTB can run almost for a month and steps are made in order to contribute to the TAI formation. At BNM/LPTF, three fountains are active, LPTF-F01 with a relative uncertainty of 1 10^{-15}, a portable fountain (2 10^{-15}) and a double fountain with caesium and rubidium atoms.

The actions proposed in the Recommendations S3 and S4 of the CCTF meeting in 1999, to be found in the proceedings of that Session, prompted the BIPM Time section to reconsider the way in which the data from the primary standards are used to evaluate the duration of the scale unit of TAI. Details can be found in the Circular T in My 2000.

TAI , Reports of the BIPM Time Section

A number of improvements and modification were introduced in the TAI formation, comparison and results presentation, following the Recommendations coming from the previous CCTF 14th Meeting. Some of these modifications are here listed:

- the formation is in large part automated,
  data and results will be available also via electronic means, but the Annual Report will be continued in paper form,
- the uncertainty of the SI second was evaluated using data coming from nine primary frequency standards (CRL, LPTF, NIST, NRLM, PTB),
- the SI second accuracy ranged from + 2 10^{-15} to +7 10^{-15}, with an uncertainty of 2 10^{-15},
- three TWSTFT links (NPL/PTB- USNO/NPL-VSL/PTB) were used for the construction of TAI.

Report of the CCTF Working Group on TAI and Report of the Sub-Group on Algorithms

As regards the CCTF Working Group on TAI details were given by Mr. Azoubib of the BIPM Time section on the new algorithm implemented on January 2001, with an improvement on the stability of TAI. Prof. Pacquet is in the final year as Chairman of the Working Group on TAI and proposed the name of Dr. P.Tavella as successor.

The Sub Group on Algorithms, formed during in 1999 started his activities in 2000, 25 people of 14 Institutions are taking part to the activities, the most important being the organisation of the 4th International Symposium on Time Scales algorithms, to be held in Paris at the BIPM in March 2002.

Redefinition of UTC: Leap seconds

A special Rapporteur Group was created by ITU-R in order to study the question raised in ITU-R 236/7 , "The future of UTC time scale". A number of options are at the moment discussed inside the Scientific Unions, ITU and other bodies concerned. The option that is gaining support is to modify the rules, enlarging the tolerance between UTC and TU1 or by a complete suppression of the leap second. Leap second was introduced more than thirty years ago and it is not necessarily appropriate now, also for the widespread use of the time information coming from the satellite navigation systems.

Time and frequency transfer methods

- CCTF Working Group on TWSTFT - Two way satellite time and frequency transfer

The TWSTFT method is currently used also for the collection of data needed for the TAI construction. Some links were calibrated using one or more of the methods:

- A portable earth station,
- A "de Jong" satellite simulator,
- Comparisons with GPS common view data.
- A number of stations are active in the Pacific Rim area and a number of research program or activities are planned for the future such as:
- Increase the number of stations and automate their operation,
- foster a link between the Pacific Rim and the European TWSTFT networks,
- calibrate participating stations,
- develop an uncertainty budget for TWSTFT,
- introduce additional TWSTFT links for the formation of TAI.

- GPS Phase measurements

As pointed out in section 2.4, this is a very promising technique based on the use of interferometric measurements performed in remote laboratories on the carriers coming from Navigation satellites. A joint research group was formed between IGS (International GPS Service) and BIPM; a report was presented by Dr. J.Ray of USNO.

The IGS/BIPM group is very active, meets frequently and presented a Recommendation.

Clocks in space

During the meeting two planned experiments with an ensemble of atomic clocks in spaceborne conditions were presented and discussed by Drs. Thomann and Sullivan. In boot cases the host will be the international Space Station.

Future satellite Navigation systems

Along the existing satellite global navigation systems, GPS and GLONASS, and the complements to provide integrity services, such as WAAS (Wide Area Augmentation System) or EGNOS (European Global Navigation Overlay System), the European Community has proposed a new navigation system named GALILEO.

GALILEO will be a spherical navigation system. Based, as the previous two systems on spaceborne clocks and a network of Earth based monitoring stations.

A report was presented about the activities of a Working Group on the Galileo Timing Interface formed inside the European Space Administration, led by Dr, Laverty, who is chairman of the abovementioned Group with other several CCTF Delegates.

Key Comparison and the Mutual Recognition Arrangement -MRA

The objective of the MRA is to establish the degree of equivalence between the National Metrological Institutes (NMI's). CCTF had formed a working group, with de Jong as a Chairman, with the task to examine and report on the consequences of the MRA for CCTF. A first report was received. The CCTF asked to Mr. De Jong to continue his activities for the future and the following terms of reference were agreed :

- To execute all actions indicated in the MRA as being the responsibility of the CCTF,
- To coordinate a required action with Regional Metrological Organisations (RMOs),
- To act as the point of contact with the CCYF on matters related to MRA,
- To report to the next meeting of the CCTF.

Meeting of the Consultative Committee for Length (CCL), 19-20 September 2001 (by Dr. J. Helmcke)

The CCL met for its tenth meeting on 19-20 September at the Bureau International des Poids et Mesures (BIPM) in Sèvres, France. It was guided by the chairman, Dr. M. Chung Myung Sai, of the Korean Institute of Standards and Science.

The main topics of the agenda were the report oft the director of the BIPM, Dr. Quinn on the implementation of the MRA, the report of the working groups in Dimensional Metrology (WGDM) about the progress in key comparisons, and in the Mise en Pratique (MePWG).

Dr. Quinn informed the meeting that the MRA had been signed and that the CCL had formally approved the first set of key comparisons. He acknowledged the enormous amount of work performed by the NMIs in submitting and reviewing Calibration and Measurement Capabilities (CMCs).

Dr. Pelelsky (NRC, Canada), chairman of the WGDM described the current situation of the various key comparisons in dimensional metrology. He defined the role of the WG as an advisory committee that makes recommendations on the need and priorities for CCL key comparisons in this subject area. All documents of from the WGDM will be available on the WGDM web site at the BIPM. They had set up seven discussion groups to consider and debate the topics of future CCL key comparisons. Six key comparisons had been approved, the duration of each comparison was between 1.5 and 2 years. In some cases it was difficult to keep the time schedule and to keep the quality of the standards to be compared.

Dr. Gill (NPL, UK), chairman of the MePWG reported that since the previous CCL meeting, there had been big progress in optical frequency and wavelengths standards and optical frequency measurements for two reasons:

First, optical frequency standards based on cold ions or atoms are beginning to demonstrate experimental line-Qs approaching he theoretical limits and potential uncertainties comparable to those of the best microwave standards.

Second, absolute phase-coherent frequency measurements have been demonstrated with wide span frequency comb generators based on mode-locked femtosecond lasers. These devices allow to phase-coherently bridge the large gap between the microwave and the optical range. It is anticipated that such frequency combs will soon be available in many standards laboratory and that the MePWG have to react on this new situation.

The following recommendations were adopted:

CCL1: The CCL, considering that

- there is an increasing move towards optical frequencies for time related activities;
- there continues to be general widening of the scope of applications of the recommended radiations of the *Mise en Pratique* to cover not only dimensional metrology and the realization of the metre, but also high resolution spectroscopy, atomic and molecular physics, fundamental constants and telecommunications

taking note of the CCTF request for a list of radiations suitable for secondary representations of the second, proposes a more encompassing title for the *Mise en Pratique*, such as

Recommended radiations for the realization of the definition of the metre and other optical frequency standards, including secondary representations of the second.

CCL2: The CCL, considering that

- new femtosecond comb techniques have clear significance for relating the frequency of high stability optical frequency standards to that of the frequency standard realising the SI second;
- these techniques represent a convenient measurement technique for providing traceability to the SI;
- comb technology can also provide frequency sources as well as a measurement technique,

recognises these techniques as timely and appropriate, and recommends further research to fully investigate the capability of the techniques,

welcomes validations now being made by comparison with other frequency chain techniques,

urges national metrology institutes and other laboratories to pursue this technology to the highest level of accuracy achievable and also to seek simplicity so as to encourage widespread application.

CCL3: The CCL, considering that

- a number of new frequency values for radiations of high stability cold atom and ion standards already listed on the recommended radiations list are now available;
- the frequencies of radiations of several new cold ion species have also recently been measured;
- new and improved values for a number of optical frequency standards based on gas cells have been determined, including the wavelength region of interest to optical telecommunications,

proposes that the list of recommended radiations be revised to include the following:

- updated frequency values for cold Ca, H and the trapped Sr^+ ion;
- frequency values for new cold ion species including trapped Hg^+, trapped In^+ and trapped Yb^+;
- updated frequency values for Rb-stabilised lasers, iodine-stabilised Nd:YAG and He-Ne lasers, methane-stabilised He-Ne lasers and OsO_4-stabilised CO_2 lasers at 10 mm;
- frequency values for standards relevant to the optical communications bands, including rubidium- and acetylene-stabilised lasers.

In CCL4 which is still provisional, values for the frequencies and wavelengths are attributed to the radiations mentioned in recommendation CCL3.

In the meantime, all recommendations have bee approved by the International Committee of Weights and Mesures (CIPM). The corresponding frequency and wavelength values are presently checked and will soon be published.

Regarding the fact, that a significant number of new and high accuracy frequency values for various cold atoms and ions have been measured which should be added to the CCL list of recommended radiations, it will probably be necessary to move some less important radiations to the list of spectral lamps and other sources. This list contains radiations which are recommended as references but where the values will not be updated.

Report of GT-RF Activities 1999-2002 (by Dr. U. Stumper)

The Working Group on Radiofrequency Quantities (Groupe de travail pour les grandeurs aux radio-fréquences - GT-RF) is a subgroup of the Comité Consultatif d´Électricité et Magnetisme (CCEM); its task is to organise key and supplementary comparisons in the RF field. Three GT-RF meetings held at the BIPM in the time from 1999 to 2001: The 13th meeting was held on 30 June 1999, the 14th meeting on 12 September 2000, and the 15th meeting on 26-27 June 2001. The 16th meeting is scheduled for 10 September 2002. An additional informal meeting was held on 19 June 2002 at the CPEM 2002 in Ottawa. The present chairman of the GT-RF is Lucien Erard (Bureau National de Metrologie-BNM, France).

At a meeting held in Paris on 14 October 1999, the directors of the national metrology institutes (NMIs) of thirty-eight Member States of the Meter Convention (MC) and representatives of two international organizations signed a Mutual Recognition Arrangement (MRA) for national measurement standards and for calibration and measurement certificates issued by national metrology institutes. The MRA is a response to a growing need for an open, transparent and comprehensive programme giving users access to reliable quantitative information on the comparability of national metrology services. Objectives of the MRA are to establish the degree of equivalence of national measurement standards maintained by NMIs, to provide for the mutual recognition of calibration and measurement certificates issued by NMIs and thereby to provide governments and other parties with a secure technical foundation for wider agreements related to international trade, commerce and for implementing new international legislation. The full text of the MRA is available in the Internet: < http://www.bipm.org/pdf/mra.pdf >.

In order to establish the degree of equivalence of national measurement standards maintained by the NMIs, international key comparisons (KCs) and supplementary comparisons of measurements are carried out, and statements of the measurement capabilities of each NMI are given in a database maintained by the BIPM available on the Web. The overall co-ordination is by the BIPM under the authority of the CIPM, which is itself under the authority of the Member States of the MC. The Consultative Committees (CC) of the CIPM (and subgroups like the GT-RF), the Regional Metrology Organizations (RMOs) and the BIPM are responsible for carrying out the key and supplementary comparisons.

In 1999, the GT-RF could already look back upon a considerable number of international comparisons performed since the mid-sixties. However, not all of these comparisons were automatically classified as KCs, and since 1999 they have to be executed according to special rules which were defined in the recent 3 years by the MC and the CCs. To initially cover as many RF measurands as possible, for a certain interim time, a number of 13 comparisons completed in 1993 or later has been approved as „interim key comparisons“ for provisional equivalence to KCs. These have to be replaced in the coming years by „full“ KCs.

The regulations for the execution of the KCs (as well as of the supplementary comparisons which are initiated and organised by the RMOs e.g. by EUROMET) are being continuously revised and improved by the CCs with participation of their subgroups (here the GT-RF) where they are also discussed. The most important rules determine how to define the KC reference values (KCRVs) from the results of the different participants and to calculate the uncertainty associated with it. All participants of the comparison must evaluate the uncertainty of measurement in the same way, namely according to the Guide to the Expression of Uncertainty in Measurement (GUM). The reports on the results of the comparisons have to be approved by the GT-RF, the Working Group of Key Comparisons (WGKC) and the CCEM itself. The WGKC is another subgroup of the CCEM. Its tasks are among others to decide which of the previous comparisons are to be considered as ²interim² KCs, to review the BIPM database concerning the electrical comparisons including the RF comparisons, and to elevate completed comparisons to KCs.

In order that the number of RF comparisons does not become too large, the GT-RF defined at several meetings a field of comparisons which would be necessary to cover all relevant RF measurands for the different measurement parameters (e.g. the different coaxial line and waveguide standards as well as the special frequency ranges) and decided that the total number of running comparisons should be constant and that a comparison of a certain RF measurand with the same parameters should be repeated not earlier than in 10 years. There are also continuous discussions on the ways of processing the CCEM and GT-RF KCs faster and more efficiently and how to publish the results in the database maintained by the BIPM. Up to now, within the GT-RF, 17 new KCs and 3 supplementary EUROMET comparisons are planned or are in progress. The Reports of 6 of them are nearly ready for approval by WGKC and CCEM. The results of one supplementary EUROMET comparison are being prepared for publication. The status of all the KCs is shown in the Internet: <http://kcdb.bipm.fr/BIPM-KCDB/AppendixB/search_results3_4.asp >.

5. Commission A sponsored meetings

Budget 1999-2002: 9000 EURO.

In the following table the data concerned with different kinds of sponsorships are reported. Mode A sponsorship does not involve any financial commitment, mode B sponsorship involves also a financial support. For this last mode Commission A grants have been offered to Young Student Programs. Usually the meetings sponsored are International Conferences, however during this triennium there was the opportunity to support also a School on Metrology organised by SIF (Italian Physical Society), IEN (Electrical National Institute), and BIPM (Bureau International des Poids et Mesures). The next School is scheduled for 2006. Among the inernational conferences CPEM, for which URSI is a permanent sponsor, is the foremost meeting series in electromagnetic metrology.

Meeting	Mode/€	Report/Representative
CPEM 2000 Sydney,Australia May 14-19,2000	B 1000	Report by Dr. J. Hunter CSIRO R S Bulletin No 294
EUROELECTRO MAGNETICS 2000 Edinburgh,Scotland,UK May 30-June 2,2000	A	
Symposium and Exhibition EMC 2000 Wroclaw, Poland June 27-30, 2000	B 1000	Report by Prof. R. Struzak ITU R S Bulletin No 295
School of Physics E. Fermi Recent Advances in Metrology and Fundamental Constants Varenna, Italy July 25-August 4, 2000	B 2000	Report by Dr. P. Tavella IEN R S Bulletin No 296
Symposium and Technical Exhibition on EMC Zurich 2001 Zurich, Switzerland February 20-22, 2001	B 1000	Report by Prof.G.V. Meyer ETH R S Bulletin No 297
2001 Asia-Pacific Radio-Science Conference Tokyo, Japan August 1-4, 2001	B 1000	URSI Representative Prof. Yoji Furuhama
CPEM 2002 Ottawa, Canada June 16-21, 2002	B 1700	URSI Representative Dr. A. Michaud NRC
Symposium and Exhibition EMC 2002 Wroclaw, Poland June 25-28, 2002	B 300	URSI Representative Prof. R. Struzak ITU
EMC EUROPE 2002 Sorrento, Italy September 9-13, 2002	B 1000	URSI Representative Prof. P. Bernardi Univ. La Sapienza Roma
JINA 2002 Nice, France November 12-14, 2002	A	URSI Representative Prof. A. Van de Capelle K.U. Leuven

Report on the Conference on Precision Electromagnetic Measurements, CPEM 2000, Sydney, 14-19 May, 2000

The biennial Conference on Precision Electromagnetic Measurements (CPEM), for which URSI is a permanent sponsor, is the foremost international conference series in electromagnetic metrology. CPEM 2000, the 21st conference in the series, was held in Sydney, Australia, from 14-19 May 2000 and hosted by the National Measurement Laboratory (NML) of the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia, and jointly organised with the Measurement Standards Laboratory of New Zealand. It was only the second time that the conference had been held outside North America and Europe, reflecting the growing importance of the Asia Pacific region in world metrology.

A total of 435 delegates attended from 43 countries. The CPEM tradition of supporting young metrologists was continued by providing 14 "Young Scientist" awards to assist recipients from the USA, UK, Switzerland, Mexico, Italy, Germany, France, Croatia, China, Canada and Australia to attend. There was also a special category of support for participation by representatives of developing economies, assisted by sponsorship from several of the National Metrology Institutes (NMIs) in developed economies.

CPEM 2000 recognised the ever-increasing emphasis on global trading and international trade agreements, and the need for mutual acceptance of national standards between economies and measurement traceability within economies. The global Mutual Recognition Arrangement (MRA) between NMIs for the mutual recognition of national standards and calibration certificates issued by NMIs was established in October 1999 to address this situation. Its success depends on the development of more accurate and more stable standards accessible either directly or indirectly by all economies. This challenge for NMIs was reflected in CPEM 2000 through a special provision for 'key comparison' papers, and an evening discussion session on participation by NMIs in the global MRA.

The pioneering work of Mr Ian Harvey in conceiving and developing the Cryogenic Current Comparator (CCC) was recognised at the conference dinner by the award of a medal on behalf of the international electrical metrology community. The CCC is now widely used in resistance measurements, including Quantum Hall Resistance, and in development work on Single Electron Tunnelling. The medal presentation was made by Dr Norman Belecki, Chairman of the CPEM Executive Committee. In reply, Mr Harvey gave a brief history of his work.

During the conference, seven plenary speakers discussed basic advances in physics, metrology in astronomy, and developments in national standards and international comparisons. The plenary speakers were Dr Michael Pepper (University of Cambridge, UK), Professor Ron Ekers (Australia Telescope National Facility, CSIRO, Australia), Dr Barry Taylor, (National Institute of Standards and Technology [NIST], USA), Dr Clark Hamilton, (NIST, USA), Dr Robert Hebner (University of Texas, USA), Dr Ernst Göbel (Physikalisch Technische Bundesanstalt [PTB], Germany), and Dr Terry Quinn (Director of the International Bureau of Weights and Measures [BIPM], France).

CPEM 2000 coincided almost to the day with the 125th anniversary of the signing of the Convention du Mètre, which is the foundation for the harmonisation of international metrology. To commemorate this occasion, the subject of Dr Quinn's plenary paper was the history and future of the Convention du Mètre and the BIPM. Members of the International Committee of Weights and Measures (CIPM) held a meeting on the anniversary day, 20 May, at Sydney Observatory and a number of CPEM 2000 delegates joined them for a luncheon to mark 'World Metrology Day' as it is now to be known.

329 other technical papers were presented, covering research developments in the traditional areas of electrical and electromagnetic metrology at frequencies from DC to millimetre waves, and also advances in quantum effect devices and their applications, automated instrumentation, calibration systems, electromagnetic compatibility, lasers and optoelectronics, optical metrology, time and frequency metrology, along with reports on fundamental constants and on progress in the development of an atomic-based kilogram. The distribution of papers is shown in the following table.

Approximately two-thirds of these papers were presented as posters in sessions reserved solely for that purpose, with the remainder presented orally in three parallel sessions. All sessions were well-attended, and good use was made of the opportunities for extended interaction between presenters and delegates at the poster sessions.

Technical discussions at the conference included the following.

Optical Frequency Standards and Frequency Chains:
The problem of practical and routine multiplication of the microwave resonance frequency of the cesium atom (which defines the second in the SI system of units) to optical frequencies is now widely regarded as having been solved by a new system based on ultra-short pulses generated by a laser. The system was developed at the Max Planck Institute for Physics in Germany, and is an essential component of the next generation of ultra-stable atomic clocks, which will be based on optical absorption resonances in atoms.

Atomic fountains and clocks:
Cesium atomic fountain clocks are now in routine operation at the Laboratoire Primaire des Temps and Frequences (LPTF) in France, NIST, and the PTB. Many others are under development by other organisations. Some of these fountains have demonstrated, or are capable of, accuracies approaching 1 part in 10^{15}, limited mainly by frequency shifts arising from collisions between the cold cesium atoms. LPTF and Yale University have recently developed rubidium fountain clocks, motivated by the much smaller susceptibility of rubidium atoms to collisional frequency shifts. For this reason, rubidium may be a more suitable atom for defining the SI second than cesium.

Several organisations are developing space-flyable cold atom clocks for a range of fundamental experiments mostly related to General Relativity.

Voltage Comparisons:
Comparisons of voltage between laboratories often use Zener-based standards, which are readily portable, but have been found to be sensitive to temperature, relative humidity and pressure. Several NMIs have started characterising such standards for these sensitivities to improve international comparisons of voltage.
The need to keep Zener standards continuously powered during transportation can cause problems. Some investigations into the effects of transporting unpowered standards have yielded promising results.

A Finnish company reported the development of micromechanical silicon devices for standards applications, including AC to DC converters suitable for batch fabrication, and a novel DC voltage reference which may prove more stable than the currently used Zener diode voltage references.

High Voltage
The PTB has developed a shielded resistive divider for 100 kV DC that uses compressed gas insulation and has a claimed uncertainty of 1 part in 10^7, which is thought to be a limit for this type of design.

AC-DC transfer
The latest international comparisons show agreement between NMIs of around 2×10^{-6} at 1 kHz and 1×10^{-5} at 1 MHz. Several NMIs are working on further reduction of measurement uncertainty by means of an absolute AC voltage standard based on the Josephson effect. Josephson arrays have been well established for many years as fundamental standards of DC voltage. The most promising techniques to extend their application to AC voltage standards involve the so-called pulse-driven arrays.

Impedance
The National Physical Laboratory (NPL), UK reported on a new four terminal-pair bridge which will ultimately improve the traceability of impedance measurements in the frequency range up to 1 MHz.

AC Quantum Hall Resistance:
AC Quantized Hall Resistance (ACQHR) measurements made at the NPL and the PTB using the same samples achieved different results, particularly for the frequency dependence of the quantised Hall resistance, confirming the difficulties of such measurements.

The BIPM has been measuring the ACQHR in the presence of an applied back gate voltage, enabling the previously observed but unwanted current and frequency dependence to be reduced or eliminated.

Electrical determination of the kilogram:
A new superconducting levitated-mass mechanism is being constructed in Japan as a means of obtaining a link between the kilogram and electrical units.

Next CPEM The next CPEM will be held in Ottawa, Canada from 16-21 June 2002. The CPEM 2002 secretariat is contactable at CPEM02@nrc.ca .

Topic	No. of Papers
Atomic Fountains and Clocks	8
Frequency Stabilised Lasers	9
Optical Frequency Standards and Frequency Chains	20
Time Transfer	9
Cesium Standards	5
Cryogenic Resonators	4
Optical Metrology	8
High Resolution Spectroscopy	3
Lasers and Length	12
DC Resistance and Comparators	21
DC Transportable Standards	5
DC Voltage and Current	12
Voltage Comparisons	6
AC Voltage and Current	4
Advances in AC-DC Transfer	17
Power and Energy	13
Impedance	24
Capacitance Standards and AC Voltage Ratio	6
High Voltage	11
Josephson Array Development	9
Quantum Hall Resistance	11
AC Quantum Hall Resistance	4
Single Electron Tunnelling	13
Microwave Reflectometry and Power	4
Microwave Field Probes, Materials and ESD	4
Microwave Oscillators	4
Microwave Noise and Material Parameters	9
Microwave Impedance and Power	13
Antennas, Fields and EMC	6
Avogadro Constant	9
Watt Balance and Newtonian Gravitational Constant	4
Gravitational Constant and Magnetic Levitation	4
Determination of G	4
Magnetic Measurements	9
International Comparisons	12
Calibration Processes	3
Signal Analysis	6
Micromechanics and Thermometry	4

Report on the 15th International Wroclaw Symposium on Electromagnetic Compatibility (EMC) 2000

See the Radio Science Bulletin, No 295, and at www.emc.wroc.pl.

Report on International School of Physics "Enrico Fermi", Varenna, Italy

Recent Advances in Metrology and Fundamental Constants
Tuesday 25 July - Friday 4 August 2000
The Course on *Recent Advances in Metrology and Fundamental Constants* was organized by the Italian Physical Society, the Istituto Elettrotecnico Nazionale of Italy, and the Bureau International des Poids et Mesures also as a contribution to the celebration of the 125 years of the Metre Convention.

This course was supported by the direct presence of the BIPM and of many National Metrological Institutions and it was attended by 71 well-qualified students from 18 different countries and who contributed with simulating and interacting discussions.

In the field of *Metrology and Fundamental Constants* many improvements took place over the past decade and these were discussed at the School; from one side the old caesium SI second definition has found a new realisation, with the "fountain" approach, replacing the classical thermal atomic beam. The use of "cold" atom techniques, in which bunches of inert atoms are collected, slowed down, and cooled, has opened a number of new and unexpected avenues for metrology and fundamental constants; one of these possibilities being the atom interferometry. Another important "quantum jump" was the demonstration of the possibility of performing a direct frequency division in the visible, using ultra short femtosecond pulses. In addition, the possibility of "counting" electrons or photons gave a fundamental support to the development of single-electron capacitance standards and to new scenarios in the absolute calibration of photo-detectors.

