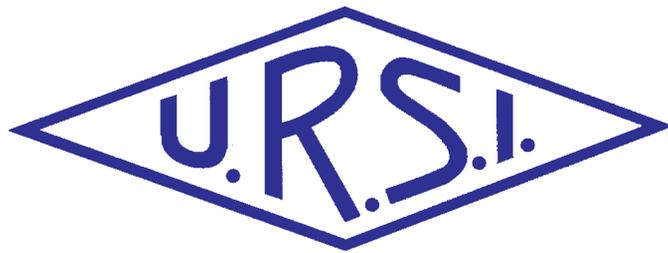


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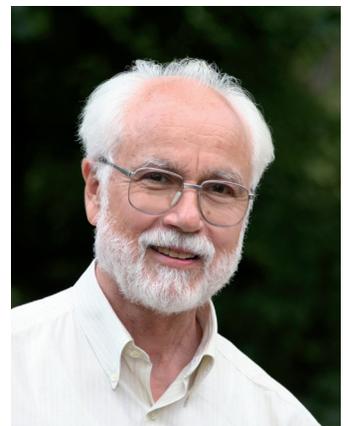
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*Front cover: At the XXXth URSI General Assembly and Scientific Symposium in Istanbul (Turkey) this August, the scientists whose pictures feature on the front cover will be presented with the URSI Awards. For more information, please turn to page 63 of this Bulletin.*

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## Editorial



This issue of the *Radio Science Bulletin* is a special issue, devoted to the papers from the Student Paper Competition from the URSI 2010 Asia-Pacific Radio Science Conference (AP-RASC'10). There is a separate introduction to the special issue by the Guest Editors, Kazuya Kobayashi, AP-RASC'10 Conference Chair, and Toru Sato, AP-RASC'10 Program Committee Chair, so I won't cover those papers here. The efforts of the Guest Editors in putting together this issue are greatly appreciated.



There are also announcements of the triennial URSI awards, which will be presented at the General Assembly and Scientific Symposium to be held in Istanbul, Turkey, August 13-20, 2011.

Finally, a full-length book version of the URSI White Paper on SPS (solar power satellites) is now available. It can be downloaded from [http://www.ursi.org/en/publications\\_whitepapers.asp](http://www.ursi.org/en/publications_whitepapers.asp).

There is still time to register for and plan to attend the XXXth URSI General Assembly and Scientific Symposium. You can find all of the information, and online registration and hotel information, at <http://www.ursigass2011.org/>. I hope to see you there!

We also have two book reviews, brought to us by Kristen Schlegel. Because this is the issue of the *Bulletin* right before the URSI General Assembly and Scientific Symposium, it contains the triennial reports of URSI. I hope you will read through these: they are an excellent summary of what has gone on within URSI over the past three years.

A handwritten signature in black ink that reads 'Ross'.

## Special Issue of Papers from the AP-RASC'10 Student Paper Competition

This special issue is a collection of papers by university students who successfully applied for the Student Paper Competition organized at the 2010 Asia-Pacific Radio Science Conference (AP-RASC'10). The conference was held at the Toyama International Conference Center, Toyama, Japan, September 22-26, 2010 (<http://www.ap-rasc10.jp/>).

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

The AP-RASC was held for the first time in Tokyo, Japan, in August 2001, and the conference was a great success. The second AP-RASC was held in Qingdao, China, in August 2004. The AP-RASC'10 in Toyama, Japan, was the third AP-RASC. This conference was sponsored

jointly by the Institute of Electronics, Information and Communication Engineers (IEICE) and by URSI. It was held in cooperation with the Science Council of Japan; Toyama Prefecture; Toyama City; the Institute of Electrical Engineers of Japan (IEEEJ); the Association for Promotion of Electrical, Electronic and Information Engineering; Toyama Prefectural University; and the University of Toyama. The subject areas covered by AP-RASC'10 were broad, and contained topics covered by URSI Commissions A-K. A total of 566 papers were accepted for presentation. These were distributed into 75 oral sessions and 10 poster sessions. The conference was successful, with 597 scientists attending from 31 countries, and 529 papers being presented.