The success of this third Course was made possible by the close co-operation and strict dedication of many Institutions, lecturers, students and persons that are here all acknowledged.

In particular, the Italian Physical Society, the Bureau International des Poids et Mesures, the "Istituto Elettrotecnico Nazionale", the "Istituto di Metrologia G. Colonnetti" of CNR, the European Community, the Italian Ministry of Foreign Affairs, the International Union of Radio Science, and the UNESCO provided financial support for the attendance of several students.

The topics presented and discussed at the school were:

- Evolution on the last decade of the International System; ν and λ metrology: laser confinement, cooling , atomic clocks, and optical frequency standards;
- Radio/photometry: new ideas on radiometry, quantum optical metrology;
- Quantum based electrical standards: quantum Hall devices, new applications of Josephson junctions, single electron devices;
- Fundamental constants: impact in physics and metrology, gravitation measurement, measurements of G, a, R, Avogadro, Planck constants;
- New horizons: Bose-Einsten condensation, atomic interferometry, chaos;
- Mass metrology, relativity and statistics in metrology.

The participating Students and Observers were 71 from 18 Countries, subdivided as follows: 1 Australia, 1 Brazil, 1 Czech Rep., 1 Denmark, 1 Estonia, 3 BIPM, 4 France, 7 Germany, 3 Mexico, 1 Nepal, 1 Netherlands, 2 Romania, 4 Russia, 1 South Africa, 4 Switzerland, 1 Taiwan, 2 UK, 4 USA, 29 Italy

The 20 lecturers giving on the whole 51 hours of lessons were: Wolf (BIPM), Davis (BIPM), Esteve (CEA, France), Vanier (Canada), Phillips (NIST), Sergienko (Boston, USA), Jeckelmann (Ofmet, CH), Mills (UK), Fox (NPL), Petley (NPL), Wilkening (PTB), Helmcke (PTB), Haensch (MPI), Andreone (IEN), Bich (IMGC), Mana (IMGC), Bittanti (Poli MI), Inguscio (LENS), Arecchi (INO), Nobili (Uni PI). and additional seminars were given by: Gavioso (IEN), Martinis and Keller (NIST)

The school directors where T.J.Quinn (BIPM) and S.Leschiutta (IEN), while Patrizia Tavella (IEN) was scientific secretary.

Report on Symposium and Technical Exhibition on EMC Zurich 2001

The 14th International Zurich Symposium and Technical Exhibition on Electromagnetic Compatibility (EMC Zurich '01) was held from February 20 through 22, 2001 at the Swiss Federal Institute of Technology in Zurich (ETH Zurich), Switzerland. The meeting was attended by 846 participants from 40 countries and has included 48 exhibitor booths.

As in the preceding years, the Symposium which is sponsored by the Swiss Electrotechnical Association (SEV), has been organized by the Communication Technology Laboratory of the ETH Zurich under the auspices of Mr. F.Rosenberg, Swisscom. Prof. Dr. P. Leuthold and Dr. G. Meyer acted again as symposium president and symposium chairman, respectively. The technical program committee was chaired by Dr. F. Tesche (Fairview, USA). A number of international and national professional organizations were cooperating, e.g. IEEE, ITU and URSI. As in the past URSI Commissions A and E have sponsored the participation of young scientists.

A total of 131 carefully selected technical papers were presented in 19 sessions devoted to: EMC protection, adverse effects of high power EM, medical and biological issues, EMC in networks, sensors and probes, EMC in power systems, transients, transmission lines, modelling large chips and packages, lightning, measurement techniques, computer codes and validation, high frequency methods and analysis, test chambers and cells, PCBs in the GHz range, EMC innovation, EMC in communication systems, reverberation chambers and chip-level EMC. The sessions covered virtually all EMC "hot" topics and reviewed the current status as well as future trends of EMC technology. The full text of the presentations has been made available in the symposium proceedings and on a CD-ROM.

As in previous symposia the program did not exclusively address experts. An introduction to EMC technology for new comers was offered by two tutorial lectures and three workshops. In the IEEE EMC Society workshop the latest standardization for measurements above 1 GHz including the uncertainties associated with these measurements have been presented. A new platform for the symposium exhibitors has been introduced, the so-called Industrial Forums, with the objective of providing the attendees some practical and industrial aspects of EMC.

An insight into the work of URSI Commission E was offered by open meetings dealing with the progress in the different working groups and identifying outstanding topics and new lines of future research. Once again, a number of national and international organizations used the opportunity of the symposium to held open and closed meetings in coordination with EMC Zurich. The IEEE EMC Society Board of Directors held the first meeting of the year as an open meeting. The research cooperation on Sustainable Mobile Communication has been introduced in a meeting. Their mission is to support innovative research on EMF risks attributed to cellular-phone technology. A further open meeting was organized by the IARU (International Amateur Radio Union) on EMC problems experienced and caused by radio amateurs. The contributions of these joint events have been made available in a supplement to the symposium proceedings.

Centres of gravity of this symposium have been the field of EMC analysis and prediction with six sessions and a workshop devoted to this area. These sessions focused on the continuous developments of numerical methods for modelling, analysis, prediction and mitigation of EMC effects. The basic strategies rely on a step-by-step treatment of well-structured EMC scenarios at different topological levels. Better defined and simpler test methods, with reduced measurement uncertainty, could significantly reduce the cost of design and testing of the final product. Four sessions and a workshop have dealt with this area. Testing gives the final answer to EMC, and sophisticated sensors and probes are prerequisites for efficient testing. It is difficult to point out general trends in the field of EMC but with the growing interest in theoretical models and numerical methods, the role of computers is becoming more and more important. Also with the trends to higher integration and to nanotechnology, EMC models and tools for MMCs, microsensors and nanomachines are gaining attention and new effects will have to be taken into account.

As usual, the Technical Exhibition has significantly contributed to the success of EMC Zurich'01 by demonstrating the fast conversion of theoretical knowledge into state-of-the-art hard- and software. The traditional inquiry returned some very interesting suggestions for the next EMC Zurich Symposium which is planned for February 18 through 20, 2003.

The call for papers of the 15th International Zurich Symposium and Technical Exhibition on EMC is scheduled for November 2001.

Report on 2001 Asia-Pacific Radio Science Conference (AP-RASC'01) Chuo University, Tokyo, Japan, August 1-4, 2001 (by Prof. Yoji Furuhama)

Organisers:

Conference Chairperson: Y. Furuhama, International Advisory Board (Chairperson: H. Matsumoto), International Steering Committee (Chairperson: Y. Furuhama), Organizing Committee (Chairperson: S. Okamura)

Sponsors and co-sponsors:

Sponsored by Japan National Committee of URSI, The Institute of Electronics, Information and Communication Engineers (IEICE) and co-sponsored by International Union of Radio Science (URSI).

Number of participants (young scientists, students, countries represented)

704 participants from 34 countries/regions, with 48 young scientists from 17 countries/regions, whose travelling expenses were partly granted by the Conference Organizing Committee.

Scientific results

The AP-RASC'01 was the first Asia-Pacific regional URSI conference to be held between URSI General Assemblies. The objective of this conference was to stimulate and to coordinate the research activities of radio science in the Asia-Pacific area. The main theme of this conference was "Radio Science - Communications, Environment, and Energy".

A total of 599 regular papers was presented (oral: 404, poster 195). A total of 86 sessions was organized; one was union session entitled "Solar power satellite and wireless power transmission", and other 85 sessions were organized corresponding to each commissions of URSI. Nine joint-commission sessions were also included. In addition to these sessions, one large unified poster session was held on Friday afternoon, August 3, 2002.

Two General Lectures were presented; one was "Mobile Communications Technology – Most Brilliant Application of Radio Science" by Prof. Yasuhiko Yasuda (Waseda University, Japan), and the other was "Challenges at the Frontiers of Science and Engineering in Radio Astronomy" by Prof. Govind Swarup (Tata Institute of Fundamental Research, India).

The conference began on the afternoon of 1 August, and was followed by Welcome Reception, both at Chuo University. A Banquet was also held on the evening of 4 August at Tokyo Dome Hotel and all participants were cordially invited. Although Accompanying Person's Program and Scientific Visits were not prepared, a demonstration of the wireless power transmission simulator (SPRITZ) was held during the conference.

Although AP-RASC'01 was its first meeting, the conference was very successful. The Joint Meeting of the International Advisory Board and the International Steering Committee for AP-RASC'01 was held on 2 August and it was agreed unanimously that AP-RASC be held triennially between two consecutive URSI GAs. After this meeting, negotiation for the next meeting was made among related nations and it was decided that the next AP-RASC would be held in China in 2004. This decision was announced by the Conference Chairperson, Dr. Furuhama, at the Banquet on the evening of 4 August. The detail of the next AP-RASC will be decided and announced soon.

6. In memoriam

Before the conclusion of this report, let us recall a few outstanding scientists who passed in this period:

- Dr. Motohisa Kanda served as Chair of Commission A, developed new theory and measurement techniques for establishing and measuring electromagnetic fields and evaluating electromagnetic compatibility;
- Dr. Louis Essen served as Chair of Commission 1, obtained important results in the measurements of the speed of light, realized highly stable quartz oscillators and the first operational Cs standard (1955);
- Dr. Kennet Evenson whose highly accurate optical frequency measurements improved the determination of the speed of light and led to the actual definition of the metre.

COMMISSION B

This triennium report was prepared by Professor S. Ström, Commission B Chair 1999-2002.

Introduction

The officers of Commission B during the triennium 1999 - 2002 have been Prof. Staffan Ström, Sweden, Chair, and Prof. Makoto Ando, Japan, Vice-Chair. Immediate Past Chair has been Prof. Chalmers Butler. The Chair, Vice-Chair and Immediate Past Chair have formed " The Commission B Executive Committee ", in which important Commission B matters have been discussed. To fulfil its role in URSI properly, Commission B relies on the dedicated and enthusiastic support of a large number of Commission B colleagues as described below in this report and its enclosures.

The 2001 International Symposium on Electromagnetic Theory

The main activity of Commission B between the General Assemblies is its International Symposium on Electromagnetic Theory (referred to by the acronym EMTS in the following). The scope of the EMTSs The seventeenth Symposium in this series took place in Victoria, Canada, May 13-17, 2001. It was hosted by the Canadian Member Committee of URSI and organised by a Local Organising Committee (LOC) at the University of Victoria, in collaboration with the Canadian National Research Council (NRC). The Chair of the LOC was Prof. Jens Bornemann, Univ. of Victoria. A group at the NRC in Ottawa headed by Pierre Lamoureux was in charge of handling the submitted papers. Thanks to the facilities available at NRC, this could be done all-electronically. The submitted papers were collected and organised into topic areas at a website with access for reviewers only. In this way a very convenient and efficient procedure could be used, which greatly facilitated the task of the Technical Programme Committee (TPC).

The scope of the EMTSs encompasses all areas of electromagnetic theory and its applications. The 2001 EMTS was attended by 221 delegates from 36 countries. The programme consisted of 215 presentations, selected by the TPC from more than three hundred submissions, and was organised into 28 sessions. Five of these were ' Special Sessions ', each organised by two convenors and consisting wholly or mostly of invited papers. The Special Sessions and their convenors were as follows:

0. Beam Superposition (E.Heyman and L. Felsen)
1. Time Domain Integral Equations (T. Sarkar and E. Miller)
2. Recent Advances in Periodic Structures (G. Eleftheriades and D. Jackson)
3. Waves and Fields in Complex Media (A. Sihvola and N. Engheta)
4. Absorbing Boundary Conditions and Their Applications (R. Ziolkowski and M. Okonievski

The report on the 2001 EMTS by Jens Bornemann and enclosed with the present report contains more details. Further statistics are given in a report that is also enclosed.

It was noted that attendance and contributed papers were lower than at the previous 1999 EMTS in Thessaloniki, Greece. This was attributed mainly to the sharp downturn that most IT-related companies experienced at the time of the 2001 EMTS, which made travel support etc harder to obtain. However, the situation encountered for the 2001 EMTS gave Commission B reason to re-consider its activities, in particular its conference activities (cf. the comments below concerning the Commission B business meeting during the 2001 EMTS).

One consequence of the budgetary constraints imposed by the lower attendance was that the number of Young Scientist Awards that could be granted was limited to ten. The total cost for these awards were born jointly by the LOC and Commission B (as before, Commission B spends essentially all of its grant from URSI on Young Scientist Awards at the EMTSs).

The 724 page Proceedings from the 2001 EMTS, edited by Maria Stuchly and Donna Shannon contain the accepted invited and contributed papers. For information about purchasing these Proceedings, contact Centre for Advanced Materials and Related Technology, c/o Donna Shannon, Tel. 1-250-721 8821, e-mail: DShannon@engr.uvic.ca, or Dept. of Electrical and Computer Engineering, University of Victoria, Box #3055, Stn. CSC, Victoria, BC V8W 3P6, Canada.

As on several previous occasions, Radio Science has kindly agreed to publish a ' Special Section ' containing selected papers based on presentations at the 2001 EMTS. Prof. Akira Ishimaru, Univ. of Washington, has again agreed to serve as Co-Editor for this Special Section, together with the Commission B Chair. It is expected to appear in a Radio Science issue during the fall of 2002.

Business meeting at the 2001 EMTS

One Commission B business meeting was held during the 2001 EMTS. All symposium participants were cordially invited to attend. Well ahead of the symposium and as a follow-up on a decision during the Toronto GA, the Commission B representatives had been invited to submit proposals to organise the 2004 EMTS. The proposals were reviewed by an ad hoc committee consisting of E. Heyman, Israel, and A. Sihvola, Finland, who recommended that a vote should take place between the proposals from Egypt and Japan. The vote, conducted by e-mail, favoured the proposal from Egypt to hold the 2004 EMTS in Alexandria. At the business meeting in Victoria, Prof. S.E. El-Khamy, representing the Egyptian proposers, gave further details of their plans for the EMTS and answered questions from the audience.

The chair also announced the upcoming issues of election of incoming Vice-chair at the 2002 Maastricht GA, as well as a planned early invitation to Commission B representatives to submit proposals to organise the 2007 EMTS.

As Commission B operates at present, the organisation of the EMTS and the Commission B part of the GA programme constitutes the main efforts of the Commission B Officers and Session Convenors. These efforts are governed by and a manifestation of scientific considerations and judgements. However, they should constantly be reviewed and modified so as to make sure that they are optimal in relation to the Commission B goals. Other types of activities and initiatives may also be motivated to realise those goals. In view of this, the Chair suggested that an ad hoc working group should be formed and charged with the task of taking a fresh look at the Commission B activities and to formulate proposals for change when deemed appropriate. The proposal was met with a positive response. The group was named the Commission B Technical Advisory Board (with acronym B-TAB). The discussion concerning the B-TAB was continued as part of the Closing Ceremony of the 2001 EMTS. Time-wise the most pressing issue was that of planning for an expanded activity relating to the preparations for the 2004 EMTS (parallel workshops, more Special Sessions, more long invited talks etc.). In view of the fact that B-TAB would deal with questions that would influence Commission B activities into the next triennium, the Chair suggested that B-TAB be chaired from the beginning by the present Vice-Chair, Prof. Makoto Ando. Prof. Ando kindly agreed to this.

Preparations for the 2002 GA in Maastricht.

Commission B has planned an extensive scientific programme for the 2002 GA. The details of this will be reported elsewhere. However, Commission B has taken note of the shorter format of the General Assemblies and we have limited ourselves to 8 Commission B oral sessions (as compared to 10 at the previous GA. In addition there is one Commission B Poster Session that is not connected to an oral session (plus poster sessions related to most of the oral sessions). Commission B also participates in 8 joint sessions, two of which are the prime responsibility of Commission B. The mail ballot concerning incoming Vice-Chair at the GA has been prepared by an ad hoc committee consisting of past chairs David Olver and Chalmers Butler. Two candidates have been nominated, namely Prof. Lotfollah Shafai, Univ. of Manitoba, Canada, and Prof. Roberto Tiberio, Univ. of Siena, Italy, and the ballot by mail concerning these two candidates has taken place as prescribed by the URSI rules (with the vote being completed at the GA).

Letters to the Commission B representatives

During the triennium the Chair has communicated with the Commission B representatives through a series of e-mail " Letter no X ". These are listed separately below.

Sponsorship for conferences within the Commission B area

Consistent with the practice of past years, Commission B has sponsored meetings held by other organisations on topics which fall within the purview of the terms of reference for Commission B. However, consistent with the policy established some years ago, Commission B only gives Mode A support (as mentioned earlier, Commission B spends its grant on Young Scientist Awards). Some 15 conferences have received Mode A sponsorship.

Conclusion

It is my great pleasure to thank all those colleagues who have participated in the activities of Commission B and who have given so generously of their time and expertise. Without your contributions there would hardly be a Commission B. I would also like to express my great appreciation of the help that the URSI Secretariat and particularly Inge Heleu has always provided. That has facilitated my task enormously. Thank you all !

COMMISSION C

This triennium report was prepared by Professor E. Bonek, Commission C Chair 1999-2002.

Commission C „Signals and Systems" deals with a variety of topics. Commission C sees its scope in the crossfertilization of radio, signal processing and telecommunications sciences. Whereas it is obvious that many core topics of radio science, e.g. radio astronomy and radar, heavily rely on tremendously sophisticated signal processing methods, signal processing is a science for itself, outside of radio. Telecommunications have seen a paradigm shift in the last decade through radio science, as evidenced by the sweeping success of cellular mobile radio, notably GSM. But telecommunications is also a world by itself. The number of annual international conferences in either field has risen enormously.

This competitive situation makes it extremely difficult to bring together scientists from all three areas, and The International Symposium on Signals, Systems and Electronics (ISSSE), traditionally organized by URSI in between General Assembles, has to compete with many other conferences.

Last year's ISSSE 01 was made a success by hard work of the Japanese URSI community. Its motto was "Questing more significant harmony and integration: Systems/Devices and Software/Hardware".

The organizers had taken great efforts to put together an interesting program and a nice, hospitable surrounding (and a grand dinner). The fashionable venue, a large hotel in Tokyo, made attendants forget how hot is was outside in the street -even the local residents said it had been unusually hot.

Altogether there were 114 papers, about half of them invited. The bulk came from Asia (58), 39 were authored by Europeans and 12 by North Americans, with the rest divided among South America, Africa, and Oceania. Registration turned out to be disappointing: only 120 persons attended, which was a shame given the fine program offered and the hard work put into the organization.

Topical meetings dedicated to a narrow field of radio science and/or signal processing offer a good value for attendants. The same is true for regional conferences. Therefore, Commission C has supported the following conferences in the last triennium, some of them also financially (see amounts in parentheses).

- Radio Africa '99, Gaborone, Botswana, 25-29 October 1999 (USD 1,500)
- ICCEA'99 - Int. Conf. On Computational Electromagnetics and its Applications, Beijing, China, 1-4 November 1999
- ISRAMT'99 : Int. Symp. on Recent Advances in Microwave Technology, Malaga, Spain, 13-17 December 1999
- 8th Int. Conf. on HF Radio Systems and Techniques, Guildford, UK, 10-13 July 2000
- Second Int. Symp. on Turbo Codes and Related Topics, Brest, France, 4-7 September 2000
- EPMCC 2001, Fourth European Personal Mobile Communications Conference, Vienna, Austria, 20-22 February 2001 (EUR 1,000)
- ISSSE'01 Tokyo, Japan, 24-27 July 2001 (EUR 4,000)
- 2001 Asia-Pacific Radio Science Conference (AP-RASC'01), Tokyo, Japan, August 1-4, 2001 (EUR 1,000)
- ICEAA'01, Int. Conf. on Electromagnetics in Advanced Applications, Turin, Italy, 10-14 Sept. 2001
- Radio Africa 2001 - Fourth Int. Workshop on Radio Communication in Africa, Cape Coast, Ghana, 15-19 October 2001 (EUR 1,000)
- APMC'02 : Asia-Pacific Microwave Conference, Kyoto, Japan, 19-22 November 2002

For ISSSE 2004 there is an offer to hold it in Austria, either Linz or Salzburg.

COMMISSION D

This triennium report was prepared by Professor A. Seeds, Commission D Chair 1999-2002.

The growing importance of wireless and optical communication technology coupled with the internet growth has led to continued strong interest in the activities of Commission D, "Electronics and Photonics".

We have continued the successful policy of providing technical co-sponsorship to a number of meetings of interest to Commission D while focusing financial sponsorship on the established International Symposium on Signals Systems and Electronics, ISSSE, jointly sponsored with Commission C. For this triennium we also provided financial sponsorship to the 2001 Asia-Pacific Radio Science Conference (AP-RASC'01).

1. ISSSE'01

The 2001 International Symposium on Signals, Systems, and Electronics- ISSSE'01 - was held on July 24 - 27 2001 at the Hotel Grand Palace, Tokyo, Japan with conference theme "Questing More Significant Harmony and Integration: Systems/Devices and Softwares/Hardwares". The Co-Chairmen were Professors M. Akaike (Science Univ. of Tokyo) and K. Kikuchi (Univ. of Tokyo), with Thechnical Programme Committee chaired by Dr. H. Ogawa (Comm. Res. Labs). Other sponsors included the Institute of Electronics, Information and Communication Engineers (IEICE), Communications Society and Electronics Society, with co-operative sponsorship by Science Council of Japan and IEEE Japan Council.

The symposium topics were: (1) Software-oriented radio transmitters/receivers, (2) Wireless channel equalization, (3) Signal detection and interference cancellation, (4) Advanced wireless radio networks, (5) Hardware/software cooperation in radio equipment, (6) Diversity/ RAKE reception, (7) Anti-fading techniques, (8) Radio-frequency synthesizers, (9) Digital signal processing, (10) Smart antennas, (11) Optical signal processing, (12) Large-capacity optical transmission, (13) Integrated modules and elements, (14) Hardware-oriented signal processing and compression, (15) Advanced technologies for RF circuits, (16) Devices for microwaves and photonics, (17) Microwave/ photonic integrated devices/systems, (18) Devices modeling and design, (19) Numerical and CAD techniques, (20) Millimeter-waves applications, (21) Cooperation of optical and microwave guides, (22) New materials and devices and their application, (23) Full-scale system on a single chip

The number of registered attendees was 117 and 114 papers were presented from 26 countries in 6 regions, as follows: Asia: 58 papers, Europe: 39 papers, North America: 12 papers, South America: 2 papers, Oceania: 2 papers, Africa: 1 paper

There were two Tutorial Sessions, the first by Dr. M.Fujise, CRL, Japan on "Millimeter-Wave ITS Communications" and the second by Dr. K.Yoshida, JTDC, Japan on "New Trend Scenarios and their Devices for Bluetooth Wireless Technology". A special session was also presented on "R & D Activities at Yokosuka Research Park (YRP) -Broadband Wireless Access Technologies"

A banquet was held on July 26 where the ISSSE'01 award was presented. A proposal is being prepared to hold the next ISSSE, ISSSE'04 in Vienna, Austria.

2. AP-RASC'01

The meeting was held at Chuo University, Tokyo, Japan on August 1-4, 2001. The Conference Chairman was Dr. Y. Furuhama, supported by an International Advisory Board (Chairperson: H. Matsumoto), an International Steering Committee (Chairperson: Y. Furuhama) and an Organizing Committee (Chairperson: S. Okamura). Other sponsors included The Institute of Electronics, Information and Communication Engineers (IEICE).

The meeting was very well attended with 704 participants from 34 countries/regions, with 48 young scientists from 17 countries/regions, whose travelling expenses were partly supported by the Conference Organizing Committee.

The AP-RASC'01 was the first Asia-Pacific regional URSI conference to be held between URSI General Assemblies. The objective of this conference was to stimulate and to coordinate the research activities of radio science in the Asia-Pacific area. The main theme of this conference was "Radio Science - Communications, Environment, and Energy".

A total of 599 regular papers were presented (oral: 404, poster 195). A total of 86 sessions were organized; one was a union session entitled "Solar power satellite and wireless power transmission", and the other 85 sessions were organized corresponding to each commissions of URSI. Nine joint-commission sessions were also included. In addition to these sessions, one large unified poster session was held on Friday afternoon, August 3, 2002.

Two General Lectures were presented; one was "Mobile Communications Technology – Most Brilliant Application of Radio Science" by Prof. Yasuhiko Yasuda (Waseda University, Japan), and the other was "Challenges at the Frontiers of Science and Engineering in Radio Astronomy" by Prof. Govind Swarup (Tata Institute of Fundamental Research, India).

The conference began on the afternoon of 1 August, and was followed by Welcome Reception, both at Chuo University. A Banquet was also held on the evening of 4 August at Tokyo Dome Hotel and all participants were cordially invited. Although Accompanying Person's Program and Scientific Visits were not prepared, a demonstration of the wireless power transmission simulator (SPRITZ) was held during the conference.

Although AP-RASC'01 was its first meeting, the conference was very successful. The Joint Meeting of the International Advisory Board and the International Steering Committee for AP-RASC'01 was held on 2 August and it was agreed unanimously that AP-RASC be held triennially between two consecutive URSI GAs. After this meeting, negotiation for the next meeting was made among related nations and it was decided that the next AP-RASC would be held in China in 2004. This decision was announced by the Conference Chairperson, Dr. Furuhama, at the Banquet on the evening of 4 August. Details of the next AP-RASC will announced soon.