One of the important, unique features at the AP-RASC'10 was the Young Scientist Program. This consisted of the Student Paper Competition (SPC) and the Young Scientist Awards (YSA). The former was for full-time university students working towards the PhD degree or a higher degree, whereas the latter was for young scientists under 35 years of age on October 1, 2010. The Student Paper Competition and Young Scientist Awards programs were financially supported by URSI and by the URSI Commissions, respectively. A total of 11 students applied for the Student Paper Competition, and 42 young scientists applied for the Young Scientist Awards. Prior

to the conference, the AP-RASC'10 Young Scientist Program Committee selected five finalists for the Student Paper Competition, and twenty recipients for the Young Scientist Awards.

All of the five finalists for the Student Paper Competition presented their papers at the Student Paper Competition Special Session, held on September 22, 2010, during the conference. After careful consideration, the AP-RASC'10 Young Scientist Program Committee decided on the following ranking:

- First Prize: Mr. Y. Cui, Tsinghua University, China (CIE)
- Second Prize: Mr. H. Wakatsuchi, University of Nottingham, United Kingdom
- 3rd Prize: Mr. I. Laakso, Aalto University, Finland

The above three winners received prizes (certificates and prize money) at the Awards Ceremony held during the AP-RASC'10 Conference Banquet on September 24, 2010. In addition, each of the two non-winning finalists (Mr. M. Akita, Osaka University, Japan, and Mr. S. Ozawa, the University of Tokyo, Japan) also received a certificate identifying them as a finalist. All the five Student Paper Competition finalists are shown on stage in Figure 1.

The following four papers by Student Paper Competition finalists appear in this special issue of the *Radio Science Bulletin*:

1. "Power Preserving Polarimetric Whitening Filter"  
Y. Cui, J. Yang  
Tsinghua University, China (CIE)
2. "Edge- or Face-Based Electric Fields in FDTD: Implications for Dosimetry"  
I. Laakso, T. Uusitupa  
Aalto University, Finland

3. "The Relationship Between the Leader Progressions and the Charge Distributions"  
M. Akita<sup>1</sup>, T. Morimoto<sup>1</sup>, T. Ushio<sup>1</sup>, Z. Kawasaki<sup>1</sup>, D. Wang<sup>2</sup>  
<sup>1</sup>Osaka University, Japan, <sup>2</sup>Gifu University, Japan
4. "Errors in Channel Prediction Based on Linear Prediction in the Frequency Domain"  
S. Ozawa, S. Tan, A. Hirose  
The University of Tokyo, Japan

The fifth paper by a Student Paper Competition finalist, "Contribution of Conductive Loss to Cut-Wire Metamaterial Absorbers," by H. Wakatsuchi, J. Paul, S. Greedy, and C. Christopoulos, University of Nottingham, United Kingdom, was not included in this special issue. This was because Mr. Wakatsuchi had already submitted his paper to another journal by the time this special issue was planned. Readers can find his paper in *Optics Express*, **18**, 21, 2010, pp. 22187-22198 (<http://www.opticsinfobase.org/oe/abstract.cfm?URI=oe-18-21-22187>).

We are happy that the AP-RASC'10 Young Scientist Program, including the Student Paper Competition and the Young Scientist Awards, was successful. This success was mainly due to the efforts of the AP-RASC'10 Young Scientist Program Committee. We are very thankful to the members of the committee for their hard work during the selection process. Thanks are also extended to URSI for its financial support for running the program. Finally, we would like to express our appreciation to the Student Paper Competition finalists who participated in the AP-RASC'10 and contributed to this special issue.

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Figure 1. The AP-RASC'10 Student Paper Competition finalists.

# Power-Preserving polarimetric Whitening Filter



Yi Cui  
Jian Yang

## Abstract

In this paper, a method that optimally preserves the power information for a polarimetric whitening filter (PWF) is proposed. In addition to minimizing the ratio of the standard deviation to the mean of the polarimetric whitening filter, a constraint of minimum mean square error (MMSE) between the input and output vectors is also added to the output of the polarimetric whitening filter. As a result, this latter constraint not only leads to automatic power preservation, but also improves the speckle-reduction performance. In the experiment, real polarimetric synthetic aperture radar (PolSAR) images, acquired by the SIR-C/X system, were used. By comparing with other power-preserving methods for the polarimetric whitening filter, we demonstrated that the speckle-reduction performance was enhanced by our method, and the power information in the output was well preserved.

## 1. Introduction

Speckle reduction is an important task for processing polarimetric synthetic-aperture-radar (PolSAR) images. Many contributions have been made toward this end [1-7]. In particular, one of the effective tools is the polarimetric whitening filter (PWF), which generates a minimum-speckle intensity image by fusing the data in all the polarimetric channels without loss of spatial resolution. Novak and Burl first proposed the polarimetric whitening filter to deal with single-look PolSAR imagery [1, 8]. Later, Lopes et al. [9] and Liu et al. [10] both extended Novak's work so that it can also be applied to multi-look PolSAR imagery.

However, due to the whitening process, the power information in the original polarimetric channels is lost. A traditional compensation method is to assign the power in an arbitrary polarimetric channel to the output of the polarimetric whitening filter [8, 10], which may lead to inferior results. This problem will be specifically analyzed in Section 2. In Section 3, a new method is proposed to preserve the power information at the output of the polarimetric whitening filter in an optimal way. Its superiority is demonstrated by the experiment in Section 4.

## 2. The Problem of the Polarimetric Whitening Filter

For single-look PolSAR data, the output of the polarimetric whitening filter is an intensity image, each pixel value of which is generated by the following quadratic form:

$$y = \mathbf{x}^H \mathbf{B} \mathbf{x}, \quad (1)$$

where  $\mathbf{x} = (S_{HH} \ \sqrt{2}S_{HV} \ S_{VV})^T$ ,  $S_{HH}$ ,  $S_{HV}$ , and  $S_{VV}$  denote the elements of the polarimetric scattering matrix, the superscript T denotes the transpose, and  $\mathbf{B}$  is a positive-definite Hermitian matrix.

The purpose of the polarimetric whitening filter is to derive the optimum matrix,  $\mathbf{B}$ , which can minimize the speckle. The speckle is measured by the standard-deviation-to-mean ratio (s/m):

$$\frac{s}{m} = \frac{\text{std}(y)}{\mathbb{E}(y)}, \quad (2)$$

where std stands for the standard deviation, and  $\mathbb{E}$  denotes the expectation. The optimum matrix [1] is given by  $\mathbf{B} = \Sigma_{\mathbf{x}}^{-1}$  where  $\Sigma_{\mathbf{x}}$  is the covariance matrix of  $\mathbf{x}$ , i.e.,  $\Sigma_{\mathbf{x}} = \mathbb{E}(\mathbf{x}\mathbf{x}^H)$  with the superscript H denoting the conjugate transpose. Consequently, Novak and Burl defined two steps to obtain the polarimetric whitening filter [8]:

1. The data of  $\mathbf{x}$  are passed through a whitening transformer to obtain uncorrelated and radiometrically equalized channels,

$$y = \Sigma_{\mathbf{x}}^{-1/2} \mathbf{x}, \quad (3)$$

so that the covariance matrix of vector  $y$  is the identity matrix,  $\mathbf{I}$ .

2. The intensity output of the polarimetric whitening filter is thus computed from

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Figure 1. The SPAN image of the ESAR C-band polarimetric data

$$y = y^H y = \mathbf{x}^H \Sigma_X^{-1} \mathbf{x}. \quad (4)$$

The polarimetric whitening filter gives the minimum s/m value among all possible combinations of polarimetric channels.

Since the average powers of each channel of  $\mathbf{y}$  all equal one, this means the power information of the original three polarimetric channels (HH, HV, VV) has been lost. To illustrate this problem, the polarimetric whitening filter was applied to an ESAR C-band single-look PolSAR image as an example. The SPAN (total power) image is shown in Figure 1. The output of the polarimetric whitening filter is shown in Figure 2. We found that because of the loss of the power information, the gray-level differences of different ground targets can hardly be seen in Figure 2.