3. 2002 General Assembly

The technical areas of interest to Commission D have been well-supported for the Maastricht General Assembly, with 92 papers scheduled in the following sessions:

- Radio over Fiber Technologies
- Femtosecond/Terahertz Technology
- Optical Microwave Interactions
- MEMS (Micro Electro Mechanical Systems) in Microwaves, Millimeterwaves and Optics
- Nanotechnologic Processes for Advanced Optic and Electronic Systems
- Wave Propagation in fast Photonic Devices
- Photonic Signal Processing
- Electromagnetic Band Gap Structures and their Applications
- Photonics in Radio Astronomy (Joint with Comm. J)
- Advances in Superconductor Components and Applications (Joint with Comms. A and J)
- Open contributed Poster Session

We are delighted to have Dr. Hideyuki Sotobayashi, (Communications Research Laboratory, Japan) give the Commission D Tutorial on the subject of "Ultrafast Photonic Networks based on Optical Code Division Multiplexing".

As at previous General Assemblies we shall provide limited financial support to invited speakers in case of need.

COMMISSION E

This triennium report was prepared by Dr. R.L. Gardner, Commission E Chair 1999-2002.

During the last triennium, most of the Commission E activities have been devoted to the organization of meetings and conferences and to the preparation of scientific sessions for the Maastricht General Assembly.

Working groups

Most of the Commission E activities have been conducted by the following Commission E working groups:

E.1. Spectrum Utilization Management and Wireless Telecommunications
Co-Chairs : G. Hurt (U.S.A.), R. Struzak (Switzerland);

E.2.Intentional Electromagnetic Interference
Co-Chairs : M. Wik (Sweden) and W. Radasky (USA)
E.3.High Power Electromagnetics
Co-Chairs : C.E. Baum (U.S.A.) and R.L. Gardner (U.S.A.);
E.4.Terrestrial and Planetary Lightning Generation of Electromagnetic Noise
Co-Chairs : Z. Kawasaki (Japan) and V. Cooray (Sweden)
E.5.Interaction with, and Protection of, Complex Electronic Systems
Co-Chairs : J. Nitsch (Germany), P. Degauque (France), M. Ianoz (Switzerland), J-P. Parmentier (France);
E.6.Effects of Transients on Equipment
Co-Chairs : J. ter Haseborg (Germany), V. Scuka (Sweden), and B. Demoulin (France);
E.7.Extra-Terrestrial and Terrestrial Meteorologic-Electric Environment
Chair : H. Kikuchi (Japan);
E.8. Geo-electromagnetic Disturbances and Their Effects on Technological Systems
Co-Chairs : M. Hayakawa (Japan) and R. Pirjola (Finland)
E.9.Interference and Noise at Frequencies above 30 MHz
Chair : J. Gavan (Israel)

Each working has tried to organise the sessions in different international EMC conferences and workshops.

Sponsored meetings

Commission E has sponsored the following meetings:

in Mode B (with financing) :

1. Wroclaw EMC Conference, Wroclaw Poland, 27-30 June 2000.
2. EMC '01 Zurich, Zurich Switzerland, 19-22 February 2001.
3. AP-RASC'01: 2001Asia-Pacific Radio Science Conference, Tokyo, Japan, August 1-4, 2001.
4. Wroclaw EMC Conference, Wroclaw, Poland, 25-28 June 2002
5. EMC Europe 2002, International Symposium on Electromagnetic Compatibility, Sorrento, Italy, 9-13 September 2002.

and in Mode A (without financing) :

1. EUROEM, European Electromagnetics Meeting, Edinburgh, Scotland, UK, 30 May- 2 June 2000.
2. Telecom 2001, Casablanca, Morocco, 17-19 October 2001
3. AMEREM, American Electromagnetics Meeting, Annapolis Maryland, USA, 2-7 June 2002.

COMMISSION F

This triennium report was prepared by Dr. Yoji Furuhama, Commission F Chair 1999-2002.

Introduction

Commission F has the title "Wave Propagation and Remote Sensing (including radio-meteorology, radio-oceanography and remote sensing of non-ionized media)" and its terms of reference are: The Commission encourages:
(a) The study of all aspects of wave propagation at all frequencies in a non-ionized environment: (i) wave propagation over the Earth's surface, (ii) wave propagation in, and interaction with, the neutral atmosphere, (iii) wave interaction with the Earth's surface, oceans, land and ice, (iv) wave propagation through, and scattering by, the subsurface medium, (v) characterization of the environment as it affects wave phenomena;
(b) The application of the results of these studies, particularly in the areas of remote sensing and communications;
(c) The appropriate co-operation with other URSI Commissions and other relevant organizations.

Prime responsibilities this triennium, as previously, have been shared between the Chairman (Dr. Yoji Furuhama) and Vice Chairman (Prof. Martti Hallikainen).

Scientific Program

Setting up a scientific program for a triennium is the prime activity of an URSI Commission in order to achieve an exchange of ideas and research results among individual scientists throughout the world. This is carried out at General Assemblies and other meetings.

At General Assemblies, Commission F traditionally has compact invited-paper sessions on specific subjects and allows a broader allocation of contributed papers as posters, as confirmed at business meetings in the previous GA, because the Commission F Triennium Open Symposium covers all Commission F topic areas. Commission F selects a number of topics and convenors to cover specific matters of interest. The convenors are then given the responsibility to invite speakers to give a balance to scientific content and geographical representation.

In the current triennium, there is a Commission F Tutorial entitled "Recent Development of Data Processing in Polarimetric and Interferometric SAR" and there are 10 Commission F sessions (including one joint session led by Commission F) entitled: "Radiometeorology"(F1), "Climatic Parameters in Radiowave Propagation and their Modelling" (F2), " Millimetric, Sub-millimetric and Optical Wave Propagation Prediction" (F3), " Point to Point and Point to Multipoint Propagation " (F4), " Microwave Passive Remote Sensing" (F5), " Microwave Active Remote Sensing" (F6), " Polarimetric and Interferometric Techniques in Remote Sensing" (F7), "Active Microwave Remote Sensing of Ocean" (F8), "Passive Remote Sensing of Atmosphere" (F9), " Wave Propagation for Satellite Navigation and Mobile Services" (FG). There is also a poster session entitled "Wave Propagation and Remote Sensing" (FP) to cover the whole subject area of the commission.

And there are 9 joint sessions led by the other Commissions entitled: " Antennas in Mobile Communication Systems" (BCF), " Broadband Access Systems in Wireless

Communication" (CAF), "Wave Propagation Modeling for Mobile Communication Systems" (CBF), "Adaption to Changing Radio Channel" (CF), "Channel Sounding in Mobile Communication Systems" (CFA), " Subsurface Remote Sensing and its Applications" (CFAB) (RRS chapter), "Interference in Communication" (EF), " Transionospheric signal Degradation" (GF), "Interference Mitigation in Radio Science" (JFC).

The sessions marked "RRS chapter" have chapters on that topic in the URSI book entitled "Review of Radio Science 1999-2002". The other RRS chapters of Commission F are "New Techniques in Microwave Radiometry for Earth Remote Sensing", " Wave Propagation for Multimedia Satellite Services", and "Remote Sensing of Inland and Coastal Waters".

Sponsored meetings

As to other meetings, between GAs, Commission F had 5 Mode B meetings (financial support requested) and 17 Mode A meetings (no financial support requested).

The **mode B** meetings comprised:

MST9-COST76 Workshop

The Ninth International Workshop on Technical and Scientific Aspects of MST Radar combined with the COST-76 Final Profiler Workshop, Toulouse, France, March 13-17, 2000, (RSB, June 2000, pp.38-39). Web site: http://www.cnrm.meteo.fr/mst/. There were 156 participants from 27 countries and 6 continents. A total of 195 papers were presented, whereof 76 were poster papers.

CLIMPARA'01

Climatic Parameters in Radiowave Propagation Prediction, Budapest, Hungary, May 28 - 30, 2001. Web site: http://www.climpara.org/. This is the fifth in a series of meetings which link closely with ITU-R Working Parties 3J and 3M. This meeting is a good example of collaborative work with ITU.

Commission F Triennial Open Symposium

Was held in Garmisch, Germany, February 11-15, 2002, Web site: http://www.dlr.de/HR/URSI-F-2002. There were in all about 130 participants at the conference, from about 22 countries, and a total of about 100 papers were presented.

AP-RASC'01

2001 Asia-Pacific Radio Science Conference, Tokyo, Japan, August 1-4, 2001, Web site: http://www.kurasc.kyoto-u.ac.jp/ap-rasc/. There were 704 participants from 34 countries/regions, with 48 young scientists from 17 countries/regions, whose travelling expenses were partly granted by the Conference Organizing Committee. A total of 599 regular papers were presented, whereof 195 were poster papers.

MWRS'01

Specialist Meeting on Microwave Remote Sensing 2001, Boulder, Colorado, November 6-8, 2001, (RSB, March 2002, pp.57-58). Web site: http://www.etl.noaa.gov/mrs01. This meeting combined the 8th URSI Commission F symposium on Microwave Remote Sensing of the Earth, Oceans, Ice, and Atmosphere and the 7th Specialist Meeting on Microwave Radiometry. There were roughly 150 participants from 20 countries and a total of 153 papers including one keynote paper, 107 oral papers and 45 interactive papers.

In the list above, "RSB—" indicates the edition of Radio Science Bulletin and page numbers where reports have been given.

The **Mode A** meetings comprised:

Radio Africa'99

Third Regional Workshop on Radiocommunication in Africa – Gaborone, Botswana, October 25-29, 1999, (RSB, September 2000, pp.6-8).

AP2000

Millennium Conference on Antennas & Propagation, Davos, Switzerland, April 9-14, 2000. Web site: http://www.estec.esa.nl/AP2000/

EUSAR 2000

European Conference on Synthetic Aperture Radar, Munich, Germany, May 23-25, 2000, (RSB, March 2001, p.14). Web site : http://www.fgan.de/fhr/eusar2002

GPR 2000

Eight International Conference on Ground Penetrating Radar, Gold Coast, Queensland, Australia, May 23-26, 2000, (RSB, June 2001 p. 19). Web site: http://www.cssip.uq.edu.au/gpr2000

33rd COSPAR Scientific Assembly

Held in Warsaw, Poland, July 23-26, 2000, (RSB, June 2001 pp. 20-22). Web site: http://cospar.itodys.jussieu.fr

IGARSS 2000

International Geoscience and Remote Sensing Symposium 2000, Honolulu, Hawaii, USA, July 24-28, 2000, Web site: http://www.igarss.org

MMET 2000

International Conference on Mathematical Methods in Electromagnetic Theory, Kharkov, Ukraine, September 12-15, 2000, (RSB, March 2001, pp.17-19). Web site: http://www.kharkov.ukrtel.net/MMET2000

Antennas and Propagation for Wireless Communications

Held in Waltham, MA, USA, November 6-8, 2000.

ISAP 2000

International Symposium on Antennas and Propagation, Fukuoka, Japan, August 22-25, 2000, Web site: http://www.crl.go.jp/pub/ISAP2000

EPMCC 2001

Fourth European Personal Mobile Communications Conference, Vienna, Austria, February 20-22, 2001, Web site: http://www.epmcc.com

ICAP 2001

Eleventh International Conference on Antennas and Propagation, Manchester, UK, April 18-20, 2001, Web site: http://www.iee.org.uk/Conf/ICAP

Remote Sensing for Monitoring Baltic Sea and Other Interior Basins

Held in Kaliningrad, Russia, May 14-17, 2001, Web site: http://www.ire.rssi.ru

MSMW' 2001 - Fourth International Kharkov Symposium

"Physics and Engineering of Millimeter and Submillimeter Waves", Kharkov, Ukraine, June 4-9, 2001, (RSB, September 2001 pp. 19-21). Web site: http://www.ire.kharkov.ua/MSMW2001/msmw.htm

IGARSS 2001

International Geoscience and Remote Sensing Symposium, Sydney, Australia, July 9-13, 2001, Web site: http://www.IGARSS2001.org

ICEAA 2001

International Conference on Electromagnetics in Advanced Applications, Turin, Italy, September 10-14, 2001.

AMEREM 2002 Symposium

The American Electromagnetics 2002 Symposium, Annapolis, Maryland, USA, June 3-7, 2002, Web site: http://www.amerem.org

EUSAR 2002

Held in Hyatt Regency Hotel, Cologne, Germany, June 4-6, 2002, Web site: http://www.fgan.de/fhr/eusar2002

Communication

Communication with individual scientists and engineers has been a problem for Commission F as for some other Commissions. Specific communications to the 44 National Committee Official Representatives with 5 Observers has had only partial success as mentioned by the former Chair of Commission F. I believe that setting up and frequently refreshing a Commission F Home Page on the internet might improve publicity drastically.

Publications

The chapters for the Review of Radio Science as mentioned above will appear in the URSI publication "Modern Radio Science 2002".

Thanks are expressed to Prof. Adriano Camps, Prof. Calvin Swift, Prof. David Noon, Prof. Ram M. Narayanan, Dr. Bertram Arbesser-Rastburg, Dr. D.V. Rogers, Dr. Arnold Dekker, and Dr. Robert P. Bukata, and to Prof. Martti Hallikainen as Commission F Editor for RRS.

Conclusion

I am glad and honored to have served as Chairman.

COMMISSION G

This triennium report was prepared byProf. P. Wilkinson, Commission G Chair 1999-2002.

1. Introduction

During the triennium 1999-2002, URSI Commission G has been active through its Working Groups (WGs) and sponsored symposia and workshops. Early in the triennium the Commission G web site was transferred from http://ulcar.uml.edu/ursi/ to the URSI Website. Later, an electronic mailing list was set up for communicating with people who had expressed an interest in Commission G activities. The mailing list membership is self-managing and the Commission Chair moderates the group. The address is http://www.ips.gov.au/mailman/listinfo/ursi-commission-g. Currently, there are 576 addresses in the mailing list. These were drawn from addresses for people who had attended past URSI Assemblies, or were known to have an interest in Commission G activities.

2. Working Group Reports

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

2.1 G1: Ionosonde Network Advisory Group

Retiring Chair : R. Conkright (USA)
Current Chair : T. Bullett
Vice-Chairs : P. Wilkinson (Australia) and J-C. Jodogne (Belgium)

The last three years have seen a great deal of consolidation in INAG. All the older INAG Bulletins have now been scanned and passed through text recognition software, the final product being placed on the INAG Website. The text recognition process has left residual errors in some of the texts, but a lack of resources has meant these errors have not yet all been removed. Plans for indexing all the Bulletins also stalled as a consequence. The complete UAG-23A has also been scanned and a PDF is available of the Website. This document is now out of print. Finally, a set of Australian ionogram scaling training notes was added.

An electronic mailing list was set up for communicating with people who had expressed an interest in INAG activities. The mailing list membership is self-managing and the INAG Vice Chair (Phil Wilkinson) moderates the group. The address is http://www.ips.gov.au/mailman/listinfo/inag-general. Currently, there are 231 email addresses registered in the mailing list.

Ray Conkright, the Chair of INAG, retired from NGDC in April this year. Ray had worked for many years to maintain the visibility of the ionosphere in the World Data Centres and the CD-ROM of hourly ionospheric data is concrete evidence of that work. Ray's work has ensured that scaled data from ionosondes from around the globe are collected together making a coherent dataset for studying a wide range of ionospheric climatology problems. The full value of this data set will persist for many years to come and be a testimony to one aspect of Ray's efforts. At the time of his retirement, Ray also retired from the Chair of INAG. On Ray's suggestion, Dr Terry Bullet, Air Force Research Labs (bullett@plh.af.mil) replaced him as Chair. This change was fully supported Phil Wilkinson, the Chair of Commission G.

INAG wishes to continue as an URSI Working Group in the forthcoming triennium.

2.2 G.2. Studies of the Ionosphere using Beacon Satellites

Chair: R. Leitinger (Austria)
Vice-Chairs: J.A. Klobuchar (USA) and P.V.S. Rama Rao (India)

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

The Working Group was active in its traditional fields, namely compilation, exchange and dissemination of information, contact with and exchange of experience with various organisations of relevance (ITU-R study group 3, the European COST Actions 251 and now 271, Augmentation Systems for GPS based satellite navigation, international and national advisory bodies, GPS data retrieval and archiving organisations, and others), providing advise on request. The work was partly carried out by correspondence, and partly through attendance of conferences and other meetings.

Among the most important activities of the BSG are the Beacon Satellite Symposia. After a forerunner organised at the Max-Planck-Institut für Aeronomie at Lindau/Harz, Germany, in 1970 the series started in 1972 with the first Symposium at Graz/Austria and continued at time intervals between two and four years. It is planned to keep to at least a three years rhythm and have Beacon Satellite Symposia in the year prior to the URSI General Assembly. The next is tentatively planned to be held at the Abdus Salam ICTP at Trieste / Italy.

The Beacon Satellite Symposium 2001 (BSS'01) ranks among the most successful held. The venue was at Boston College, Chestnut Hill, MA, USA from 4 through 6 June, 2001. Ms. Patricia Doherty (Boston College), who was also the US branch of the program committee, which consisted of the chairman and the co-chairmen of the BSG, and chaired the Local Organising Committee (LOC).

The LOC had the following membership: Dr. Jules Aarons, Ms. Susan Delay, Dr. M. Patricia Hagan, Dr. Michael Mendillo, Mr. Leo Power, Dr. Cesar Valladares, Boston University; Dr. Santimay Basu, Air Force Geophysics Laboratory; Dr. Anthea Coster, MIT Lincoln Laboratory; and Dr. Ed Fremouw, Northwest Research Associates.

The first session of BSS'01 was "A Tribute to Dr. Jules Aarons in the year of his 80th Birthday" with an address given by the Co-Chairman of the Beacon Satellite Group, John A. Klobuchar. In the years before the BSG was founded, Dr. Aarons had played an important role in bringing together scientists and engineers interested in beacon satellite studies in the "Joint Satellite Studies Group" and in establishing co-operation with several other research groups. His continuing scientific interests and activities give an outstanding example to the younger generations.

The statistics on the Beacon Symposium are as follows:
Number of participants: 150
Number of countries represented: 24
Number of sessions: 13 (12 oral sessions and 1 poster session)
Number of papers presented: 107 (counting posters)
Number of sponsors: 8 (including URSI)
Number of sponsors with monetary support: 7

For organisational and funding reasons it was convenient to have a Space Weather Workshop (SWW) at Boston College immediately following the BSS'01. On the one hand, this lead to a shorter Beacon Satellite Symposium with sessions in parallel, although, on the other hand, some papers with more general space weather related topics could be shifted to the SWW where they found a partly different audience.

From the beginning there have been two main areas of interest in Beacon Satellite Studies which can be summarised under the key words: "Electron Content" and "Scintillation". With the developments in Ionosphere Tomography using the Global Satellite Navigation Systems (GNNS, presently the US system GPS and its Russian equivalent, GLONASS) and GPS receivers onboard Low Earth Orbit Satellites (LEOs) the "Electron Content" part gained new momentum and new perspectives.

There is now considerable interest in assessment studies for various applications of satellite-to-ground and satellite-to-satellite propagation of L band signals. Very large numbers of GPS receivers are operated by different organisations, many of who lack experience with the ionosphere and plasmasphere propagation effects. The members of the BSG produce only a small fraction of data compared with the very large amount of potentially usable GPS data collected elsewhere. However, the members of the BSG have expertise in the ionosphere and plasmasphere and need to assess so-called "ionosphere products" produced by others, to provide advice, suggestions and even warnings. It is an important task for the BSG to organise assessment studies, to act as a distribution centre for relevant requests and to archive answers of more general interest.

GNSS-LEO occultation is a very important source of ionospheric data but needs further relevant assessment studies. GNSS occultation receivers will be installed simultaneously on several LEO satellites in the near future. The primary purpose is neutral atmosphere research and system development (e.g., climate research, possible data sources for weather prediction systems). These ambitious applications (e.g., to gain stratospheric temperature or tropospheric water vapour profiles) need to include very careful consideration of the residual plasma influences that necessarily remains after removal of the first order influences.

VHF/UHF beacons onboard Low Earth Orbit satellites still exist and it is expected (and hoped) that the NIMS system with three active beacons will stay in operation until a new beacon system is operational. Ground reception of the VHF/UHF beacon signals provides the data for high-resolution ionosphere tomography.

There is a considerable potential for high quality ionosphere and plasmasphere data to be derived from ground and space observation of GNSS signals as well as from advanced retrieval systems for data gained by means of the ground reception of VHF/UHF beacons aboard LEO satellites. However, these "Novel Data Sources" and the relevant data retrieval and preparation procedures need careful testing and comparison with data from established instrumentation.

Recently the need has appeared for high resolution and high accuracy absolute values of vertical and slant electron content, especially in the context of near real-time ionospheric corrections for advanced satellite navigation systems. Other applications (e.g., the use of GNSS signals in surveying) need information on smaller scale wavelike disturbances (mostly, but not exclusively, from Travelling Ionospheric Disturbances).

Reacting to the new challenges, one sub-group on "Ionospheric Tomography" (already mentioned) has been formed at the occasion of the BSS'01 (leaders: Jim Secan and Ed Fremouw) and is working very successfully. Among other activities the sub-group had a data workshop at the Ionospheric Effects Symposium 2002. A sub-group on matters of advanced GNSS-based navigation systems is being organised under the leadership of Patricia Doherty.

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

The Working Group proposes that the Beacon Symposium 2004 be endorsed as an "URSI Generated Symposium". The tentative location is Trieste / Italy, the tentative host is the Abdus Salam International Centre for Theoretical Physics and Prof. Sandro Radicella will chair the LOC. However, it is more and more difficult to ensure that our Symposia fulfil one very important task, namely to bring young(er) scientists to the meetings and to maintain direct contact at meetings with scientists of all generations from countries and regions with serious lack of travel funds. The small amount of money that may be available from URSI for Symposia is no longer sufficient as "seed money" to help national sources.

2.3 G.3 Incoherent Scatter

Chair: A.P. van Eyken (Norway)
Vice-Chair: W. Swartz (USA)

No report was received for this Working Group at the time this report was prepared. However, the primary output of this Working Group, the annual schedules for the operation of incoherent scatter radars around the world, were prepared and distributed successfully. This necessary function is expected to continue as part of the output of this Working Group.

2.4 G.4 Ionospheric Informatics

Chair: S.M. Radicella (Argentina)
Vice-Chair: R. Hanbaba (France)

The work of this working group is now complete. It has been recommended to Commission G that this group should be terminated at the next URSI General Assembly.

2.5 GF Middle Atmosphere

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

In March 1999 a major session was held at the conference PIERS 1999 (Progress in Electromagnetic Research Symposium) in Taipei, ROC Taiwan, with the title "Radar Applications for Atmosphere and Ionosphere Research", which was convened by the co-chair J Röttger. The symposium was sponsored by several institutions of Taiwan through the involvement of the co-chair C.H. Liu. A special issue of the Journal of Atmospheric and Solar-Terrestrial Physics, vol. 63. No. 2-3, 2001, with guest-editor J. Röttger and T. B. Jones, resulted from this major session.

In May 1999 the 14th ESA Symposium on European Rocket and Balloon Programs and Related Research was held in Potsdam, Germany, where the scientific program committee was chaired by J Röttger. It included several sessions with papers on applying radio science techniques. Besides the Symposium Proceedings, published by ESA, Summary and Conclusions for Future Research were adopted during this symposium and published by ESA.

In March 2000 the Ninth International Workshop on Technical and Scientific Aspects of MST Radar MST9, combined with the COST76 Final Profiler Workshop, was held in Toulouse, France, under the chairmanship of JR. This resulted in the Proceedings, published by SCOSTEP and MeteoFrance in October 2000, and in the special issue of the journal Annales Geophysicae, vol. 19, No. 8, 2001.

In November 2000 a 2-weeks course was held at the International Center for Theoretical Physics in Trieste (ICTP) on "Physics of Mesosphere-Stratosphere-Troposphere Interactions with Special Emphasis on MST Radar Techniques", which was also devoted to activities of URSI WG GF1, and J Röttger as lecturer.

In July 2001 the Tenth International EISCAT Workshop was held in Tokyo, Japan. A session and several papers were directed to coupling and research of the middle atmosphere with radio methods.

During three weeks in November and December 2002 the Third International School on Atmospheric Radar, ISAR-3, will be held at the International Center of Theoretical Physics in Trieste. J Röttger is directing this school, which will allow young scientists to become acquainted with the radar and radio techniques used for middle and lower atmosphere research. Financial support has been requested from URSI.

J Röttger is chairing the International Steering Committee of the Tenth Workshop on Technical and Scientific Aspects of MST Radar MST, which will be held in

May 2003 in Piura, Peru. Financial support from URSI will be applied for. Preparations for this are part of the URSI WG GF work. A significant part of this workshop will deal with preparations of reports and outlines of new techniques, methods and science for radio/radar studies of the middle and lower atmosphere.

Together with C. Hanuise and C. Lonsdale, J Röttger is co-convening a session of commission G and J at the forthcoming URSI General Assembly in August 2002.

The EISCAT Scientific Association has established a committee on defining the needs and future directions for the coming decades for scientific research of the Earth's ionosphere, magnetosphere and atmosphere. J Röttger is member in this committee.

In summary, the Working Group GF "Middle Atmosphere" has had a successful triennium and recommends it should continue for another three years period. At the forthcoming Assembly URSI Commission G and F will consider this recommendation.

2.6 GH.1. Active Experiments in Plasmas

Co-Chair for Commission G : Sa. Basu (USA)
Co-Chair for Commission H : T. Leyser (Sweden)

The Working Group GH1 on Active Experiments in Space Plasmas reports very enthusiastic response to its call for papers for this XXVIIth URSI General Assembly. A session entitled, "Ionospheric Modification by High Power Radio Waves: Coupling of Plasma Processes" has been organized that features 11 oral presentations and a further 19 papers will be presented in the poster session.

The Working Group reports continued international co-operation in the field during the period under review (September 1999 to August 2002). Co-operative research has been performed at the Sura, EISCAT and HAARP ionospheric modification facilities in Russia, Norway and USA respectively. At Sura, research has been focused on the spectral features of Stimulated Electromagnetic Emissions (SEE) and the use of SEE as a tool for the study of HF induced nonlinear plasma processes. At Sura, ionospheric heating experiments by X-mode waves following O-mode heating have yielded interesting results on artificial ionospheric turbulence. The HF radiation from the Sura facility has been successfully received at the WIND satellite in the interplanetary medium and significant results have been obtained on focusing, scintillation, frequency broadening and distortion of radiation pattern. At EISCAT, experiments on HF pump induced electron heating and enhanced airglow emission have been performed and the emission has been located by the use of multi-station airglow imaging system. The features of the distribution of Langmuir turbulence caused by HF heating continue to be investigated at EISCAT using the UHF and VHF radars. The HF CUTLASS radar is studying the characteristics of decameter scale irregularities caused by the EISCAT heater. The High Frequency Active Auroral Research Program (HAARP) has built a new ionospheric interaction facility in Gakona, Alaska for the study of Radio Science and plasma physics. The high power HF transmitters at HAARP currently operate at a level of 960 kW and the facility is co-located with an impressive set of radio, radar and optical diagnostics. Since the last General Assembly in 1999, HAARP has conducted 18 research campaigns with significant results. Research has been conducted in areas such as, ELF/VLF wave generation in the ionosphere, SEE, field aligned artificial airglow emission, propagation experiments with the WIND satellite and the study of HF interaction with Polar Mesospheric Summer Echoes (PMSE). These results provide a promising start for the HAARP facility that is currently only 25 per cent complete.

The group wishes to continue as an URSI Working Group in the forthcoming triennium.

2.7 GH.2. Computer Experiments, Simulation and Analysis of Wave Plasma Processes

Co-Chair for Commission G : H. Thiemann (Germany)
Co-Chair for Commission H : H. Matsumoto (Japan)

No report was received for this Working Group at the time this report was prepared.

2.8 GH.3. Wave and Turbulence Analysis

Co-Chair for Commission G : A.W. Wernik (Poland)
Co-Chair for Commission H : F. Lefeuvre (France)

This WG was initiated in 1972. The objective was to organize sessions and symposia around the presentation of new developments in signal analysis and their applications to studies of waves in plasmas. The WG changed several times its format, name and leaders. Initially, it was considered that there was not enough new material in signal analysis to have a big event at each GA. It is the reason why we used to alternate a regular scientific session with a symposium. Since 1996 we have regular sessions at each General Assembly and special events (symposia or summer school) in between two General Assemblies.

The Working Group was actively involved in a School "Analysis Techniques for Space Plasma Data" (La Londe-Les Maures, France, 8-13 October 2001). The School, hosted by CNRS, was co-convened by T. Dudok de Wit (LPCE, Orleans, France) and J. Vogt (IUB, Bremen, Germany). Support was provided by URSI, CNRS, CNES, COSPAR, ESA, ISSI-Switzerland and others. The objective of this school was to review the basic and more advanced methods for analysis of spacecraft plasma data. The attendance was limited to 70 participants, but the number of applications was much larger. Invited experts presented nine tutorial lectures, and other participants gave 16 short talks. Participants have had an access to computers during the computer sessions. The round-table discussion concluded the school. The School was a great success and showed a need for this kind of activities in the future. More information and copies of some presentations can be found at: http://web.cnrs-orleans.fr/~weblpce/semin_stages/colloques/la-londe/

At the General Assembly of URSI in Maastricht the Working Group organizes an intercommission HGJC Session on "Analysis Methods for Plasma Waves and Turbulence". This session is dedicated to data analysis techniques in the radio-scientific study of space plasmas, on scales from interstellar down to ionospheric. The group wishes to continue as an URSI Working Group.

2.9 URSI-COSPAR on International Reference Ionosphere (IRI)

Chair : D. Bilitza (USA)
Vice Chair for COSPAR : K.I. Oyama (Japan)
Vice Chair for URSI: B.W. Reinisch (USA)

The main activity the IRI Working Group concentrated on during this time period was the development and release of the newest version of the IRI model, IRI-2000. This version includes

(1) two new options for the D region electron density (Danilov, Russia; Friedrich, Austria);
(2) an improved description of the F2 bottomside electron density profile (Radicella, ICTP, Italy; Reinisch, Bilitza, USA; Adeniyi, Nigeria; Mosert, Ezquer, Argentina; Pulinets, Russia; Leitinger, Austria; Buresova, Czech Republic);
(3) an algorithm for foF2 storm-time updating (Fuller-Rowell, Araujo, USA);
(4) a new option for the electron temperature (Triskova, Truhlik, Czech Republic);
(5) inclusion of drift model for low latitudes (Fejer, Scherliess, USA). The new version was presented in talks at several science meetings (EGS, COSPAR, IRI) and was described in an article in Radio Science (Volume 36, Number 2, pages 261-275, 2001).

The 1999 IRI workshop was held from August 9 to 12 at the University of Massachusetts Lowell, Center for Atmospheric Research (UMLCAR) organized locally by B. Reinisch and supported financially by URSI, COSPAR, NSF and UMLCAR. 47 participants attended the meeting representing 14 countries. The 56 papers were divided into the following sessions: Ray Tracing, D Region, Measurements and Comparisons, Temperature and Ion composition, Topside and Plasmasphere, Total electron Content, Improvements and New Inputs, Drift Data and Model, Evaluation of IRI and Other Models, Applications. Selected papers from the meeting are published in Advances in Space Research, Volume 27, Number 1, 2001. For a summary see: http://nssdc.gsfc.nasa.gov/space/model/ionos/iri/iri_99_report.html.

A special 2-day session on modeling the topside and plasmasphere was organized by the IRI group during the 33rd COSPAR scientific assembly in Warsaw, Poland, 12-19 July, 2000. Modeling efforts were presented based on data from ionosondes, incoherent scatter radars, and on satellite data from Interkosmos 19, SROSS C2, ISIS 1, 2, Magion 3, 5, Active, ISS-b, and Hinotori 29 papers from this session were published in Advances in Space Research Volume 29, Number 6, 2002. The summary report of the meeting is at http://nssdc.gsfc.nasa.gov/space/model/ionos/iri/irinfo/irinfo_19.html .

In 2001 the annual IRI workshop was held at the Instituto Nacional de Pesquisas Espaciais (INPE) in Sao Jose dos Campos, Brazil from June 25 to 29 organized locally by J. H. A. Sobral, M.A. Abdu, and I.S. Batista. It was attend by about 60 scientists including representatives from USA, Russia, India, Peru, South Africa, Japan, Spain, Argentina, U.K., Czech Republic, Chile, and Brazil. 75 papers were presented in 8 oral sessions and in 1 poster session with the following titles: The Equatorial Anomaly Region, Total Electron Content and Topside, Description of Ionospheric Variability, Modeling the Low Latitude Ionosphere, Ion composition, Scintillation and Spread-F, Representation of F Peak and Bottomside Parameters, New Data and Model Inputs, and Applications. Financial support was provided by COSPAR, URSI, the International Center for Theoretical Physics (ICTP), INPE, the Fundação deAmparo à Pesquisa do Estado de São Paulo (FAPESP), the Sociedade Brasileira de Geofísica (SBGf), and the Fundação Coordenação de Aperfeiçoamento de Pessoal de Nível Superios (CAPES). Selected papers and posters from this workshop are being considered for publication in a dedicated issue of Advances of Space Research. See http://nssdc.gsfc.nasa.gov/space/model/ionos/iri/iri_01_report.html for summary and details of this meeting.

Several new members were accepted into the IRI working Group during this time period including Prof Kouris from (University of Thessaloniki, Greece), X. Huang (UMLCAR, USA), L.-A. McKinnell (University of Grahamstown, South Africa), V. Truhlik (Czech Republic), V. K. Depuev (IZMIRAN, Russia), M. Abdu (INPE, Brazil). IRI continues to publish a quarterly newsletter (K. Oyama, editor) and provide model updates through an electronic mailer (more than 400 subscribers). The IRI home page is at http://nssdc.gsfc.nasa.gov/space/model/ionos/iri.html.

2.10 Other Working Groups

Other Working groups in which Commission G is active will be reported on in the lead Commission Reports. These include:

· EGH EM Effects Associated with Seismic Activity
Co-Chair for Commission E : M Hayakawa (Japan), Co-Chair for Commission G : S. Pulinets (Russia), Co-Chair for Commission H : M. Parrot (France)
· FG Ionosphere and Atmosphere Remote Sensing using Global Positioning Systems (GPS/GLONASS)
Co-Chair for Commission F : J. P. V.Baptista (Netherlands), Co-Chair for Commission G : P. Høeg (Denmark),
· URSI/IAGA VLF/ELF Remote Sensing of the Ionospheric and Magnetosphere (VERSIM)
Co-Chair for URSI Commission G and H: M. Parrot (France), Co-Chair for IAGA Commission 2 and 3: A.J. Smith (UK)

The Working group report appears in the Commission H report.

3. Sponsored Meetings

3.1 Mode A Sponsorship

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

· Radio Africa 99, Gaborone, Botswana, 25-29 October 1999.
· AP-2000 Millenium Conference on Antennas and Propagation, Davos, Switzerland, April 2000.
· Sources and scintillations: refraction and scattering in radio Astronomy, Guiyang, China, April 2000.
· ISAP 2000, Fukuoko, Japan, August 2000.

· First S-RAMP Conference, Sapporo, Japan, October 2000.
· International Space Environment Conference 2001 – Radiation Belt Science and Technology, Queenstown, New Zealand, July 2001.
· Getting the Most out of the Spectrum, London, United Kingdom, October 2002.

3.2 Mode B Sponsorship

Mode B sponsored meetings received seed funding from Commission G, and other Commissions in some cases. Brief summary reports follow.

3.2.1 MST-9 / COST-76 Meeting

Full report: The Radio Science Bulletin, June 2000, P38.

The Ninth International Workshop on Technical and Scientific Aspects of MST Radar (MST-9) combined with the COST-76 Final Profiler Workshop and was held at the International Conference Centre of Meteo France in Toulouse, March 13-18, 2000. 156 participants attended the workshop from 27 countries and a total of 195 papers were presented, 76 of which were poster presentations.

3.2.2 ISEA 2000, International Symposium on Equatorial Aeronomy

Full report: The Radio Science Bulletin, December 2000, P26.

The tenth International Symposium on Equatorial Aeronomy was held in Antalya, Turkey, May 17 – 24, 2000. Over 110 scientists from five continents attended. Young scientists and scientists from developing countries made up a significant fraction of the attendees.

3.2.3 COSPAR / IRI Session

Full report: The Radio Science Bulletin, June 2001, P20.

The 33rd COSPAR Congress was held in Warsaw, Poland, 16 – 23 July 2000. The IRI session, held during COSPAR, was a 2-day meeting reviewing topside ionosphere and plasmasphere modelling with special emphasis on improvements of the IRI in these regions.

3.2.4 IRI Workshop Brazil

Full report: The Radio Science Bulletin, December 2001, P23.

The 2001 IRI Workshop was held at the Instituto Nacional de Pesquisas Espaciais in São José doe Campos, Brazil, June 25 to 29, 2001. About 60 scientists from over 12 countries attended it. The 75 papers were presented in eight oral sessions and one poster session.

3.2.5 2001 Asia-Pacific Radio Science Conference (AP-RASC 01)

Full report: The Radio Science Bulletin, September 2002, P

The AP-RASC 01 Conference was held in Tokyo at Chuo University, 31 July – 06 August. 2001. It was the first in a planned series of conferences on radio science in the South East Asian region. Roughly 700 people registered for the conference, from 34 countries with 48 young scientists from 17 countries/regions, whose travelling expenses were partly granted by the Conference Organizing Committee. A total of 599 regular papers were presented (oral: 404, poster 195) in 86 sessions. The Commission G sessions were attended by roughly 40 to 60 people per session. This strong local support for the meeting was most heartening and hopefully will extend to future RASC meetings in the region.

3.2.6 34th COSPAR Meeting

At the time of preparing this report the 34th COSPAR meeting had not taken place. Commission G has offered funding assistance for the IRI session.

COMMISSION H

This triennium report was prepared by Dr. G.H. James, Commission H Chair 1999-2002.

1. Working group reports

Commission H scientists have been active in a number of working groups (WG) during the triennium. Almost all of these have Commission G leading; the reports therefore are found in the Commission G triennial report.

VLF/ELF Remote Sensing of the Ionosphere and Magnetosphere(VERSIM), URSI/IAGA Joint WG)

Co-Chairs: M. Parrot(France) and A.J. Smith(U.K.)

This WG serves as a forum for researchers studying the behaviour of the magnetosphere and ionosphere by means of ELF and VLF waves. Since the 1999 URSI General Assembly (GA), the VERSIM WG had a half-day session at IAGA2001, maintained a bibliography and circulated three newsletters. A detailed VERSIM triennial report and other WG information may be read at: http://www.nerc-bas.ac.uk/public/uasd/versim.html.

2. Specialist conferences and meetings sponsored by Commission H

2.1 Mode A (Without financial support)

COSPAR Scientific Assembly, Warsaw, Poland, 16-23 July 2000.

Report published in the JUNE 2001 issue of the Radio Science Bulletin(RSB).

First STEP-Results, Applications and Modeling Phase (S-RAMP) Conference, Sapporo, Japan, 2-6 October 2000.

Report received and to be published in the RSB.

Summary: One of the programs organized by the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP), which followed on from the earlier Solar-Terrestrial Energy Program (STEP), was S-RAMP, the STEP-Results, Applications, and Modeling Phase (S-RAMP) program. S-RAMP is designed to capitalize on the vast data sets and powerful modeling techniques developed under STEP auspices, running from 1998 through 2002. S-RAMP has three main goals:

1. Enable detailed understanding of Sun-Earth coupling mechanisms;
2. Facilitate effective information transfer between experimentalists, theoreticians, and modelers; and
3. Demonstrate the benefits of the STEP endeavour to funding agencies, the media, and the general public.

The first comprehensive conference of the S-RAMP program was held in Sapporo during 2-6 October 2000, at roughly the mid-point of the five-year international program. This conference was convened with goals described above in mind. Besides enabling the effective flow of data and information throughout the wide S-RAMP community, this conference also emphasized the importance of conveying exciting science findings to the general public and to the media as well as to funding agencies. In so doing, the organizers sought to maintain current support and generate new support to enhance scientific programs, cross-disciplinary studies, and the practical applications of this knowledge of the Sun-Earth system to various important areas in society.

The First S-RAMP Conference with over 700 papers presented was held in the Conference Center of the Hotel Royton Sapporo and Sapporo Media Park. Some 580 scientists were registered attendees. There were 19 separate scientific symposia, three tutorial lectures, three workshops, and numerous affiliated side and splinter meetings. Radio scientific topics were discussed in most of the 19 symposia. Commission H interests were particularly present in the following symposia: S12: "ULF and VLF Waves in the Magnetosphere"; S13: "Aurora Dynamics and Plasma Wave Emissions"; S14: "Wave-Particle Interactions at Shocks and Boundary Layers"; S15: "Kinetic Theory and Simulations of Micro and Meso Scale Phenomena"; S19: "Active Experiments and Spacecraft-Environment Interactions".

Int. Space Environment Conference (ISEC) 2001 - Radiation Belt Science and Technology, Queenstown, New Zealand, 23-27 July 2001.
Report published in the MARCH 2002 issue of the RSB .

International Conference on Electromagnetics in Advanced Applications (ICEAA) 2001, Turin,Italy, 10-14 September 2001.
Report published in the MARCH 2002 issue of the RSB.

2.2 Mode B (With financial support)

Sources and Scintillations: Refraction and Scattering in Radio Astronomy, Guiyang, China, 17-21 April, 2000 (in collaboration with IAU); EUR 500.
Report published in the DECEMBER 2000 issue of the RSB.

International Conference on Mathematical Methods in Electromagnetic Theory(MMET)'2000, Kharkov, Ukraine, 12-15 September 2000; EUR 560.
Report published in MARCH 2001 issue of the RSB.

Sixth International School for Space Simulations (ISSS-6), Germany, June 2001; EUR 1,000.
Report published in the MARCH 2002 issue of the RSB.

IRI Workshop - Modeling the Low Latitude Ionosphere, Sao Jose dos Campos, Brazil, 25-29 June 2001; EUR 300.
Report published in the DECEMBER 2001 issue of the RSB

2001 Asia-Pacific Radio Science Conference (AP-RASC'01), Tokyo, Japan, August 1-4, 2001; EUR 1,000.
Report received and to be published in RSB

Summary: The AP-RASC'01 was the first Asia-Pacific regional URSI conference to be held between URSI General Assemblies. The objective of this conference was to stimulate and to coordinate the research activities of radio science in the Asia-Pacific area. The main theme of this conference was "Radio Science - Communications, Environment, and Energy".

A total of 599 regular papers were presented (oral: 404, poster 195). 86 sessions were organized. An H-organized union session was entitled "Solar power satellite and wireless power transmission", and 85 other sessions were organized corresponding to each commission of URSI. Other sessions in Commission H were: H1,2: "Plasma as a Complex System"; H3,4: "Observation and Theory of Plasma waves in Space"; H5,6: "Wave propagation, and Remote Sensing of Magnetosphere"; H7,8: "Modeling and Simulations in Space Plasmas".

It has been proposed to hold the next AP-RASC in China in 2004.

La Londe School "Analysis techniques for plasma data as obtained by satellites", Marseille, France, 8-13 October 2001; EUR 1,000.
Report published in the DECEMBER 2001 issue of the RSB.

COMMISSION J

This triennium report was prepared by Prof. J. Hewitt, Commission J Chair 1999-2002, with contributions from S. Ananthakrishnan, A. Beasley, J. Dreher, J. Moran, J. Salah, A. Wooten, and M. Yun.

Scientific Highlights

From the largest scales of cosmology to the smallest scales in stellar-mass black hole systems, radio astronomy has made important contributions to our understanding of astrophysical systems. In cosmology, spectacular results from the cosmic microwave background experiments have been reported. The first and second Doppler peaks in the fluctuation spectrum, and probably even higher order peaks, have been detected, giving us our strongest evidence to date that the universe is flat. This, combined with data from supernova photometry, has led to the remarkable conclusion that a significant amount of dark energy controls the dynamics of the universe. Pulsar astronomy has surged forward as the number of known pulsars exceeded 1000 for the first time, and new examples of the rare systems, such as binary neutron stars, are found. New insights into the generation and extraction of energy in black hole systems were made with the demonstration of interactions between the accretion disk and the radio jet in the galactic microquasars. The detection of radio afterglows in gamma ray bursts has helped to eludicate the developing picture that these high energetic systems may be the result of massive star explosions in other galaxies.

Technical Developments

The most recent triennium has seen great progress in the development of new radio astronomy facilities and the expansion of existing ones. The Giant Metrewave Radio Telescpoe (GMRT) consisting of 30 steerable parabolic dish antennas, each of 45-m diameter, has been constructed in western India and is operation in bands ranging from 150 MHz to 1.4 GHz. The GMRT represents an important step forward in sensitivity at these low frequencies. In April 2002 mm-VLBI reached a milestone with the detection of fringes at 147 GHz, representing the highest angular resolution astronomical observations ever made. The stations involved were at Haystack Observatory, Steward Observatory, the MPIfR and IRAM. At NRAO in the United States the Green Bank Telescope is now in operation and progress continues on the Enhanced VLA. The Submillimeter Array, a US-Taiwan project, is nearing completion on the summit of Mauna Kea in Hawaii. Five antennas (of the planned complement of eight) are in operation as an interferometric array; the array is expected to be fully operational an the end of 2003. The Atacama Large Millimeter Array (ALMA), a telescope planned to operate in the millimeter and submillimeter bands, has entered construction phase. Its 7000 square meter collecting area and its site high in the Andes mountains will provide unprecedented sensitivity and resolution at these wavelengths. The European and North American partners are developing prototype antennas, and in the following year will consider funding of the full construction phase of the project. Design and development efforts continue on the Combined Array for Research in Millimeter-wave Astronomy (CARMA), a 23-antenna millimeter array planned in the northern hemisphere to complement ALMA. Studies of three sites in eastern California are in progress. Work on the Allen Telescope Array, a planned 350-element centimeter-wave telescope to be sited at Hat Creek Observatory in California, continues with antenna design nearly complete and array prototyping under way. Construction is expected to begin in 2003 with the goal of completion in 2005. Construction of the Large Millimeter Telescope on Sierra Negra in Mexico continues. Instrumentation is under development and includes an array receiver, a correlator, and bolometer cameras. Completion in expected in 2004. A Dutch-US consortium has formed and is engaged in the design and development of LOFAR, an array that is expected to improve the sensitivity and resolution of low frequency radio astronomy by two orders of magnitude. Development of concepts and designs for the Square Kilometer Array continues as an international effort with active groups in Australia, Canada, China, Europe and the United States.

COMMISSION K

This triennium report was prepared by Dr. G.H. James, Commission H Chair 1999-2002.

Over the past few decades, bioelectromagnetic research has increased worldwide due to the ever-present and ever-increasing growth of electromagnetic fields in our natural environment. Commission K promotes research and development in the following domains: physical interactions of electromagnetic fields with biological systems; biological effects of electromagnetic fields; interaction mechanisms; human exposure assessment; experimental exposure systems; medical applications.

In the past triennium, the Commission continued the successful policy of promoting research initiatives through its member committees by sponsoring various conferences, symposia, and meetings, and by striving to cooperate with other scientific, health, and engineering organizations including BEMS, EBEA, and IEEE. URSI and Commission K have provided the platform for communicating and disseminating new results and developments with the international scientific community.

Conference Organization and Sponsorship

During the past triennium, Commission K has been active through sponsored symposia, conferences, and workshops.

Organization of the 4th International Symposium on Electromagnetics in Biology and Medicine

The 4th International Symposium on Electromagnetics in Biology and Medicine was held at the University of Tokyo, Tokyo, Japan from 2-4 April 2001. In the tradition of past meetings, the current Chair of Commission K, Shoogo Ueno, organized this symposium. About 100 scientists and 4 Young Scientist Awardees representing Japan, USA, Canada, France, Switzerland, Sweden, Italy, Finland, United Kingdom, Germany, and South Korea attended this 3-day all invited symposium. Each day of the symposium was devoted to one particular topic, Imaging and Measurement of the Human Brain, Transcranial Magnetic Stimulation and Medical Applications, and the Biological Effects of Electromagnetic Fields, to provide a high quality, comprehensive, well-balanced scientific program.

Information about this symposium was found on the follwing website: http://members.tripod.com/isebm/Symposium.htm

Sponsorship of International Conferences and Symposia

Mode B

- 15th International Wroclaw Symposium on Electromagnetic Compatibility (EMC Wroclaw 2000) Wroclaw, Poland, 27-30 June 2000
- Electromagnetic Aspects of Self-organization in Biology, Prague, Czech Republic, 9-12 July 2000
- MMET'2000, Kharkov, Ukraine, 12-15 September 2000
- 3rd International Conference on Bioelectromagnetism (ICBEM), Bled, Slovenia, 8-12 October 2000
- 2001 International Symposium on Electromagnetics in Biology and Medicine, Tokyo, Japan, 2-4 April 2001
- MSMW 2001, Kharkov, Ukraine, 4-9 June 2001
- 2001 Asia-Pacific Radio Science Conference (APRASC01), Tokyo, Japan, 1-4 August 2001
- 16th International Wroclaw Symposium on Electromagnetic Compatibility, EMC Wroclaw 2002, Wroclaw, Poland, 27-30 June 2002
- EMC Europe 2002, Sorrento, Italy, 9-13 September 2002

Mode A

- AMEREM 2002, Anápolis, MD, 3-7 June 2002
- Endogenous Physical Fields in Biology, Prague, Czech Republic, 1-3 July 2002
- JINA 2002, Nice, France, 12-14 November 2002
- EMF and Cardiac Pacemakers and Defibrillators, French Radio Protection Society, Paris, France, 25 October 2002
- APMC'02: Asia-Pacific Microwave Conference, Kyoto, Japan, 19-22 November 2002

International Cooperation

Commission K is actively cooperating with other scientific, health, and engineering organizations including BEMS, EBEA, and IEEE. **C**ommission K and the World Health Organization (WHO) have for many years had joint interests in determining the health effects of EM exposure, but recent proposals have been to see whether closer association might be beneficial to both parties. Dr. Micheal Repacholi, Coordinator, Radiation and Environmental Health Protection of the Human Environment, WHO, will introduce and discuss the WHO's International EMF Project at the second general lecture during the 2002 General Assembly. With the continued efforts of the Chair of the URSI Scientific Committee for Telecommunications (SCT), Mr. Martin Hall, and the incoming Commission K Chair, Professor Bernard Veyret, we hope to promote better interaction with the WHO through Dr. Michael Repacholi and Dr. Leeka Kheifets, particularly through a possible joint effort of the 5th International Symposium of Electromagnetic Fields in Biology and Medicine, which is planned for the spring of 2004 in Bordeaux, France.

Review of Radio Science

The Review of Radio Science is a compilation of reviews and tutorials on the advances and research in radio science that have been of significant importance over the last three years. In keeping with past tradition, the Vice-Chair, Professor Bernard Veyret, edited the Commission K chapters. We thank the following authors for their contributions in the 1999-2002 Review of Radio Science.

1. "Possible Exposures from Future Mobile Communications Systems" by J. Bach Andersen, P. Morgensen, and G.F. Pedersen
2. "Biological Effects of Microwaves: Animal Studies" by Zenon Sienkiewicz

2002 General Assembly

General Lecture II: WHO's assessment of the health effects of EMF exposure, Dr. Michael Repacholi

K-Tutorial: High field human MRI: Clinical applications and safety aspects, Professor Alayar Kangarlu

The technical areas of interest to Commission K are well represented with 70 oral presentations and 39 poster presentations in the following sessions.

- **K1:** Mechanisms & Modeling of Electromagnetic Interaction with Biological Systems
- **K2:** Biological Effects of Electroamgnetic Fields
- **K3:** Hazard Assessment for Wireless Communication
- **K4:** Biomedical Applications of Electromagnetic Fields and Waves
- **K5:** Epidemiology of Exposure to Environmental Electromagnetic Fields
- **K6:** Topics in Bioelectromagnetics
- **KA:** Exposure Assessment for Cellular and Personal Telecommunications
- **KB:** Computation of Electromagnetic Fields in the Human Body
- **KC:** Health Effects of Mobile Phones
- **KE:** Electromagnetic Interference with Medical Devices

Shoogo Ueno
Chair, Commission K

Radio-Frequency Radiation Safety and Health

James C. Lin

Health and Safety Associated with Personal Wireless Telecommunication Base Stations

While there are new, next-generation network roll-outs due this year, projected cellular mobile phone shipments from major makers continue to show a slow-down in growth. When these companies rebound, more wireless systems are likely to come online, each with its own network of base stations. This would extend the trends for the future, which look much the same as before the stall in the current product cycle, except that economic, public relations, and regulatory interests would likely lead to co-location of towers and antennas (i.e., locating base stations from different services on the same site or structure.)

The geographic region served by a base station is called a cell. A cellular base station, or cell site, refers to the antennas and their associated electronic equipment. Each base station is the equivalent of a radio station. Co-location of a greater number of base stations would undoubtedly result in increased levels of public exposure to microwave energy over time.

Cellular mobile communication systems make use of many base stations (or cells), located throughout a service area. When a user places a call, the handset communicates with a nearby base station. The base station then relays the call to a switching office, and then to another cell-phone handset, or to the conventional wired telephone network. As the user moves about from one cell to another, the system automatically hands off the call, seamlessly, to the next base station. Base stations and antennas are essential for cellular telephone and other wireless communications services. Microwave radiation is used to carry telephone messages and data between the mobile unit and base-station antenna at a fixed cellular site. Together, they make mobile telephony and wireless communication a reality, so that the user can communicate, and can access data and information, while on the go. While the message or data-handling processes and computational capability are all necessary aspects of a wireless communication system, the form and intensity of the transmitted microwave energy is of the greatest interest to biological responses.

There are considerable public concerns regarding the biological effects and safety of microwave exposure from wireless base stations. There have been repeated calls for measures and tools that would reduce the exposure to microwave radiation from cellular mobile telephone operations. In fact, at any given time, there are always one or two – or maybe a dozen – communities trying to stop a proposed base-station site.

The radiated power from a base-station antenna can vary from less than a watt to as high as 500 watts per channel (or transmitter), depending on the location and type of the antenna used for a cellular communication system. A typical base-station antenna is mounted on a tower, on the roof, or on the sides of a building, or on another structure that provides the required height. It may also be mounted indoors, on the ceilings of offices, homes, or airport terminals. These antennas provide tether-less access, with short distances between the transmitter and receiver, to enhance and supplant existing wired networks. Higher-power antennas are used at rural base stations to relay calls between the user and the wireless telephone system base stations, which are spaced far apart.

The distributions of base stations and antenna powers are determined by two related factors of the wireless communication system: Coverage and capacity. An adequate signal strength is necessary to cover the entire service area, and a sufficient capacity is needed to provide enough free channels to accommodate any user within the cell who might wish to use the system. As the number of users grows, more base stations are installed closer together, to increase capacity. However, they are operated at lower power levels, to provide comparable signal strength and to prevent interference among neighboring base stations. Thus, in urban areas, base stations (or cells) are closer together, but are operated at lower power levels than in rural areas, where the cells tend to be larger.

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The amount of microwave power radiated from a base station is limited by national and international regulations. For example, in the US, the Federal Communications Commission (FCC) permits an effective radiated power (ERP) of up to 500 W per channel. A cellular base station may transmit using as many as 21 channels per sector in a sectoral arrangement, typically with three sets of directional transmitting and receiving antennas to cover 360 degrees. Thus, the total ERP can be as high as 10.5 kW per sector. An ERP of 500 W corresponds to an actual radiated power of 25-50 W, depending on the type of antenna used. The ERP is higher than the power that is radiated, because it takes into account the directional characteristics of the antenna.

In rural or less-populated areas, a cellular base station may use several omnidirectional antennas, 3 to 5 m (10 to 15 ft) in length. The antennas may be from 30 to 100 m (100 to 300 ft) above ground. When omnidirectional antennas are used, up to 96 channels could be implemented at a cell site, with a maximum radiated power of 48 kW. An omnidirectional antenna radiates uniformly in all directions in the horizontal plane. Its radiation pattern might be visualized as a thin doughnut, centered on the antenna.

Base-station antennas are frequently located on free-standing, tall, tapered poles, much like lamp standards, or on towers of a metal-strut lattice construction. They may be located on existing structures, such as buildings, water tanks, or high-voltage transmission-line towers.

The majority of currently installed cellular base stations in urban and suburban areas of the US operate at an ERP of 100 W or less per channel. In major metropolitan areas, typical ERPs are on the order of 10 W or less per channel, and they also use smaller antennas. The power output of the base station could be reduced to as low as 1 W or less for a microcell configuration, using digital techniques.

Cellular mobile telecommunications use frequencies in the 800-2200 MHz region of the microwave spectrum. The first-generation cellular telephones are based on analog technology, and the output power is typically 600 mW. Digital communication service has been rapidly expanding in recent years. Its advantages over analog systems include compression by source coding, and transmission through channel coding, to reduce noise, error, and crosstalk. These features have made digital mobile technology competitive at power consumption as low as 10 mW. The digital systems use several modulation schemes, and the data transmission rate varies from 10s to 100s of kb/s. In addition, amplitude-modulated fields are intrinsic in all present and future mobile telephone systems using time-division multiple access (TDMA) and code-division multiple access (CDMA) schemes. The global system for mobile communication (GSM) is a variation of the TDMA system, incorporating frequency-division multiple access (FDMA). It is thus a hybrid TDMA/FDMA system. In TDMA, each call only uses a frequency band for part of the time. CDMA encodes each transmission to provide, in theory, much higher capacity.

The levels of public exposure to microwave energy from any base station would vary depending on antenna type, location, and distance from the base station. Base-station antennas, most commonly used in a sectoral arrangement, produce a beam that is pie-shaped. It is wide in the horizontal direction, but narrow in the vertical direction. While most of the radiated energy is contained in the main beam, as one moves away from the antenna, the signal spreads and decreases in strength as the inverse square of the distance from the antenna. Therefore, microwave fields are much weaker outside of the main beam than within it. The microwave exposure a person receives from a base station thus depends on both the distance from the antenna, and the angle below the direction of the main beam. At ground level, the signal is relatively weak near the base of an antenna tower, since the main beam is directed toward the horizon, and passes mostly overhead.

While a typical base station could have as many as 63 to 96 channels, not all of the channels would be expected to operate simultaneously, thus reducing overall emission levels. Exposure levels from cellular base stations can be determined by calculations, and confirmed by direct measurements. For example, at the base of 46 to 82 m (150 to 250 ft) towers with the cellular base station (omnidirectional, 880 to 890 MHz) antennas operating on 96 channels, 100 W ERP per channel, the maximum measured microwave power density was 0.01 W/m^2 or less [1]. The signal strength at ground level, at head height, increased gradually with distance from the tower, reached a maximum between 30-100 m (100 to 300 ft) from the base of the tower, and then decreased at still greater distances. Note that a comparison of measured power densities with the corresponding values calculated from the free-space transmission formula indicated that the analytical technique tended to overestimate the strength of the actual microwave fields.

As mentioned earlier, in an urban environment, base-station antennas may be located on existing structures, such as rooftops, elevator penthouses, sides of buildings, or on “sleds” some distance from the building parapet. The same investigators made measurements with typical base-station antennas (co-linear arrays, 880 to 890 MHz) on a flat rooftop. This showed (at head height) maximum microwave power densities of 0.001 W/m^2 per 100 W ERP per channel at 30 to 50 m (90 to 150 ft) from the base of the antenna, which decreased gradually with distance from the antenna. This would correspond to a maximum power density of 0.021 W/m^2 for a base station operating simultaneously on 21 channels. Similar measurements, made in the horizontal plane through the center of the antenna’s main beam, showed maximum power densities of 1.3 and 0.13 W/m^2 at 10 and 50 m (30 to 150 ft) from the antenna, respectively, for 21 channels.

Another study considered the exposure of – and power deposition in – a subject, for a typical rooftop-mounted antenna operating near 900 MHz, in an urban environment [2]. The study provided theoretical evidence to suggest that the presence of reflecting and scattering structures, such as building walls, can have a profound influence on both the exposure and the power deposition inside the human body. For instance, a subject standing on the rooftop at a distance of 8 m (24 ft) from the base of the antenna, operating with 21 channels at a radiated power of 7.5 W per channel, would be exposed to spatial average and maximum incident fields of 15 and 22 V/m (0.6 and 1.3 W/m^2).

If the human subject (1.8 m in height), with shoes, is facing the base-station antenna, a maximum power deposition, or specific absorption rate (SAR), of 28 mW/kg, averaged over 1 g, would be found in the head. A corresponding average SAR of 0.63 mW/kg would be obtained for the whole body. If the same subject stands 2 m (6 ft) away from the building wall, on a balcony located 30 m (90 ft) away, facing the antenna on the building next door, the spatial average and maximum exposure would be 29 and 42.5 V/m (2.2 and 4.8 W/m^2), respectively, in the main beam of the antenna. The maximum SAR in the head would be 69 mW/kg, and the SAR would be 2.4 mW/kg for the whole-body average. Note that the increase in exposure and SAR can be twofold or more. These results indicate that the highest exposure can occur not on the rooftop, where the base-station antenna is mounted, but instead on nearby buildings, in the direct path of the antenna's main beam.

The microwave power density will be lower inside buildings than outside, since a portion of the signal is absorbed when it passes through most building materials. (The attenuation factor for glass, wood, or cement is between 10 and 100.)

That exposure to radio- and microwave-frequency fields can produce adverse biological effects in human beings has been recognized for some time. Indeed, a sizable volume of studies has suggested that at sufficient power levels, exposure to microwave fields can produce heating of tissues in the body. The heating may or may not be detectable as a temperature elevation using available temperature-sensing devices. Nevertheless, the absorbed energy initiates translation, vibration, and rotation of ions and molecules in tissue that would ultimately be converted to heat. This knowledge was instrumental in the establishment of 10 mW/cm^2 (100 W/m^2) of incident power density as the guideline for human exposure to microwave fields in 1966. Subsequent research led to the development of a minor revision in 1982.

The scientific database continued to expand, as did the interest in biological effects and safety associated with microwave radiation. During the 1990s, recommendations for safety standards and exposure guidelines at frequencies used by cellular personal telecommunications systems were developed through several national and international organizations. Some of the principal organizations include the American National Standards Institute/Institute of Electrical and Electronics Engineers (ANSI/IEEE) [3], the US National Council on Radiation Protection and Measurements (NCRP) [4], the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [5], the European Commission (EC) [6], and the National Radiological Protection Board (NRPB) in the UK [7].

While there are subtle differences among the various safety guidelines, the basic metrics used for permissible exposure limits in the microwave region, used by wireless personal telecommunications, are similar. The concept of SAR and its frequency-dependent connection to incident power density formed the basis for the maximum permissible exposure (MPE). A SAR of 4 W/kg, temporally and spatially averaged over the whole body mass, was adopted as the threshold for adverse biological effects in humans. Above this threshold, disruption of work schedules in trained rodents and primates has been demonstrated. Note that a metabolic heat-production rate of 4 W/kg falls well within the normal range of human thermoregulatory capacity. Clearly, these guidelines provide recommendations to prevent adverse thermal effects on the functioning of the human body, although the assessment criteria for archival scientific reports of biological effects were without regard to mechanisms (thermal or non-thermal) of interaction.

As basic criteria, the specific SAR values adopted were 0.4 W/kg averaged over the entire body, or 8.0 W/kg for a gram of tissue. These SAR guidelines incorporate a safety factor of 10, to keep exposures below levels that are considered to be potentially adverse. Note that these values are further reduced by a factor of five for the general population (or in uncontrolled environments, where the user does not have control of the microwave source.). Likewise, reference levels were established for allowable incident power densities at different frequencies.

The consensus of the scientific community, based on present knowledge as reflected in these exposure guidelines, is that exposure to microwave radiation from wireless base stations, below the recommended limits in these guidelines, is safe.

In 1996, the US Federal Communications Commission (FCC) adopted guidelines for evaluating human exposure to microwave radiation from wireless base stations. The FCC guidelines [8] are identical to those recommended by the NCRP, and are also similar to the 1992 guidelines recommended by ANSI/IEEE C95.1-1992. Indeed, this is the only microwave-exposure standard that is enforceable by law in the US. At the wireless mobile telecommunication frequencies between 800 and 2200 MHz, the maximum permissible exposures are specified by $\left[f\left(MHz\right)/1500\right]$ mW/cm^2, as averaged over any 30-minute period, for the general population. In the case of base stations operating at a frequency of 880 MHz, the FCC's radio frequency (RF) exposure guidelines recommend a maximum permissible exposure level of about 0.59 mW/cm^2 (5.9 W/m^2). For base-station antennas transmitting at 1990 MHz, the FCC's exposure limits for the public are approximately 1.27 mW/cm^2 (12.7 W/m^2).

As mentioned above, the maximum exposures to RF radiation at ground level, on rooftops, or on balconies (i.e., in areas of public access) from base stations transmitting at 880 MHz are, respectively, 0.01, 1.3, or 4.8 W/m^2. These values are all below the 5.9 W/m^2 FCC limit, and are well within other widely promulgated guidelines. Based on present knowledge as reflected in these exposure guidelines, exposure of the general public to microwave radiation from wireless base stations is safe.

When base-station antennas are mounted at rooftop locations, it is possible that RF exposures approaching the safety guidelines could be encountered directly in front of the antennas, and on the balconies of very close-by buildings. However, within the buildings themselves, such exposure levels are very low, because rooftop antennas are normally designed to radiate energy in the horizontal direction away from the building, and a building's roof significantly attenuates the signal's strength.

The persistent public concern about the biological effects and safety of microwave exposure from wireless base stations can be traced, in part, to the public's desire to protect itself from unnecessary exposure to potentially harmful radiation, including RF and microwaves associated with cellular mobile telecommunication operations. This concern is posing new questions on the adequacy of the existing knowledge of biological effects of RF and microwave electromagnetic fields, and on the adequacy of the protection afforded the public from the harmful effects of these fields. Existing guidelines and standards were developed primarily from a scientific database derived using continuous-wave (CW) exposures. While some studies have reported biological effects specific to the signal forms and modulations commonly used by wireless mobile telecommunication, a majority of recent studies using these signal forms and modulations did not show any effect. However, given the confined scope and extent of recent studies, a wider range of investigations would be propitious in elucidating the safety of wireless base stations.

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UTC Time Step

On n'introduira pas de seconde intercalaire à la fin de décembre 2002.

La différence entre UTI et le Temps Atomique International TAI est :

du 1er janvier 1999, 0h UTC, jusqu'à nouvel avis : UTC - TAI = -32 s

Des secondes intercalaires peuvent être introduites à la fin des mois de décembre ou de juin, selon l'évolution de UT1-TAI. Le Bulletin C est diffusé deux fois par an, soit pour annoncer un saut de seconde, soit pour confirmer qu'il n'y aura pas de saut de seconde à la prochaine date possible.

No positive leap second will be introduced at the end of December 2002.

The difference between UTC and the International Atomic Time TAI is :

from 1999 January 1, 0 h UTC, until further notice : UTC - TAI = -32 s

Leap seconds can be introduced in UTC at the end of the months of December and June, depending on the evolution of UT1-TAI. Bulletin C is mailed every six months, either to announce a time step in UTC, or to confirm that there is no time step at the next possible date.

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XXVIIth General Assembly

NEWLY ELECTED OFFICERS, 2002-2005 TRIENNIUM

Following the elections at the XXVIIth General Assembly in Maastricht, The Netherlands, the Officers of the Board, the Scientific Commissions and the Scientific Committee for the 2002-2005 triennium are as given below.

Board 2002-2005

President: Kristian Schlegel (Germany)
Vice-Presidents:
- Chalmers M. Butler (U.S.A)
- François Lefeuvre (France) (*URSI Exposure* Officer)
- Andrzej W. Wernik (Poland) (*Treasurer*)
- Paul H. Wittke (Canada)

Secretary General: Paul Lagasse (Belgium)
Past President: Hiroshi Matsumoto (Japan)
Honorary President: A.P. Mitra (India)

Chairs 2002-2005

Commission A: Quirino Balzano (U.S.A)
Commission B: Makoto Ando (Japan)
Commission C: Masami Akaike (Japan)
Commission D: Peter Russer (Germany)
Commission E: Pierre J. Degauque (France)
Commission F: Martti T. Hallikainen (Finland)
Commission G: Christian Hanuise (France)
Commission H: Umran Inan (U.S.A.)
Commission J: Makoto Inoue (Japan)
Commission K: Bernard Veyret (France)

Vice-Chairs 2002-2005

Commission A: Stuart Pollitt (U.K.)
Commission B: Lotfollah Shafai (Canada)
Commission C: Andreas F. Molisch (U.S.A.)
Commission D: Frédérique de Fornel (France)
Commission E: Flavio Canavero (Italy)
Commission F: Piotr Sobieski (Belgium)
Commission G: Paul S. Cannon (U.K.)
Commission H: Richard B. Horne (U.K.)
Commission J: Richard Schilizzi (The Netherlands)
Commission K: Frank Prato (Canada)

The next URSI General Assembly will be heldin New Delhi, India, in October 2005.

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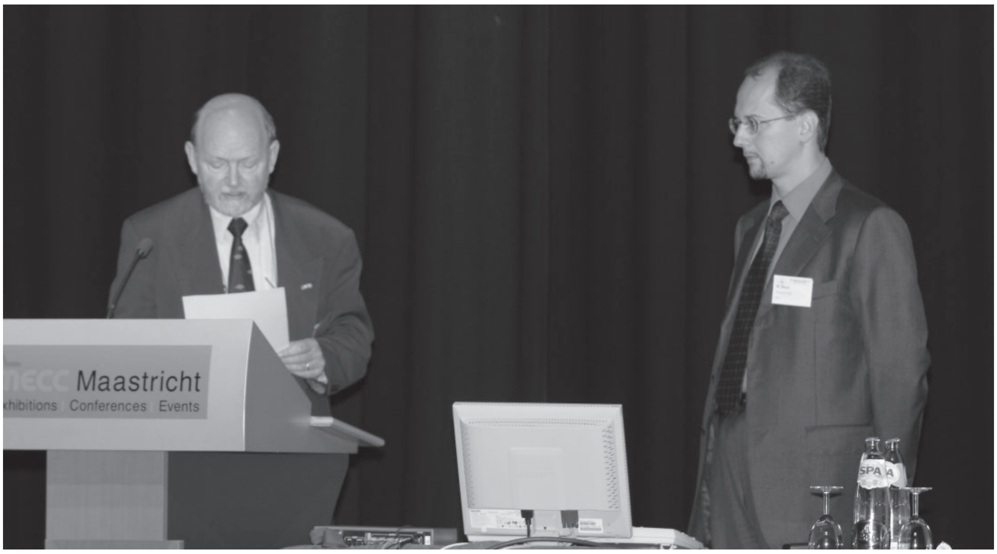
PHILIPS BEST YOUNG SCIENTIST PAPER AWARD



When the General Assembly of URSI convened after an interval of 48 years again in the Netherlands, Philips Research decided to finance an award for the best Young Scientist's contribution. This gesture was also made in view of the many important contributions made over a period of many years by Philips collaborators to Radio Science. The award consisted of a plaquette and an amount of € 1000,00. The selection was made in the following way. The chairpersons of each of the commissions were asked to nominate one Young Scientist for the award. A jury was set up consisting of the following senior scientists: Professors H. Matsumoto (URSI President), T.B.A. Senior (Past President), P.H. Wittke (Vice-President), E.V. Jull (Past President) and Dr. P. Bauer (Past President).

They interviewed each of the nominees and asked them to give a short review of their contribution. With this information at hand they had to make the difficult decision to select the best one.

The jury decided upon Dr. Maurizio Bozzi from Italy, now working at the University of Valencia in Spain. The title of his prize-winning contribution is "Efficient analysis of dichroic plates for large Reflector antennas".

Dr. Maurizio Bozzi studied at the University of Pavia where he obtained a PhD in electronics and computer science in December 2000. Since October 2001 he is with the Department of Applied Physics of the University of Valencia There he is mainly concerned with the development of tools for the analysis for wideband modelling of waveguide circuits including dielectric obstacles. Dr. Bozzi also serves on the Editorial Board of the IEEE Transactions on Microwave Theory and Techniques. Professor Frans W. Sluijter, acting on behalf of Dr. A. Harwig, the Managing Director of Philips Research hands over the prize to Dr. Bozzi during the Closing Ceremony of the General Assembly.

Conferences

CONFERENCE REPORTS

2001 Asia-Pacific Radio Science Conference

Tokyo, Japan, 1 - 4 August 2001

The 2001 Asia-Pacific Radio Science Conference (AP-RASC'01) was held at the Chuo University in Tokyo, Japan, on August 1-4, 2001.

The AP-RASC'01 is the first Asia-Pacific regional URSI conference which was held among URSI General Assemblies. The objective of this conference was to stimulate and to coordinate the research activities of radio science in the Asia-Pacific area. For many years, there had been expectations to hold radio science conferences or symposia in the Asia-Pacific area, where there are less member committees than in other regions such as in Europe and North America. Moreover, as well known, the URSI activities that covers all Commissions has a delta-functional peak at the time at GA every three years and almost no activities during the inter-GAs period. The AP-RASC'01 was one of the solutions to these requirements. After long discussions, the Japan National Committee of URSI decided to hold this Conference at Tokyo in 2001, and started the preparations in 1998, just before the URSI Toronto General Assembly.

The Conference was sponsored by the Japan National Committee of URSI, the Institute of Electronics, Information and Communication Engineers (IEICE) and co-sponsored by the International Union of Radio Science (URSI), supported by the Chuo University in cooperation with the following organizations: Association for Promotion of Electrical, Electronic and Information Engineering, Astronomical Society of Japan, Communications Research Laboratory, IEEE Japan Council, Japan Biomagnetism and Biomagnetics Society, Japan Society of Medical Electronics and Biological Engineering, National Space Development Agency of Japan, Society of Atmospheric Electricity of Japan, Society of Geomagnetism and Earth, planetary and Space Sciences, the Geodetic Society of Japan, the Institute of Electrical Engineers of Japan, the Institute of Space and Atronautical Science, the Japan Society of Applied Physics, the Laser Society of Japan, The Physical Society of Japan and the Remote Sensing Society of Japan.

Organisers

The Conference Chairperson was Dr. Yoji Furuhama, assisted by the International Advisory Board (Chairperson: Prof. Hiroshi Matsumoto), the International Steering Committee (Chairperson: Dr. Yoji Furuhama) and the Organizing Committee (Chairperson: Prof. Sogo Okamura)

Conference Program and Highlights

Two General Lectures were presented; one was "*Mobile Communications Technology – Most Brilliant Application of Radio Science"* by Prof. Yasuhiko Yasuda (Waseda University, Japan), and the other was *"Challenges at the Frontiers of Science and Engineering in Radio Astronomy"* by Prof. Govind Swarup (Tata Institute of Fundamental Research, India).

Prof. Yasuda reviewed the history of mobile communications in Japan, the new services (e.g. i-mode service, personal navigation service, music distribution service, cinema preview service, wireless POS (point\of sales) system, environmental monitoring service and other services), and the new technologies foreseen in IMT-2000 systems and future fourth generation systems. Prof. Swarup reviewed the typical existing large radio telescopes and some of the outstanding atrophysical problems. He also introduced several ambitious radio telescopes that were being planned to investigate these problems, e.g. Low Frequency Array (LOFAR), Square kilometre Array (SKA), and Atacama Millimeter Array (ALMA) Projects.

The main theme of this conference was "Radio Science - Communications, Environment, and Energy". Following this main theme, one Union Session entitled *"Solar Power Satellite and Wireless Power Transmission"* was organized and nine papers were presented. In connection with this session a demonstration of the wireless power transmission simulator (SPRITZ) was held during the conference.

A total of 86 sessions were organized, which covered all areas of radio science of ten Commisions of URSI. Nine Joint-Commission sessions were also included.

Those session titles were:

Commission A: Electromagnetic Metrology

- Frequency Standards
- Time Scales and Time and Frequency Transfer
- Frequency Stabilized Laser and Its Applications
- Electromagnetic Measurement and Standards

Commission B: Fields and Waves

- Scattering and Diffraction
- Media Effects in Electromagnetics
- Guided Waves
- Intelligent Antennas
- Electromagnetic Theory - Basics and Applications
- Electromagnetics in EMC Problems (BCE joint)
- IMT2000: Its development and Challenge (BCE joint)

- Computational Techniques and EM Field Simulator (BCDEFK joint)

Commission C: Signals and Systems
- Advanced Radio Technologies
- Radio Agents for Future Multimedia Personal Communications
- Microwave Photonics (CD joint)

Commission D: Electronics and Photonics
- Surface Emitting Lasers and Novel Microcavity Devices
- Advanced Devices for Wavelength Division
- Femtosecond Optoelectronics and Ultrafast Communications
- Lightwave Radio and Relevant Technologies (DBC joint)

Commission E: Electromagnetic Noise and Interference
- Ligthning Discharge
- Sprites, Elves and their Global Activities (EGH joint)
- Electromagnetic Compatibility in Communication Systems Apparatus (EC joint)
- EMC Problems in Printed Circuits Boards and Systems
- EMC Problems of Electrical Power Systems

Commission F: Wave Propagation and Remote Sensing
- Earth-Space Propagation
- Fixed Terrestrial Propagation
- Mobile and Indoor Propagation
- Polarimetric Remote Sensing of Earth's Environment
- Interferometric Remote Sensing of Earth's Environment
- Remote Sensing of Rain and Clouds
- Subsurface Remote Sensing and Ground Penetrating Radar
- Advanced Remote Sensing Technologies

Commission G: Ionospheric Radio and Propagation
- International Reference Ionosphere
- Ionospheric Dynamics and Disturbances
- Ionospheric Irregularities and Structures
- Progress of Ionospheric Radio Observations
- Electromagnetic Phenomena Related with Earthquake and Volcanic Activities (GE joint)

Commission H: Waves in Plasmas
- Plasma as a Complex System
- Observation and Theory of Plasma Waves in Space
- Wave Propagation and Remote Sensing of Magnetosphere
- Modeling and Computer Simulations in Space Plasmas

Commission J: Radio Astronomy
- Large Telescopes and Projects - Millimeter and Submillimeter Facilities
- Low-Frequency Telescopes and/or Dense Arrays
- VLBI Projects and Their Scientific Perspective
- Collaboration and Development of Radio Astronomy in Asia-Pacific Region
- Future Plans in the 21st Century

Commission K: Electromagnetics in Biology and Medicine
- Mechanisms and Physics
- Health Assessment
- Biological Effects of DC and ELF Fields
- Biological Effects of RF Fields
- Biomedical Applications
- Recent Activities of Electromagnetics in Medicine and Biology in Asia-Pacific Countries
- Dosimetry for Wireless Communications (KAB joint)
- EMC Problems Including Human Bodies (KE joint)

404 oral presentations were made in these sessions. A poster session was also scheduled at 16:00 to 19:00 on August 3, and 195 papers were presented. A Conference Digest, including one-page summaries of all papers, was issued and distributed to participants at the conference.

Country/Region	Participant	Oral paper	Poster paper
Argentina	1	0	0
Australia	27	20	7
Austria	2	1	1
Canada	6	4	1
China	23	21	1
Czech republic	3	1	0
Egypt	1	0	1
Fiji	1	0	0
France	5	2	1
Germany	12	6	4
Greece	2	1	0
India	10	11	2
Indonesia	5	2	2
Israel	2	1	1
Italy	4	3	1
Japan	453	211	138
Korea	23	22	1
Malaysia	2	1	0
New Zealand	2	3	1
Norway	1	0	1
Philippines	2	0	1
Poland	5	1	4
Russia	6	6	9
Singapore	5	6	0
Slovak Republic	1	1	0
Spain	1	1	0
Sweden	1	1	0
Switzerland	1	0	0
Taiwan R. O. C.	18	16	7
Thailand	11	3	3
The Netherlands	1	1	0
Turkey	2	2	0
U. S. A.	58	56	4
Ukraine	7	0	4
Total	704	404	195

Table 1: Number of participants and papers

Attendance

704 participants attended, including 20 accompanying persons from 34 countries/regions, with 48 young scientists from 17 countries/regions, whose travelling expenses were partly granted by the Conference Organizing Committee.

Social Activities

The conference began on the afternoon of 1 August, andTokyo Dome Hotel and all participants were cordially invited. Although Accompanying Person's Program and Scientific Visits were not prepared in this Conference, sightseeing tour desk was opened near the Conference registration desk.

Next Conference

The conference was very successful, although AP-RASC'01 was its first meeting. The Joint Meeting of the International Advisory Board and the International Steering Committee for AP-RASC'01 was held on August 2, and it was agreed unanimously that AP-RASC be held triennially between two consecutive URSI GAs. After this meeting, relating Member Committees negotiated the issues on next meeting and it was decided that the next AP-RASC would be held in China in 2004. This decision was announced by the Conference Chairperson at the Banquet on the evening of 4 August. Details of the next AP-RASC will be decided and announced soon.

Acknowledgments to URSI Community

AP-RASC'01is heartily thankful for the support from the whole URSI community, especially for the financial support from URSI Commissions, all but one of which assisted this symposium under mode B.

BIANISOTROPICS 2002

Marrakech, Morocco, 8 - 11 May 2002

Elias Canetti, who won the Nobel Prize for literature in 1981, collected his impressions of Morocco in the book *Voices of Marrakech* (originally, *Stimmen von Marrakech*). Should you have read this book, you may already have an idea about the feelings and setting of the Bianisotropics 2002 meeting. Marrakech was the venue for our meeting, the 9th International Conference on Electromagnetics of Complex Media. The fabulous city has not changed much in the 40 years that have passed since Canetti wrote his text.

Bianisotropics meetings have been forums for discussion of interactions of electromagnetic waves with chiral and other materials with complicated response. The first one of the series was held in Espoo, Finland (February, 1993), and that was followed by the subsequent meetings in Gomel, Belarus (October, 1993) Perigueux, France (1994), State College, Pennsylvania (1995), on a river cruise between St. Petersburg and Moscow (1996), in Glasgow (1997), Braunschweig (1998), and Lisbon (2000).

The Bianisotropics meeting this time was jointly organized by the Cadi Ayyad University of Marrakech and the University of Paris VI (Pierre et Marie Curie). The co-Chairs were Mohamed Arsalane (Morocco) and Said Zouhdi (France). There was assistance from Moroccan universities and the International Bianisotropics Conference Committee.The four days of the conference comprised 89 presentations, and 75 scientists from 24 countries participated. Characteristic to the bianisotropics meetings is that the organizers make special efforts to provide financial assistance to participants from countries with difficulties in funding international travel. The wide international spectrum of the participation in the Marrakech meeting was prominent. For example, we had participants from Russia (eight scientists), Belarus (seven), Ukraine (six), Georgia (one), Algeria (one), and from Morocco (14).

Figure 1. Professor Victor G. Veselago gave his keynote presentation on the history and state-of-the-art of "Veselago media," materials that display negative permittivity and negative permeability at the same time.

The keynote presentation of the meeting was given by Professor Victor G. Veselago (Figure 1) from Moscow. His topic was most up-to-date: materials with simultaneously negative permittivity and permeability. These media have been the object of extreme interest in the past two years or, so after the work of John Pendry of Imperial College in London, and David Smith and his group at the University of California, San Diego, who have indeed been able to fabricate such materials. But it was Veselago himself who "invented" such materials, in his article of 1967. There, he studied properties of such media, and showed that they would produce anomalous refraction, backward waves, inverse Cherenkov radiation, and an inverse Doppler effect. Very interesting applications can be envisioned for such media in problems where waveguiding, propagation, and refraction phenomena are involved.

In the recent literature, such materials have been given labels and names with imaginative variety: in addition to the very easy and concise "materials with simultaneously negative permittivity and negative permeability," we can see names like material with negative index of refraction, double-negative material, backward-wave medium, and even left-handed medium, nowadays very popular in articles by physicists (because the triplet of the electric-field vector, the magnetic-field vector, and the Poynting vector – which have a right-hand orientation for waves propagating in "ordinary"materials – are a left-handed triplet, in this case). However, especially in the community of bianisotropic and chiral electromagnetics, the use of "left-handed materials" is unfortunate. The attribute is misleading, because there is no handedness in the structure of these negative materials. On the other hand, handedness is the essential geometrical property of chiral media. But why should we choose among such complicated and non-positive names? Let us use the name "Veselago media" for electromagnetic materials that have the dielectric permittivity and magnetic permeability both negative (of course, because of the inevitable dispersion in all materials, the simultaneous negative values can only take place within a finite frequency range).

Speaking of terminology, in today's literature, the name of a new and complex material is also often reinforced by speaking of a "metamaterial," instead of a "material." But this also may be unnecessary: is there really a need to elevate the material to a higher level (like metaphysics is completely different and above from physics), and no longer consider it to be conceptually an ordinary material? After all, all materials are composites and mixtures of scattering and resonating elements on the lower level. Terminology has always been a source of misunderstandings. We can think of, for example, the present interest in photonic crystals, or photonic band-gap structures (PGBs), where microwave engineers have felt somewhat of the reinvention of the wheel. The studies and results of electromagnetic waves in periodic structures have been known for decades.

Figure 2. The closing session of Bianisotropics 2002 in the Sahara. The famous kasbah, named Ait Ben Haddou (the fortress behind the conference group), in medieval times guarded the lucrative trading route through the desert to Timbuktu. It is no wonder if the scenes are familiar: *Lawrence of Arabia*, among other famous movie classics, was filmed here. The Atlas mountains are in the far background.

- B. Jecko (IRCOM, France): "Anisotropic properties of PBG Materials – Applications to Design a New Kind of Antenna"
- D. Karkashadze (Tbilisi State University, Georgia): "Simulation and Investigation of Finite Photonic Crystals made of Biisotropic or Chiral Material"
- S. A. Khakhomov (Gomel State University, Belarus): "Artificial Anisotropic Omega-Structure at an Oblique Incidence of Electromagnetic Waves"
- I. Lyubchanskii (National Academy of Sciences of Ukraine): "Photonic Band Gap Effects in Magnetic Film with Stripe Domain Structure"
- R. Marques (University of Sevilla, Spain): "On the Electromagnetic Modeling of Left-Handed Metamaterials"
- S. L. Prosvirnin (Institute of Radio Astronomy, Ukraine): "Resonances of Closed Modes in Thin Arrays of Complex Particles"
- J. Psilopoulos (Technische Universität Braunschweig, Germany): "On a Statistical Assessment of Real Chiral Materials"
- A. Saib (Université Catholique de Louvain, Belgium): "From Ferromagnetic Nanowires to Magnetic PBG: Design of Microwave Devices"
- I. V. Semchenko (Gomel State University, Belarus): "Analytical Model of Artificial Chiral Media: Not Canonical Helixes but Real Spirals"
- C. R. Simovski (St. Petersburg State Institute of Fine Mechanics and Optics, Russia): "Dispersion Plots for Photonic Crystals from Infinitely Long Perfectly Conducting Spirals"
- A. L. Topa (Technical University of Lisbon, Portugal): "Surface and Leaky Modes of Multilayered Omega Structures"

Bianisotropics 2002 was also a NATO Advanced Research Workshop (ARW), with considerable financial assistance from this organization, which is very often associated in people's minds with the military. Wider perspectives to this one-sided picture of NATO were given in the opening ceremony of the meeting, where Dr. Fausto Pedrazzini (the PST Program Director of the Scientific and Environmental Affairs Division in the organization) gave a presentation about NATO's scientific dimension and activities.

The closing ceremony of Bianisotropics 2002 was held in the city of Ouarzazate, on the border of Sahara, on the other side of the High Atlas mountains (Figure 2).

Of the contributions presented in the Bianisotropics 2002, two collected works will be edited: a NATO ASI Series book, published by Kluwer, and a special issue in the journal *Electromagnetics*. But even before these, for those very eager to learn about what was presented in the meeting, there are the summaries of the presentations to be found at the conference Web site: http://www.ccr.jussieu.fr/bian02/conference/.

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Summer School on Spectrum Management and Radio Astronomy

Green Bank, WV, USA, 9 - 14 June 2002

The first ever Summer School on Spectrum Management and Radio Astronomy was held from 9 to 14 June 2002 in Green Bank, West Virginia, USA, and was, by any criterium, a great success. Approximately 35 formal lectures were presented during the week, in addition to some hardware demonstrations by Green Bank staff.

There were 45 participants from 12 countries; 23 from the United States and 22 foreign. Seven of the participants were female, 38 male - a much higher female representation than is generally found in Astronomy, Engineering or in Spectrum Management.

The Summer School was made possible by grants from the NSF, from URSI, and via IUCAF from ICSU (The International Council for Science).

Details of the Summer School, including most of the Power Point presentations, are available via http://www.iucaf.org/sschool/. The lectures will be compiled into a book, to be printed by NRAO. The intention is to repeat the Summer School on a 3-year cycle.

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CPEM 2002

Ottawa, Ontario, Canada, 16 - 21 June 2002

The biennial Conference on Precision Electromagnetic Measurements (CPEM 2002) was held in Ottawa, Canada from June 16 to June 21, 2002. It was hosted by the Institute for National Measurement Standards (INMS) of the National Research Council of Canada (NRC). A total of 366 delegates from 37 countries in all parts of the world attended the conference. There was a good representation of the metrology community of developing economies.

Among the highlights of the conference were the presentations in the plenary sessions. The speakers and their subjects were:

- Dr. A.J. Carty of the National Research Council of Canada who discussed the role of metrology and precision measurement in scientific advancement and economic growth.
- Dr. C. Salomon from Laboratoire Kastler Brossel who presented the latest projects on cold atomic clocks.
- Dr. J. Faller of NIST/JILA who described some of the work directed towards the precise measurement of gravity.
- Dr. E. Braun of PTB who reviewed the history of quantum hall effect in metrology over the past 22 years.
- Dr. J. Hall of NIST/JILA who presented the most recent advances in optical frequency measurement and standards.

CPEM 2002 had 53 technical sessions of contributed papers during which the latest research and development in electromagnetic metrology were discussed. There were 289 papers presented at the conference 103 of these being oral presentations and 186 as posters.

The subject matter of the papers includes: Electrical metrology ranging from quantum-based standards to high voltage precision measurements, Time and frequency metrology, Optical measurements, Lasers, Fundamental constants. There was also a session devoted to the Mutual Recognition Arrangement (MRA) and its implications on the National Measurements Institutes (NMI).

Summaries of all the contributed papers have been published in the CPEM 2002 Conference Digest. Extended versions of many of these papers will appear in a Special Issue of the IEEE Transaction of Instrumentation and Measurement.

A key element in the success of CPEM 2002 was the support from the following sponsors:

CPEM Permanent Sponsors: Bureau International des Poids et Mesures (BIPM), IEEE Instrumentation and Measurement Society, National Institute of Standards and Technology, USA (NIST), National Research Council Canada (NRCC), Union Radio Scientifique Internationale (URSI)

Sponsors of CPEM 2002: International Union of Pure and Applied Physics (IUPAP), Measurements International Limited (MI), National Conference of Standards Laboratories International (NCSL International), National Research Council Canada (NRCC), Union Radio Scientifique Internationale (URSI).

With the help from the sponsors of CPEM 2002, it was possible to support 10 young scientists to attend the conference and present their work. The young scientist grants were awarded to: Erkan Danaci, TUBITAK UME, Turkey, Gianni Durando, CNR-Instituto di Metrologia "G Colonnetti", Italy, Martin Galik, Slovak Institute of Metrology, Slovak Republic, Jana Horska, Czech Metrology Institute, Czech Republic, Jason Jones, JILA, University of Colorado, USA, Clayton R. Locke, University of Western Australia, Australia, Alexey Lugovoy, Institute of Laser Physics, SB, Russian Academy of Sciences, Russia, Kresimir Malaric, Faculty of Electrical Engineering and Computing, Croatia Holger Muller, Universitat Konstanz, Fachbereich Physik, Germany, Ruslan Papazyan, Royal Institute of Technology, Sweden.

The conference facilitated 12 expert meetings of interest to the delegates. A half-day technical tour of the Institute for National Measurement Standards Laboratories at the National Research Council of Canada was organized during the last day of the conference. CPEM 2002 also provided the delegates with a complete social program including a reception and banquet held at the Canadian Museum of Civilization. The next CPEM Conference will be held in London, England from June 27 to July 2, 2004.

16TH INTERNATIONAL WROCLAW SYMPOSIUM ON ELECTROMAGNETIC COMPATIBILITY (EMC)

Wroclaw, Poland, 25 - 28 June 2002

General

Co-sponsored by the URSI, the 16th International Wroclaw Symposium on Electromagnetic Compatibility (EMC) took place June 25-28, 2002, at the premises of the Wroclaw University of Technology in Wroclaw, Poland. It was held under the patronage of Mr. Marek Pol, Deputy Prime Minister, and under the auspices of the Polish Academy of Sciences Committee on Electronics and Telecommunications. As previously, the symposium was co-organized by the Wroclaw University of Technology, the National Institute of Telecommunications, and the Association of Polish Electrical Engineers, with dozens of cooperating international organizations and professional associations from various countries. Prof. D.J. Bem and Prof. A.Wierzbicki were the symposium co-chairmen and Mr. W. Moron' was its honorary chairman. The symposium council was chaired by Prof. W. Majewski with Prof. A. Pilatowicz and Dr M. Rusin as vice-chairmen. Prof. F.L. Stumpers, the URSI honorary president, was the honorary chairman of the program committee and I served as its chairman, independently of my URSI representative function. The two-volume, 794-page, symposium proceedings (edited by G. Lewandowski, W. Moron and W. Sega), were available at the opening the Symposium in paper volume and in electronic versions (CD-R). A short overview of the symposium contributions is given below. Further details are available at www.emc.wroc.pl.

Programme

Plenary lectures

There were four plenary lectures, dealing with general issues of EMC regulations and standardization, and with the EMC publications. Mr. W.A. Luther and Ms. D. Dalton presented the experience of the Federal Communication Commission and the Environmental Protection Agency in setting regulations through negotiations among the parties involved. Their talk was supported by a book offered to participants for free. The book, totalling over 900-pages of source texts was produced by the US government to improve the efficiency, adequacy and fairness of procedures by which federal agencies conduct regulatory programs in various controversial areas involving conflict of interests. EMC and spectrum sharing fall within that category. The US approach could be applied in other countries. Mr. K.-H. Rosenbrock reviewed recent access technologies and discussed the role of the regulations and standards in supporting technology development. His lecture summarized the experience of the European Telecommunication Standardization Institute he headed since many years. Mr. P. Kerry, the CISPR president, reviewed the worldwide EMC standardization. The major standardization bodies are the IEC/ ACEC and the CISPR. He described specific problem areas (thermostat interference, lightning interference, magnetron emissions, and low power radio receivers) and new EMC issues (broadband emissions, electric vehicles, digital immunity, and selective screening). He concluded with an extrapolation on what electromagnetic environment could be in the year 2010. In the last plenary lecture, Mr. M. D'Amore presented the IEEE and the IEEE Transactions on EMC, in his capacity of its Editor-in-Chief.

Sessions sponsored by URSI Commission E

There were 6 sessions sponsored by URSI Commission E. Sessions on terrestrial EM noise (organized by Prof M. Hayakawa, past chair of the commission): A.P. Nickolaenko, L.M. Rabinowicz, and A.Yu. Schekotov discussed polarization characteristics of the horizontal component of natural magnetic field in the Schumann resonance band (4-40 Hz). The resonance is observed in the spherical cavity earth-ionosphere when excited by thunderstorm activity. A.V. Shvets presented a technique and algorithm of tomographic reconstruction of the spatial structure of lightning activity. He discussed the spatial structure of Africa thunderstorms reconstructed from the observations performed in 1991. Y. Hobara and M. Hayakawa discussed the recent results obtained in continuous monitoring of natural ELF EM waves in Japan. A wideband (1Hz-1kHz) three-component ELF measurement system was installed in Japan to investigate continuous background signals, Schumann resonances and transient events. It was used for global mapping of thunderstorm activities and lightning location. M. Hayakawa presented an overview of electromagnetic phenomena associated with earthquakes studied within a national project on earthquake remote sensing just finished in Japan (the author served as principal scientist). In a separate presentation, K. Ohta, K. Umeda, N. Watanabe, and M. Hayakawa discussed changes in anomalous ELF propagation effects observed 4-5 hours before 1999 Taiwan earthquakes. Yu. Ya. Ruzhin, V.N. Oraevsky, I.I. Shagimuratov and V.M. Sinelnikov discussed ionospheric anomalies observed before the 1999 earthquakes in Turkey. These depended on the position of the epicentre, season, and time of the day. The authors noted the steady plasma anomaly above the Black Sea meaning that the plasma 'felt' the sea-land boundary. V.I. Larkina, Yu. Ya. Ruzhin, N.G. Sergeeva, and B.V. Senin discussed multiple manifestations of the earth crust structure dynamics observed in the ionospheric plasma parameters as evidenced by satellite observations. A correlation was discovered between anomalous bursts of noise at 0.1-20 Hz and low-energy precipitated electron flows above the Barents-Kara sea deep fault region. The authors suggested that the phenomenon is related to active development of stretch cracks of the earth crust, or to radioactive contamination of the sea water in the region.

Related to the above session (but not explicitly sponsored by URSI) was the session on natural EM environment phenomena, organized by Prof. T. Yoshino. It contained the following contributions: V. Oraevsky, K.A.

Bondarchuk, and Ya.Yu. Ruzhin discussed the nature of electromagnetic precursors of earthquakes observed at high frequencies (e.g. near 20 MHz). S. Shvets, M.Hayakawa, and O.A. Molchanov monitored sub-ionospheric earthquake-related phenomena at VLF. They noted possible precursory anomalies for nine of eleven seismic events of magnitude 5 and stronger. T. Yoshino presented results of decade-lasting observations of global natural background noise variations at the topside of the ionosphere at VLF, LF and VHF.

Session on gravito-electrodynamics, EHD, and their applications to natural hazards (organized by Prof. H. Kikuchi, past chair of the commission): N. Blaunstein discussed remote sensing of ionospheric indicators of precursors of earthquake by use of vertical and oblique ionosounds. A new anomalous effect in ionosphere was observed 10-12 hours before the seismic event. Additional effects were observed 2-3 hours before the event. He presented a model of interaction of acoustic-gravity waves generated by the litospheric displacements during the seismic events with cold ionospheric plasma in the presence of magnetic field. J. Chiba, T. Obata, Y. Nemoto analyzed seismic gravity and gravitational field detectors. They studied the turbulence of Newtonian gravitational field due to seismic waves and the detection of the turbulent field by an interferometric gravitational field detector. The source of turbulence was the variation of the mass density due to seismic waves. The possibility of observing gravitational turbulence due to earthquake was discussed also by T. Obata and H. Oshima. They studied the vertical gravitational turbulence 100 km from the epicentre of a shallow earthquake with the magnitude of M = 6. H. Kikuchi considered thoroughly electrodynamics of dust in an electric field with application to thunderstorms.

There were four sessions devoted to issues of spectrum use and management, a topic of the URSI Working Group E1 '*Spectrum utilization management and wireless telecommunications*'. These were organized by Mr. W.A. Luther, Chief, Radiocommunication Policy, FCC International Bureau. The first session dealt with spectrum congestion as a factor limiting the development of all applications of radio and having significant economic impact. The issue was raised by W.A. Baan and P. Delogne at the 26th General Assembly of URSI. In spite of the discussions at the assembly continued by P. Delogne and myself in the Radio Science Bulletin, the spectrum congestion problem was still unsolved. At EMC 2002, T.A.Th. Spoelstra discussed facts and fictions related to the problem. He indicated the weak points of the current radio spectrum policy, regulation, and management, especially in view of the proliferation of non-licensed and ultra-wideband devices. Representing the ESF Committee on Radio Astronomy Frequencies, he noted that spectrum congestion was ill defined and used in a confusing manner. He addressed the need for a dynamic spectrum management, for signal processing improving the efficiency of the spectrum usage, for regulatory control of the proliferation of unlicensed devices, for conditional frequency assignment, and for a standing item at world radio conferences that would aim at reduction of existing allocations. V. Tikhvinski reviewed economic aspects of the spectrum re-deployment in Russia. The spectrum allocated to military/ governmental systems must be released to accommodate new mobile radio services, which required the spectrum re-deployment. This involved strategic, technical and economic aspects. The author analysed various scenarios and proposed a formula to evaluate the re-deployment costs. N.I.Kharitonov and S.Ur. Pastuh considered the problem of selection of appropriate frequency bands for new radio technologies. For that purpose they proposed a statistical approach, frequency sharing and compatibility indexing, selection criterion, and algorithm. A. Medeisis presented spectrum management considerations associated with the wide-scale implementation of fixed wireless access systems. He showed that the implementation of such systems demanded novel spectrum management approaches. The author discussed a case study of frequency sharing with analogue radio relay links.

Session on spectrum management processes was second in this series. H. Toure, R. Mayher, B. Nurmatov and A. Pavliouk presented the ITU spectrum management computerized systems. The Basic Automated Spectrum Management System (BASMS) began was developed during the years 1992-1995. It was upgraded to WinBASMS in 1997. Now the ITU developed specifications for an Advanced Automated Spectrum Management System (AASMS). A. Geiss discussed an international frequency utilisation information system. The purpose of the system was to promote transparency, to facilitate access to information on specific uses of specific frequency bands in specific regions, and to give a means of checking the extent of harmonization of the spectrum use in Europe, meeting the practical requirements of industry and spectrum managers. The first version of the system was made available to public via internet. B. Eiselt described frequency management software system of the communication authority in Hungary. It was an integrated system supporting engineering tasks, national and international coordination procedures, licensing, fee collection, spectrum monitoring, archiving, and workflow control. H. Uryga discussed the future UMTS/ IMT2000 spectrum usage. She pointed out the main topics studied under the World Radiocommunication Conference 2003 in relation to future development of IMT2000 and adequate protection of terrestrial services from broadcasting satellite services.

The next session dealt with the spectrum management solutions. M. Stojkovic described recent activities of Intelsat, created in 1964 to bring satellite communications to the world. As an intergovernmental organization it was not subject to the regulations of any particular country or government. Under the pressure of the privatization/ liberalization wave, Intelsat was transformed in 2001 into private company. This resulted in a series of regulatory steps. E. Harroch, D. Vigier, and L. Elicegui presented compatibility study between GSM and UMTS cellular systems in adjacent bands using Monte-Carlo simulation. D. Vigier and P. Moorut discussed how SEAMCAT could be used to analyse the compatibility issues between ultra-wideband systems and GSM 1900 systems. SEAMCAT is the name of Spectrum Engineering Advanced Monte Carlo Analysis Tool developed in Europe and freely available from the European Radiocommunications Office (www.ero.dk). It was described in details in a separate presentation by M. LeDevendec and A. Refik, on behalf of the SEAMCAT Management Committee.

The fourth session dealt with the spectrum monitoring. The monitoring, i.e. observing the uses made of the radio spectrum, is a crucial element of spectrum management. J.J. Verduin described recent developments in this area in the ITU. An ITU handbook on spectrum monitoring was to be published in 2002. J. Pfitzner discussed new monitoring stations developed in Germany. P. Chahine, M. Dufour, E. Matt, J. Lodge, D. Paskovich, and F. Patenaude discussed an update of the digital monitoring and analysis system that was presented at a previous Wroclaw symposium. This high-speed system, developed by the Communications Research Centre of Industry Canada, was now in use by the Canadian government. Its open system hardware and software architecture allowed for facile adaptation to various application programs. H.I. Toure discussed increased location capabilities of HF spectrum monitoring networks. S. Kawase presented a new radio-interferometer using movable mirrors for monitoring geosynchronous-satellite orbital positions. It was created by a pair of small-aperture antenna combined with planar mirrors capable of rotating horizontally. The system was less expensive than other solutions.

Sessions sponsored by ITU-T SG5

Prof. G. Varju, V-chair of ITU T SG5 organized two panel sessions on EMC and EMF effects in telecommunication, sponsored by ITU-T Study Group 5 '*Protection against electromagnetic environment effects*'. A. Zeddam, V-chair of ITU-T SG5, who replaced R. Pomponi, chair of ITU T SG5, presented current studies undertaken in the group, aimed at setting standards, recommendations, directives, and handbooks related to electromagnetic phenomena that can cause damage or disturbance to telecommunication installations or injury to telecommunication personnel, or health effects to population. P. Day reviewed current work on over-voltage protection of equipment. C.F. Barbarossa discussed current problems in lightning protection for telecommunication systems. J. Boksiner dealt with EMF environmental characterization and guidance on human exposure. F. Brunello presented software for numerical prediction of the exposition to RF radiation in the vicinity of base station antennas. C. Monney discussed EMC problems related to the broadband access systems. D. Carpenter addressed the problems of EMC prediction through mathematical (statistical) modelling. H.G. Ohlin presented problems of interference from power systems, stressing sharing responsibilities between the telecommunication and non-telecommunication bodies involved. All these topics were covered by appropriate ITU publications. G. Varju offered practical guide on when and how to use the ITU standards, directives, recommendations, and handbooks, and how are they inter-related.

Sessions sponsored by NATO SWG10

Two sessions sponsored by NATO Special WG10 on "EM Environment Effects" were organized by Mr. R. Azzarone and Mr. M. Kukulka. The first session dealt with EMI measurement technology and methodology for naval applications. R. Azzarone presented the latest achievements in preventing naval electromagnetic interference (EMI). K. Dymarkowski and J.M. Uczciwek discussed unification of military and civilian EMC procedures and research facilities related to the immunity against the electrostatic discharge, especially in view of electro-explosive devices. R. Desideri and A.M. Ricci presented the EMC facilities and measurement methodology employed at the Italian Navy Institute for Telecommunications and Electronics for determining shielding effectiveness of missile containers and radar absorbing panels. Z.M. Joskiewicz and T.W. Wieckowski presented double-loaded half-loop antenna for measurements of emissions from printed circuit boards. The second session was devoted to modelling of maritime electromagnetic environment effects (E3). M. Bandinelli, F. Marsich, and G. Sammarone presented a performance analysis procedure and simulation tools for HF multiple-antenna ground station design. M. Kukulka discussed EMC problems related to ship radar operations over littoral waters under congestion conditions. M. Bandinelli and M. Bercigli presented an efficient computation of rotor-blade modulation effects on antenna pattern and link performance.

Other invited sessions

Session on coupling in and interaction with linear structures and electronics (organized by Prof. G. Wollenberg): His presentation (with S.V. Kochetov and A. Gorisch) dealt with transients in 3D interconnection structures with nonlinear loads excited by an incident field or lumped sources. The authors applied the Partial Element Equivalent Circuit method. N.V. Korovkin, J. Nitsch, A.A. Potienko, and E.E. Selina discussed unstable modes in distributed transmission systems with periodic parameters. G. Zschau and K-H. Gonschorek presented study on the magnetic and electrical field coupling into shielded cables in a complex environment. D. Nitsch and F. Sabath discussed prediction problems of ultra-wide band coupling to modern electronic equipment. F. Gronwald, J. Nitsch, and S. Tkachenko considered antenna coupling with cavities using hybrid representation methods.

Session on EMC and transmissions performance of telecommunications access networks (organized by Dr. L. Halme): The first paper, by L. Halme and R. Kyotonen, presented studies on modelling and simulation of telecommunication access networks. J.H. Walling studied random noise tolerance of 1000-base T-protocol channels, alien cross talk and a way to correlate the noise power to the unbalance attenuation of the channel. T. Hahner and B. Mund presented current IEC studies on measurements of the screening effectiveness of connectors and cable assemblies. C.W. Dole and L.J. Choate discussed accuracy of measurement of screening effectiveness of telecommunication access cables using statistical approach. S. Halme, R. Kyotonen, and V. Nassi considered transmission and EMC aspects of low-voltage power-lines used also for telecommunications.

Session on power line communication vs. radio services (organized by Prof. M.V. Ianoz, co-chair of URSI WG on interaction with, and protection of, complex electronic systems): G. Goldberg reviewed practical problems encountered in transmission of signals via low-voltage power lines and in planning power-line communication (PLC) systems. F. Issa, J-P. Rouzaud, and E. Perrier de la Bathie presented some in-situ measurements of the radiated power from an indoor installations and household appliances. F. Weinmann and K. Dostert discussed cumulative effect of power line communication installations in the far field. M. Ianoz discussed problems related to the definition of appropriate limits for radiated emissions due to power line communications. K.S. Kho considered protection requirements for HF military radio services against unwanted emissions from power line communication systems.

Sessions on electromagnetic field (EMF) exposure limits and standardisation in IEC and CENELEC (organized by Mr. G. Goldberg, past chair of the IEC Advisory Committee on EMC and the IEC TC77-EMC): The sessions began with his overview of the current status (2002) of international standardization activities and with suggestions concerning further work in this area. Then, M. Ianoz, J-Y. Gaspard, and F. Deschamps discussed the IEC theoretical approach to determine current induced in human body by external electric and magnetic fields at low and intermediate frequencies. C. Dale, J. Wiart, and M-F. Wong presented current studies related to EMF exposure due to radiation from base stations antennas. J. Robijns discussed the problem of EMF and household appliances. I. Brooker considered electromagnetic field exposure from electronic article surveillance systems (EAS), radio frequency identification systems (RFID) and similar systems. EAS systems are designed to prevent unauthorized removal of items from shops, libraries, etc. RFID systems are designed to carry/ check machine readable information imbedded in a tag (transponder) attached to various items such as a vehicle, a location, an individual, or an animal. H.J. Aniolczyk discussed new (2001) safety limits for occupational exposure in Poland. H. Mecke, T.K. Czarnecki, T. Winkler, and R. Doebbelin investigated ELF magnetic fields from resistance welding machines. B.W. Jakel studied magnetic fields from single-pole switchgear installations.

Session on interference modelling in wireless systems (organized by Prof V.Ya. Kontorovich): S. Sanchez Urieta, V.Ya. Kontorovich, and M. Lara Barron discussed problems of multi-user detection in DS-CDMA systems immersed in non-Gaussian environment. R. Chavez Santiago and V.Ya. Kontorovich presented a probabilistic approach to interference between fixed radio services and new cellular systems.

Session on EMC in amateur radio service (organized by Prof. H Trzaska): M. Rochalska discussed EM radiation hazard in amateur radio service. C. Verholt considered threats to short-wave radio communications and the status of the work within standardization organizations aimed at the protection of radio services below 30 MHz. P. Rinaldo presented the amateur radio interference assessment program (ARIA) initiated in 2001. The program is conducted in cooperation with the U.S. FCC Technology Advisory Council.

Other regular sessions

Session on technical aspects of biological effects of EM radiation: J.Wang and O.Fujiwara discussed modelling problems of EM interaction between an antenna mounted on personal computer and human body at 5 GHz frequency band. N. Uzunoglu, G.S. Stamatakos C. Christodoulopoulos and C. Tsilias presented a semi-analytical method for the determination of electromagnetic power density originating from radar and microwave link stations with practical dosimetric applications. M. Minosian, H. Sato, Q. Chen and K. Sawaya studied frequency-selective properties of surface-layered tissues of human head.

Session on lightning phenomena: K. Aniserowicz and G.G. Chavka considered distribution of currents and EM fields due to lightning discharge near lightning protection systems, using computer simulation. R. Zich and S. Marchi considered the relationship between the fine structure of the EM field radiated by a lightning return stroke and the geometry of the discharge channel. A. Ramli, N.A. Idris, A.H. Samad, B.Shariff and R.Hassan presented experimental study of multiple lightning-induced surges on telecommunication subscriber cable terminals in Malaysia.

Session on antennas and propagation: A. Gorbachev, T.M. Zaboronkova, A.A. Vasenkov and E.P. Chigin discussed remote sensing of moving objects using nonlinear EM wave scattering. R. Zich, M.Musetta, M. Tovaglieri, P. Pirinoli, and M. Orefice presented design method of microstrip reflectarrays (printed re-radiating antenna patches excited by EM waves). B. Levin analysed the near-zone EM fields of linear vibrators and loops.

Session on EMC in power systems: N. Henze and T. Degner discussed radio interference from photovoltaic power systems that contain an inverter transforming the direct current (DC) from the solar cells into alternating current (AC). S. Leva, A.P. Morando, and R.E. Zich presented study of radiation field of three-phase power-line system using the Park transform. R. Zich, S. Leva, and A.P. Morando discussed an exact full-wave model of three-phase power-line system.

Session on EMC regulatory aspects: U. Kartmann discussed European regulatory requirements and standards related to short-range (e.g. Bluetooth-based) devices. J. Rajamaki, and A. Kasanen presented an EMC market surveillance project on energy-saving lamps in Finland. F. Mussino, and E. Nano discussed the CENELEC and IEC standardization work on EMC of equipment and cable distribution networks for sound and television signals.

Session on EMC analysis, modelling and prediction: S. Baranowski, B. Demoulin, and L. Kone studied ray-tracing calculations of EM fields in oversized cavities and compared line source and dipole excitations. G. Chavka and N. Litwinczuk considered broadband matching of EMP simulators using computer modelling. H.Harms presented EMC analysis of a research and trial vessel to be produced in Germany. J. Kolodziejski and S. Kucinski discussed power supply current analysis for EMC purposes in integrated circuits.

Sessions on EMC measurement techniques: S. Fourcaudot, G. Vasilescu, G. Alquie, and V. Fouad-Hanna described an original method and experimental setup employed to measure the coupling capacitance responsible for the crosstalk between PCB tracks. F. Fiori and F. Musolino dealt with measurements of electromagnetic emissions induced by operation of integrated circuits. R. Azaro, S. Caorsi, and M. Pastorino considered a low-invasive investigation of EM field distribution (known in antenna technique as modulated scattering technique), its theory and EMC applications. A. Sowa, J.S. Witkowski, B. Paszkiewicz, and I. Zborowska-Lindert presented a light-powered and light-controlled switch for modulated scatterer technique applications. L. Nuno-Fernandez, F.D. Quesada, J.V. Balbastre, and A.B. Diaz-Morcillo presented a new approach to design of semi-anechoic chambers with arbitrary absorbers. A. Kriz, W. Muellner, J. Riedelsheimer, and F. Trautnitz considered validation methods of semi-anechoic chambers. K. Fujii, A. Sugiura, Y. Matsumoto, Y. Yamanaka, and T. Iwasaki discussed effects of a limited size of the test site ground plane on test-site calibration validation.

Session on shielding: R. Zich, D. Monopoli, and V. Daniele analysed the effectiveness of a slotted shield. W. Kreitmair-Steck and W. Tauber discussed the cable shielding and suggested that current requirements imposed on cables are useless in some cases. A. Vogt, H.A. Kolodziej, and A.E. Sowa presented new absorbing materials for L, S, and C bands. M. Paliogova, J. Vilcakova, P. Saha, V. Kresalek, O. Quadrat, and J. Stejskal discussed electric and dielectric properties of composites of polianiline-coated short carbon fibres in epoxy resin. H. Aniolczyk, J. Koprowska, and P. Mamrot considered applications of electrically conductive textiles as EM shields in Physiotherapy and electrosurgery.

Session on ESD and Transients: S. Leva, A.P. Morando, M. Sacchi, and R.E. Zich presented an effective numerical approach to transient phenomena induced by external EM fields in grounded multi-conductor transmission lines. O. Fujiwara and H. Seco discussed a new FDTD algorithm used in studies of EM fields due to electrostatic discharges through time-varying spark-channel. K. Kawamata, S. Minegishi, and A. Haga considered time-domain frequency-domain measurement of transient EM processes in micro-gap discharges using a 4.5 GHz-bandwidth experimental system. J. Sroka discussed calibration uncertainty of ESD simulators.

Session on EMI Reduction Techniques: R. Zich and F. Cavelzani discussed 'genetical' optimization of perforated EM shields. H.H. Park, J.W. Lee, and J-H. Kwon considered common-mode current travelling along a wire penetrating a corrugated aperture. W. Kreitmair-Steck and W. Tauber discussed aircraft hazards caused by the onboard operation of portable electronic devices and proposed new emission limits, because the current limits are inadequate. F. Fiori and P.S. Crovetti considered a new high-immunity complementary differential pair for operational amplifiers. V. Trigubovich presented statistical considerations concerning an adaptive polarization filter.

Poster sessions and tutorial lectures

Poster sessions grouped contributions on
(a) Biological Effects of EM Radiation,
(b) EMC in Radio and Wire Communications,
(c) EMC Analysis, Modelling, Prediction,
(d) EMC in Transport Systems,
(e) Lightning and Transients,
(f) Antennas and Propagation - EMC Aspects, and
(g) EMI Reduction Techniques.

There were tutorial lectures on EMC as an inseparable part of system design, offered Mr. E.B. Joffe.

Exhibitions and workshops

A technical exhibition and an exhibition of EMC books, regulations, and standards complemented the programme. Both were well attended. Four workshops took place during the Symposium. These covered the following topics: 'SEAMCAT' (D. Vigier/ Motorola) 'Measurement Fidelity and Analysis of High-Speed Signals' (convenor: T. Asyngier/ Tektronix), 'EMC Measurement Software for Use in R&D, Compliance and Batch Testing' (M. Donhauser/ Rohde & Schwartz), 'RF Tester for Antenna Development, Specific Absorption Rate Measurements, and Quality Assurance of Wireless Products' (M. Donhauser/ Rohde & Schwartz) 'End to End Performance Monitoring, Reporting and Analysis for Wireless Networks (Agilent Co.), 'Meeting the Challenges of Deploying GPRS Networks' (Agilent Co.) and '3G Test Challenge for the Deployment of UMTS Networks' (Agilent Co.).

Arrangements

Desktop computers with access to Internet were made available, free of charge, to all participants. For those interested, amateur radio station was made available, and a ham's meeting was organized. Post office, payphones, coffee shops and canteen were at the disposal of the participants at the place. The four days of the symposium were filled tightly. On the evening of the first day, all participants were invited to a cocktail party held in historical rooms of the 13th-century, gothic architecture City Hall, serving now as a museum. The local Opera Quintet and fine food and drinks created a friendly atmosphere. It was reinforced during the picnic party on the third day of the symposium. Special buses were offered to transport the participants from hotels to the sessions, cocktail, picnic, and back. The last evening, the members of the symposium committees and session Chairmen with accompanying persons were invited to the final reception. An accompanying-persons programme and post-symposium tours were offered, including visits to classified first-class UNESCO's registry of World Heritage Sites.

Participation and Young Scientists Programme

There were 195 participants from 34 countries. Figure 1 shows details, and Figure 2 shows the totals in comparison with previous events. A half of all participants came from four countries and a half of all contributions come from five countries. Thanks to the financial contributions obtained from the URSI and from the European Office of the United States Air Force Research Laboratory, it was possible to support 16 participants from Ukraine (4), Russian Federation (4), Germany (3), Czech Republic (2), Belarus (1), Poland (1), and Bangladesh (1), including young scientists. It was suggested at previous occasions that it would be a good idea to organize URSI open meetings with national URSI members, and the local university professors and graduate students, but unfortunately local organizers have found that not possible this time.

Comments

The contributions accepted for presentation covered almost all theoretical and practical aspects of EMC. Most of them were directly related to the terms of reference of URSI Commission E (Electromagnetic Noise and Interference). Some were relevant also to the terms of reference of Commissions A (Electromagnetic Metrology, Measurements and Standards), B (Fields and Waves), C (Signals and Systems), F (Wave Propagation and Remote Sensing), G (Ionospheric Radio and Propagation), H (Waves in Plasma), J (Radio Astronomy), and K (Electromagnetics in Biology and Medicine). Others were dealing with studies carried out by ITU, CISPR and other co-operating organizations. Note that EMC 2002 dealt with areas felt as inadequately covered by other similar events, such as natural and man-made EM environment, EM phenomena associated with processes in the earth thrust, atmosphere and ionosphere, the radio spectrum management, and international aspects of convergence of civilian and military standards. All the participants that contacted me have found the symposium well organized and beneficial. They lauded the high quality of contributions, which was evidently due to the invited speakers of international reputation and highly competent reviewers. However, at an earlier phase, the symposium web site was not always working as expected due to viruses.

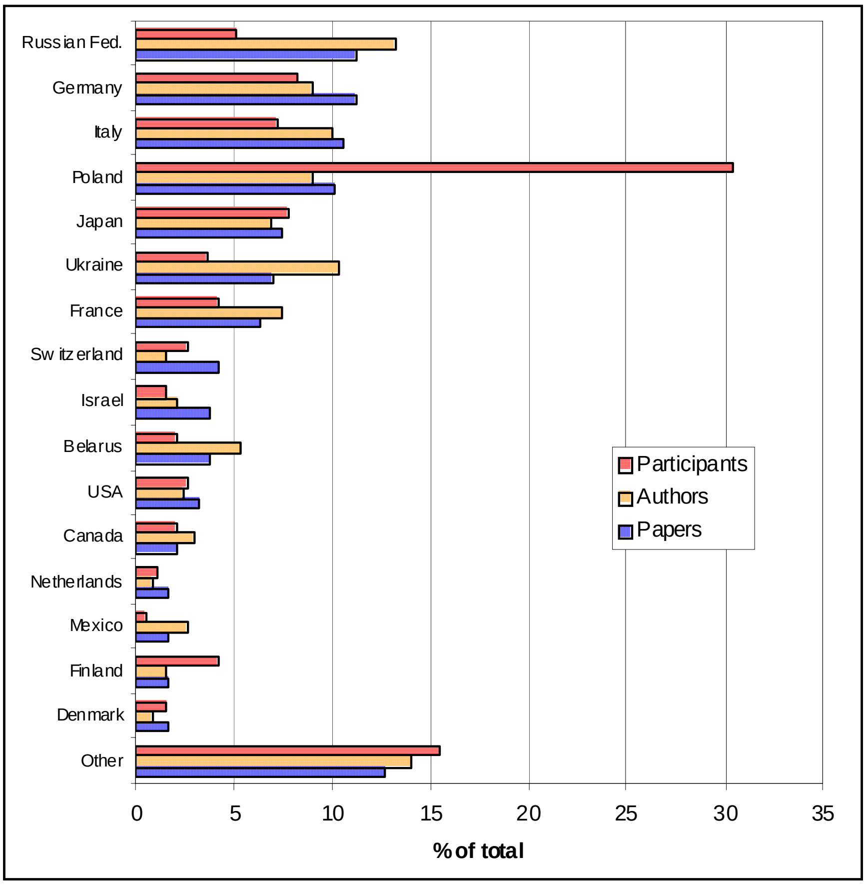

Figure 1. EMC Wroclaw 2002 participation vs. country of origin

The members of all symposium committees and the session chairmen met together at the end of the symposium, to discuss its outcome. Some submitted their comments via email later. Comments of a general nature are discussed below. Detailed comments of operational character (such as those concerning careful selection of place for poster sessions) have been transferred to the organizers.

An opinion was voiced that standards and regulations, being '*not scientific*' topics, should preferably be dealt with at workshops rather than at URSI-sponsored symposia. My personal view is that scientific approach to standardization and regulation activities should be encouraged and supported by URSI at any occasion. EMC regulations and standards are a framework critical to all applications of radio. They impact heavily the industry, services, sciences, and general public. For that reason they should be rational and unbiased as much as possible. Only scientific approach can guarantee that. Others share that understanding: for instance Dr Spoelstra appealed at EMC 2000 that scientists should play more active role in regulation and standards development, spectrum management, and related technical studies.

A member of the program committee wrote that we should not loose the historical perspective when discussing the outcome and future of this symposium. In the past, he saw at the Wroclaw gatherings '*the outburst of the willingness of people (especially young) to study EMC*'. But at EMC 2002 he was disappointed seeing a very low number of papers from the hosting country, especially by young authors. Earlier, he saw fruitful interaction between Western and Eastern scientists and engineers, as former USSR engineers were participating in Wroclaw EMC conferences very actively. '*Wroclaw was the only one place for such an interaction'*, he wrote, but now '*Russians [...] showed no interest...'* Also the EMC field coverage was wider as Wroclaw was the only possibility to have sessions on natural noise, a topic '*excluded at many EMC symposia*'. '*It is [now] a great pity that there are few papers dealing with the fundamental aspects of EMC field in any EMC conference...*' He wrote further: '*Wroclaw is located between East and West, [and] there are so many engineers and scientists from Russia, Poland, Ukraine, etc. This history should be kept for [the] Wroclaw Symposium, and we hope to maintain [it]*'.

These remarks reflect the changes we witness today, and apply equally to other EMC symposia that base on R&D work, I believe. Slowdown of world economy, especially troubles the telecommunication sector has suffered in

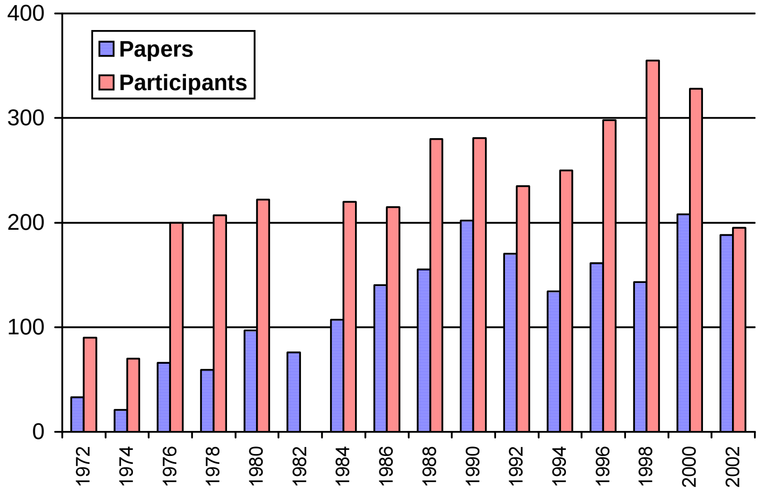

Figure 2. Participation in EMC Wroclaw Symposia in the years 1972 – 2002

recent years, has changed the priorities. Almost everywhere spending public money on fundamental research has been limited to areas critical for the national defence. With budget difficulties, usually education and research suffer most. Few people have the participation in EMC symposia in mind when stock market plunges, companies bankrupt one after another, and countries like Argentina fight for survival. Terrorist threat at airports also does not encourage. In this region of the world there are also structural causes. After the system changes, most of research and development have to be financed from the enterprise budgets. Massive buyouts of local industries by international companies results in reduction of R&D work in the region, as it is more cost-effective to concentrate R&D at headquarters where the already existing infrastructure is better developed. Under the pressure of merciless competition, the non-governmental R&D has been restricted to minimum necessary to survive. Trade secrets and intellectual property have become more sensitive issues, and many companies approve publishing only if it can bring them a measurable profit. Few companies that still make profit prefer often spending money on conferences over which they have full control, following their business strategy.

Being one of co-founders of this symposium in 1972, I recall the original idea of bringing together scientists, engineers, and administrators dealing with electromagnetic interactions and electromagnetic compatibility, no matter their professional, national, political, racial, or religious roots are. It was a delicate task, as the world was divided and cross-the-iron-curtain contacts were difficult. The concept of electromagnetic compatibility was established in the United States and EMC conferences were regularly being held there, but there were no such events in Europe. To eliminate the language barrier, the Wroclaw symposium was convened in two languages, English and Russian, for several years. With time, this oldest EMC biannual event in Europe has enjoyed the support of major organisations and renowned international experts and gained its reputation. Today, communication problems no more exist, but the organizers are confronted with financial difficulties. Russian language could no more be supported, which reduced the conference attractiveness for all potential participants coming from the ex-Soviet block. With reduced subventions, the income from the participation and exposition fees is often insufficient to cover all necessary expenses. The support of young scientists and authors unable to cover the participation costs is a problem. Competition on the exposition market is sharp, and many companies prefer to be seen at big events like the ITU Telecom, instead of EMC conferences of only 200 people or less, like the Wroclaw event. As a solution to financial problems, I suggested earlier a new format of internet-based '*symposium at a distance*', but with the present status of multimedia services the idea was not supported.

Another factor addressed was the character of the symposium. Two opposite directions were mentioned: a more specialized, academically-oriented conference (which means smaller number of participants), or a more general, technology-oriented one (with larger number of expected participants). Until now, the Wroclaw conference tried to combine both, the high-level academic contributions and technology/ engineering-oriented papers on such key problems as EMC regulations, spectrum management, and standards. That broad range of various topics included in the programme was generally praised, and continuation of efforts towards a balanced representation industry vs. academia, practice vs. theory, was encouraged. No clear preference was seen at the discussion, and continuation without change would thus be the third possible direction. What direction the conference would really go, depends on the visions and on limitations of the organizers of future events. A wish was expressed that the members of EMC 2002 program committee be informed about further developments in that matter. As the committee formally dissolves after the conference, this would imply informal communications among those interested.

Information on other EMC symposia in Europe was noted. As the population of EMC society is limited, any EMC conference is a potential competitor to others. Coordination seems to be necessary. The Wroclaw symposium enjoys time-coordination with the Zurich EMC symposium from the very beginning, and both symposia have been held every second year consecutively since 1975. Each new symposium disturbs that arrangement. One solution would be to have each symposium highly specialized in its own specific area; to not interfere with each other. Another possibility would be to transform all of them into one European EMC symposium wandering from one place to another, as it was suggested earlier at various occasions. The meeting supported this solution. It would satisfy the needs and ambitions of various regional groups. The URSI, European Commission, other European bodies could play a role in such coordination. Independently, Prof. R. Vahldieck, President of the Zurich EMC Symposium, in his letter presented at the meeting, submitted similar idea of pan-European co-ordination. So did representatives of the IEEE EMCS. This conclusion is submitted for consideration by organisers of future EMC symposia.

Acknowledgment

The EMC 2002 Wroclaw symposium would not be possible without active support of numerous individuals. As the program chair, I would like to thank the program committee members, session convenors, and session chairmen for their time and talents they offered generously to arrange the symposium program, to select contributions, to make the symposium happened, and to evaluate it and discuss its future. They are listed alphabetically: T. Asyngier (*Germany*); R. Azzarone (*Italy*); J.V. Balbastre (*Spain*); T. Boe (*Norway*); M.A. Bykhovsky (*Russia*); J. Catrysse (*Belgium*); G.M. Chavka (*Poland*); M. D'Amore (*Italy*); P. Degauque (*France*); M. Donhauser (*Germany*); V.E Fortov, (*Russia*); O. Fujiwara (*Japan*); G. Goldberg (*Switzerland*); K.H. Gonschorek (*Germany*); E. Habiger (*Germany*); L. Halme (*Finland*); J. Hamelin (*France*); M. Hayakawa (*Japan*); M.V. Ianoz (*Switzerland*); E.B. Joffe (Israel); U. Kartmann (*Germany*); A. Karwowski (*Poland*); P.J Kerry (*UK*); H. Kikuchi (*Japan*); V.I. Kontorovich (*Mexico*); W. Kreitmair-Steck (*Germany*); M. Kukulka (*Poland*); H. Lorke (*Germany*); W. Luther (*USA*); J. Malko (*Poland*); A.C. Marvin (*UK*); V.I. Mordachev (*Belarus*); E. Nano (*Italy*); A.S. Podgorsky (*Canada*); R. Pomponi (*Italy*); V. Rawat (*Canada*); K. Ruf (*Germany*); A. Schiavoni (*Italy*); J. Shapira (*Israel*); A.W. Sowa (*Poland*); T.A.Th. Spoelstra (*The Netherlands*); J. Sroka (*Switzerland*); F.L.H. Stumpers (*The Netherlands*); H. Trzaska (*Poland*); G. Varju (*Hungary*); D. Vigier (*France*); G. Wollenberg (*Germany*); T. Yoshino (*Japan*); A. Zeddam, (*France*) R.E. Zich (*Italy*). Special thanks go to W. Sega (*Poland*) for taking over the responsibilities of coordinating the technical program of the symposium.

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CONFERENCE ANNOUNCEMENT

TENTH INTERNATIONAL WORKSHOP ON TECHNICAL AND SCIENTIFIC ASPECTS OF MST RADAR - MST 10

Piura, Peru, 20 - 27 May 2003

The international workshop on MST radar, held about every 2-3 years, is a major event gathering together experts from all over the world, engaged in research and development of radar techniques to study the mesosphere, stratosphere, troposphere (MST). It offers also excellent opportunities to young scientists, research students and also new entrants to the field for close interactions with the experts on all technical and scientific aspects of MST radar techniques. The tenth MST radar workshop (MST10) -as the previous MST workshops- will focus on the following topics:

* Radar scattering processes in the neutral atmosphere
* D, E, and F region coherent scattering (PMSE, Es, EEJ, ESF)
* Winds, waves and turbulence in the lower and middle atmosphere
* Meteorological phenomena and applications.
* Operational aspects and recent system developments

As a new approach, the workshop MST10 will consist of two major parts:

* Standard workshop papers presented orally or as posters (4 days), and
* A brain-storming meeting (1.5 days) with the aim to highlight open questions and potential solutions, to produce proposals for innovative approaches, define new programs and prepare recommendations.

The latter bases on the Permanent Working Groups of the MST radar community on:

(1) System Calibrations and Definitions,
(2) Data Analysis, Validation and Parameter Deduction Methods,
(3) Accuracies and Requirements for Meteorological Applications,
(4) International Collaborations.

The workshop MST10 will be held at the wonderful campus of the Universidad de Piura (UDEP, http://www.udep.edu.pe) in northern Peru. This site is known due to its operation of ST and boundary layer radars, which are part of the activities of the Instituto Geofísico del Peru, operating the Jicamarca Radio Observatory (JRO), in collaboration with international institutions like the University of Colorado (via CIRES) and NOAA (via the Aeronomy Lab). Included in the workshop activities are site-seeing tours and a visit of the Jicamarca Radio Observatory (http://jro.igp.gob.pe) in Lima.

The International Steering Group of MST10 consists of: J. Roettger (Chair, Germany), J. Chau (Peru), S. Fukao (Japan), E. Kudeki (USA), and R. Woodman (Peru). Adherent to the International Steering Group are the Chairpersons of the MST Radar Permanent Working Groups: P. Chilson (USA), D. Holdsworth (Australia), G. Nastrom (USA), P.B. Rao (India), and M. Yamamoto (Japan). Honorary Members of the Steering Group are: M.F. Larsen (USA), C.H. Liu (Taiwan), A.P. Mitra (India).

The National Organizing Committee of MST10 consists of: R. Woodman (Chair, IGP), J. Chau (ROJ-IGP), Antonio Mabres (UDEP) and M. Sarango (Ciencia Internacional).

The Local Organizing Committee of MST10 consists of: Rodolfo Rodriguez (Chair), William Ipanaque, and Sergio Balarezo.

The Scientific and Technical Program Committee will be established before the circulation of the Second Circular.

The Tenth International Workshop on Technical and Scientific Aspects of MST Radar - MST10 - is an activity sponsored by the Scientific Committee on Solar Terrestrial Physics (SCOSTEP), the Instituto Geofísico del Peru (IGP) and the Universidad de Piura (UDEP). Further sponsors, such as URSI, Ciencia Internacional, and other agencies and foundations are expected.

If you are interested in attending the MST10 and like to receive the Second Circular of MST10 please send an e-mail to: mst10@jro.igp.gob.pe by August 15, 2002, including in your message:

1. Your name and affiliation
2. Full mailing address
3. Telephone and fax numbers including the international code
4. E-mail address
5. An indication whether you are planning to present paper(s)
6. Potential topic of your paper(s)

The Second Circular of MST10, which will be distributed in October 2002, will contain details about abstract submissions, information about the venue and logistics for the meeting.

URSI CONFERENCE CALENDAR

October 2002

34th COPSPAR Scientific Assembly - World Space Congress 2002
Houston, Texas, USA, 10-19 October 2002
Contact: COSPAR Secretariat, 51 bd de Montmorency, 75016 Paris, France, Tel: +33 1 4525 0679, Fax: +33 1 4050 9827, E-mail:cospar@cosparhq.org,Internet:http://www.copernicus.org/COSPAR/COSPAR.html

Getting the Most Out of the Radio Spectrum
London, United Kingdom, 24-25 October 2002
Contact : Getting The Most Out of the Radio Spectrum Secretariat, Event Services, Institution of Electrical Engineers, Savoy Place, London WC2R 0BL, Tel: +44 20-7344 5422, Fax: +44 20-7497 3633, E-mail: emaycock@iee.org.uk

EMF and Cardiac Pacemakers and Defibrillators
Paris, France, 25 October 2002
Contact : Secrétariat de la SFRP, BP 72, 92263 Fontenay-aux Roses Cedex, France, Tel : +33 1 46 54 72 85, Fax : +33 1 46 54 83 59, E-mail : jacques.lombard@irsn.fr, http://www.sfrp.asso.fr and http://www.cardio-sfc.org

November 2002

JINA 2002 - 12th International Symposium on Antennas
Nice, France, 12-14 November 2002
Contact: Secrétariat JINA 2002, France Télécom R&D, Fort de la Tête de Chien, 06320 La Turbie, France, Fax: +33 4 9210 6519, E-mail: jina.cnet@wanadoo.fr, Internet: http://www.jina2002.com

APMC2002, Asia-Pacific Microwave Conference
Kyoto, Japan, 19-22 November 2002
Contact: Prof. Shozo Komaki, Chair, Steering Committee, c/o Realize Inc., 4-1-4 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan, Tel: +81-3-3815-8590, Fax: +81-3-3815-8529, Email: mweap mc@bleu.ocn.ne.jp, http://www.apmc-mwe.org

ISAR-3 - Third International School on Atmospheric Radar
ICTP Trieste, Italy, 25 November - 13 December 2002
Contact : Dr. Juergen Roettger, Max-Planck-Institut fuer Aeronomie, Max-Planck-Strasse 2, D-37191 Katlenburg-Lindau, Germany, Tel. +49 5556-979163, Fax +49 5556-979473, E-mail : roettger@linmpi.mpg.de

ISAP-i02, Intermediate International Symposium on Antennas and Propagation
Yokosuka, Japan, 26-28 November 2002
Contact: Prof. Kenichi Kagoshima, Chairperson, ISAP i-02, Ibaraki University, 4-12-1 Nakanarusawa, Hitachi, 316-8511 Japan, http://www.ieice.org/cs/ap/ISAP2002/

February 2003

EMC Zurich '03 - 15th International Zurich Symposium and Technical Exhibition on Electromagnetic Compatibility
Zurich, Switzerland, 18-20 February 2003
Contact : Dr. G. Meyer, Chairman EMC Zurich, ETH Zentrum - IKT, CH-8092 Zurich, Switzerland, Tel. +411-632-2790, fax +411-632-1209, gmeyer@nari.ee.ethz.ch , http://www.emc-zurich.ch/emc03/

April 2003

Supernovae
Valencia, Spain, 22-26 April 2003
Contact : Prof. Jon Marcaide, Dpto. Astronomia, Universidad de Valencia, E-46100 Burjassot, Valencia, Spain, Phone: +34-963983079, Fax: +34-963983084, E-mail: sne2003@reber.uv.es

May 2003

MST 10 - Tenth International Workshop on Technical and Scientific Aspects of MST Radar
Piura, Peru, 20-27 May 2003
Contact : Dr. Jürgen Röttger, Max-Planck-Institut fûr

Astronomie, D-37191 Katlenburg-Lindau, Germany, Fax +49 5556-979 410, E-mail roettger@linmpi.mpg.de, http://jro.igp.gob.pe (conference site not yet installed)

August 2003

ISMOT 2003 - 9th International Symposium on Microwave and Optical Technology
Ostrava, Czech Republic, 11-15 August 2003
Contact: Prof. Jaromír Pištora, Symposium Chair, Department of Physics, Technical University of Ostrava, 708 33 Ostrava - Poruba, Czech Republic, E-mail: ismot2003@vsb.cz , http://www.ismot2003.cz

November 2003

APMC 2003
Seoul, Korea, 4-7 November 2003
Contact : Prof. Hyo Joon Eom, Dept. of Electrical Engineering, Korea Advanced Institute of Science and Technology, 373-1, Kusong-dong, Yusong-gu, Taejon, Korea, Fax : +82 42-869 8036, hjeom@ee.kaist.ac.kr , http://www.apmc2003.org

August 2004

ISAP'04 - 2004 Intermediate Int. Symp. on Antennas and Propagation
Sendai, Japan, 17-21 August 2004
Contact : ISAP'04, Attn. Dr. Tokio Taga, NTT DoCoMo, Inc., 3-5, Hikarino-oka, Yokosuka, 239-8536 Japan, E-mail : isap-2004@mail.ieice.org ,
http://www.ieice.org/cs/isap/2004

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News from the URSI Community

NEWS FROM THE MEMBER COMMITTEES

PERU

NEWS FROM JICAMARCA RADIO OBSERVATORY

Our colleagues from the Peruvian Member Committee recently released the following good news.

On August 13th, a law expropriating 1900 hectares (6 km. x 3.3 km.approximately) of land around the Jicamarca Radio Observatory was passed by the Peruvian Government. The new law culminates a more than five-year-long battle to secure the land around the observatory. The land in question includes all the area in the optical horizon of the antenna, which must remain free of development if Jicamarca's radio noise-free environment is to be preserved. The law also prevents mining activity in the surroundings. The location of the observatory, the first incoherent scatter facility in the world built specially for this purpose, was selected because of its proximity to the geomagnetic equator and to Lima, Peru, a large city capable of providing the necessary logistical support. While the location was originally sufficiently remote to avoid man-made radio interference, the rapid demographic expansion of Lima threatened to change this.

The ability of Jicamarca to continue to operate in an environment free of man-made noise is vital if the international scientific community is to continue to make progress in the area of equatorial aeronomy and space physics. The expropriation law is the best birthday present that the observatory, which just celebrated its 40th anniversary, could have received. Among the celebration activities organized was an international workshop held in May 20-23, 2002. The workshop had 51 attendees from all over the world and featured 4 topics of discussion:

1) Radar Scattering Theory: New Ideas and Capabilities
2) D, E, and F Region Electrodynamics and Irregularities
3) Modeling the Low Latitude Ionosphere, and
4) Space Weather Activities at Equatorial Latitudes.

One obvious conclusion of the workshop was that Jicamarca is as active now in making important scientific contributions as in its "younger" years, if not more.

For more information, visit the Jicamarca Web page at http://jro.igp.gob.pe

POLAND

X National Symposium of Radio Science

Poznan, Poland, 14-15 March 2002

The Tenth National Symposium of Radio Science, URSI 2002, has been held at the Poznan Center of Science in Poznan, Poland, March 14-15, 2002 under the auspices of the International Union of Radio Science. The symposium has been organised by the Institute of Electronics and Telecommunications, Poznan University of Technology. The Rector Magnificus of Poznan University of Technology, Prof. Jerzy Dembczynski has been the Chairman of Honour of this conference. The firm Alcatel Poland S.A. has become its main sponsor.

The Program Committee consisted of: Stefan Hahn (chairman), D.J. Bem, A. Dobrogowski, M. Domanski, S. Gorgolewski, J. Karpowicz, T. Kosilo, B. Mroziewicz, J. Pawelec, W. Pawlowski, M. Piekarski, K. Radecki, I. Stanislawska, A. Turski, A. Wernik and K. Wesolowski. The Organising Committee has been formed of: A. Dobrogowski (chairman), P. Szulakiewicz, Z. Szymanski, K. Wesolowski, H. Bogucka (scientific secretary) and A. Strycka (secretary).

There were 89 attendees, participating in the conference, coming from Poland, France, Finland, Italy, Greece and Ireland. 61 technical and 5 plenary papers have been presented. The topics covered by the conference sessions pertained to the key research areas of the URSI commissions. The leading subject matters of the presented papers were: Mobile Communications, Electromagnetic Metrology, Satellite Systems, ELM Field Theory, Radio Astronomy, Radio Wave Propagation, Signals and Systems, ELM Noise and Interference, ELM Fields in Biology and Medicine

There were the following plenary presentations held in English:

- Prof. K. Wesolowski – Poznan University of Technology, Poland: "Information Theory Aspects of Digital Transmission Over Fading Channels"
- Dr. H. Sari – Juniper Netw orks, France: "Standardization in Broadband Wireless Access"
- Prof. A. Mammela – VTT Electronics, Finland: "Data and Channel Estimators: A Systematic Classification."
- Prof. A. Polydoros – University of Athens, Greece: "Towards Ubiquitous Wireless Communications: A Signal-Processing Perspective"
- Prof. S. Gorgolewski – Torun Radio Astronomy Observatory, Poland: "Radio Astronomy in the Quietest Lunar Radio Environment"

There have been also two technical sessions organised in English, as the working language: "Advanced Signal Processing In Wireless Communications" and "Mobile Radio Communications I". All the submitted and accepted papers have been published in the conference proceedings.

Three awards for the most interesting papers have been founded and given to young scientists. The prize winners were: B. Porosinski, R. Rogoza, M. Rybakowski, K. Wincza (the co-authors of one paper), J. Mlynarczyk and A. Kaszubowska.

Detailed information about the conference program can be found on the website: www.et.put.poznan.pl/ursi The symposium proceedings can be purchased from the Institute of Electronics and Telecommunications, Poznan University of Technology.

The organisers of the Tenth National Symposium of Radio Science, URSI 2002 would like to thank all the attendees for their attendance, valuable contributions, interesting presentations, stimulating discussions and the friendly atmosphere in Poznan.

Prof. A. Dobrogowski & Dr. Hanna Bogucka

IN MEMORIAM

CARLO NOVERO

1954 - 2002

Carlo Novero was a physicist, doing research in the field of time and frequency metrology and basic problems in quantum mechanics. He obtained his PhD degree in Metrology from the Politecnico di Torino in 1988. He joined IEN (Istituto Elettrotecnico Nazionale) in Torino, where he collaborated in the realization of a magnesium frequency standard, measuring the clock transition frequency with an uncertainty of . He also investigated the time stability of the fine-structure constant, alpha, and collaborated to test the Einstein equivalence principle via a "null" gravitational-red-shift experiment. In recent years, his interests moved to the field of parametric fluorescence, and the production of bi-photon fields for quantum-efficiency measurements of photodetectors. During this research, he developed a non-linear optics laboratory, where he performed studies on the founding principles of quantum mechanics, as the realization of a new experimental test of the Bell inequalities using a non-maximally entangled photon state. He devoted part of his energies to the constitution of the museum of old instruments at IEN, and coordinated the IEN activities in the training of young researchers. He died on 30 April 2002, aged 48. Though debilitated by illness, he did research with usual enthusiasm until the end.

This In Memoriam was provided by Dr. Patrizia Tavella of the Istituto Elettrotecnico Nazionale. Special thanks are also due to Prof. Elio Bava of the Dipartimento di Elettronica e Informazione, Politecnico di Milano.

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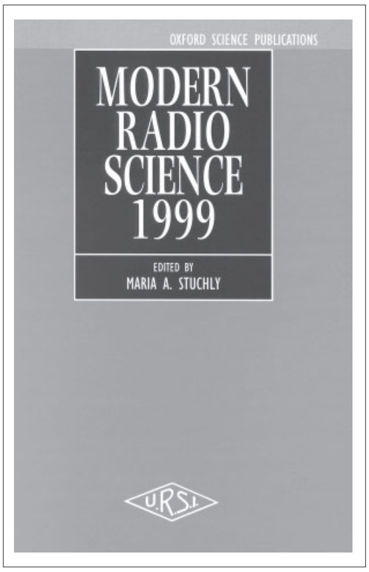

Modern Radio Science 1999

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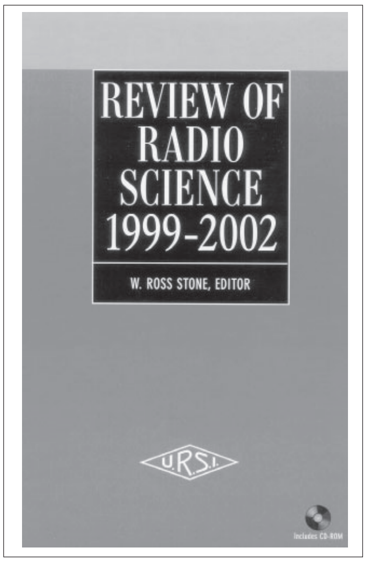

Review of Radio Science 1999-2002

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Handbook on Radiopropagation Related to Satellite Communications in Tropical and Subtropical Countries

Editor: G.O. Ajayi
with the collaboration of :
S. Feng, S.M. Radicella, B.M. Reddy

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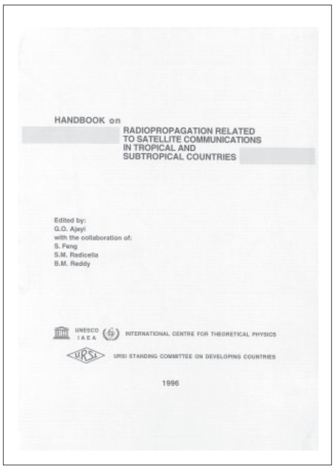

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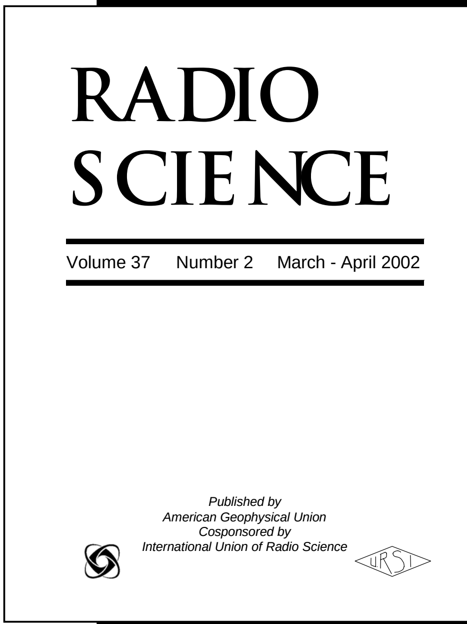
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The Journal of Atmospheric and Solar-Terrestrial Physics

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AIMS AND SCOPE

The *Journal of Atmospheric and Terrestrial Physics* (JASTP) first appeared in print in 1951, at the very start of what is termed the "Space Age". The first papers grappled with such novel subjects as the Earth's ionosphere and photographic studies of the aurora. Since that early, seminal work, the Journal has continuously evolved and expanded its scope in concert with - and in support of - the exciting evolution of a dynamic, rapidly growing field of scientific endeavour: the Earth and Space Sciences. At its Golden Anniversary, the now re-named *Journal of Atmospheric and Solar-Terrestrial Physics* (JASTP) continues its development as the premier international journal dedicated to the physics of the Earth's atmospheric and space environment, especially the highly varied and highly variable physical phenomena that occur in this natural laboratory and the processes that couple them. The *Journal of Atmospheric and Solar-Terrestrial Physics* is an international journal concerned with the inter-disciplinary science of the Sun-Earth connection, defined very broadly. The journal referees and publishes original research papers, using rigorous standards of review, and focusing on the following: The results of experiments and their interpretations, and results of theoretical or modelling studies; Papers dealing with remote sensing carried out from the ground or space and with in situ studies made from rockets or from satellites orbiting the Earth; and, Plans for future research, often carried out within programs of international scope. The Journal also encourages papers involving: large scale collaborations, especially those with an international perspective; rapid communications; papers dealing with novel techniques or methodologies; commissioned review papers on topical subjects; and, special issues arising from chosen scientific symposia or workshops. The journal covers the physical processes operating in the troposphere, stratosphere, mesosphere, thermosphere, ionosphere, magnetosphere, the Sun, interplanetary medium, and heliosphere. Phenomena occurring in other "spheres", solar influences on climate, and supporting laboratory measurements are also considered. The journal deals especially with the coupling between the different regions. Solar flares, coronal mass ejections, and other energetic events on the Sun create interesting and important perturbations in the near-Earth space environment. The physics of this subject, now termed "space weather", is central to the Journal of Atmospheric and Solar-Terrestrial Physics and the journal welcomes papers that lead in the direction of a predictive understanding of the coupled system. Regarding the upper atmosphere, the subjects of aeronomy, geomagnetism and geoelectricity, auroral phenomena, radio wave propagation, and plasma instabilities, are examples within the broad field of solar-terrestrial physics which emphasise the energy exchange between the solar wind, the magnetospheric and ionospheric plasmas, and the neutral gas. In the lower atmosphere, topics covered range from mesoscale to global scale dynamics, to atmospheric electricity, lightning and its effects, and to anthropogenic changes. Helpful, novel schematic diagrams are encouraged. Short animations and ancillary data sets can also be accommodated. Prospective authors should review the *Instructions to Authors* at the back of each issue.

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