A solution to this problem [8, 10] is to multiply  $\mathbf{y}$  by a factor of  $\sigma_{HH}$ , so as to make the output of the polarimetric whitening filter match the HH intensity:

$$y = \sqrt{\frac{\sigma_{HH}}{d}} \Sigma_X^{-1/2} \mathbf{x}, \quad (5)$$

$$y = y^H y = \frac{\sigma_{HH}}{d} \mathbf{x}^H \Sigma_X^{-1} \mathbf{x}, \quad (6)$$

where  $d$  is the dimension of  $\mathbf{x}$ , with  $d = 3$  for the reciprocal polarimetric vector. The coefficient  $1/d$  is added so that  $\mathbb{E}(y) = \sigma_{HH}$ ;  $\sigma_{HH} = \mathbb{E}(|S_{HH}|^2)$ , which is the first element of  $\Sigma_X$ , i.e.,

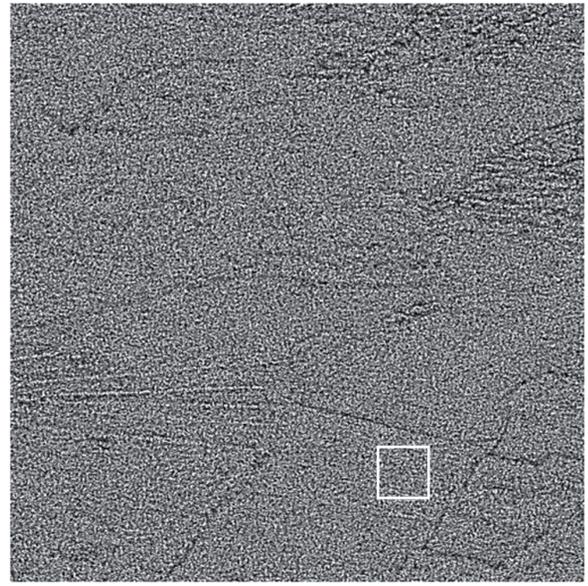


Figure 2. The output image of the original polarimetric whitening filter for the ESAR polarimetric data. The s/m value calculated within the area marked by the white rectangle was 0.4431.

$$\sigma_{HH} = \mathbf{e}_1^T \Sigma_X \mathbf{e}_1, \quad (7)$$

where  $\mathbf{e}_1 = (1, 0, 0)^T$  for  $d = 3$ . We will refer to this method as  $\text{PWF}_{HH}$  hereafter. Using this method, the output of  $\text{PWF}_{HH}$  is shown in Figure 3.

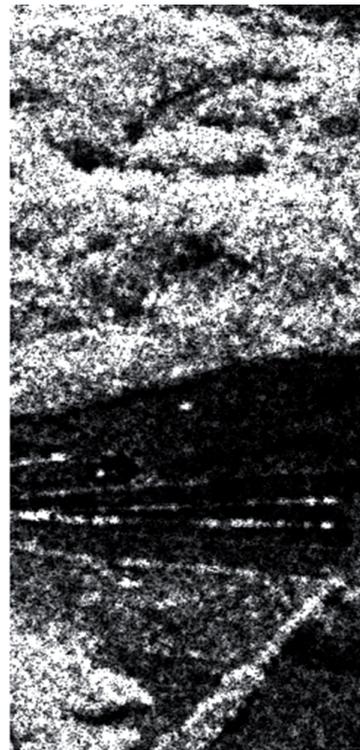


Figure 3. The output image of  $\text{PWF}_{HH}$  for the ESAR polarimetric data. The s/m value calculated within the area marked by the white rectangle was 0.6301.

However, if we select the same sub-region in the two images of Figure 2 and Figure 3 and calculate their respective s/m values, we find that in the original polarimetric-whitening-filter output image, the s/m value in the selected area was 0.4431, while in the PWF<sub>HH</sub> output image, the s/m value in the selected area became 0.6301. Thus, it had suffered a significant performance degradation from the original polarimetric whitening filter. Theoretically, the speckle-reduction performance of PWF<sub>HH</sub> and the original polarimetric whitening filter should be the same, since the only difference between them is the deterministic power term,  $\sigma_{HH}$ . However, in practice, the covariance matrix  $\Sigma_X$  is mostly unknown, and has to be estimated. Consequently,  $\sigma_{HH}$  is not deterministic, but is also an estimated value according to Equation (7). The estimation accuracy thus greatly influences the performance of such a power-preserving method.

There are also the other two polarimetric channels, HV and VV, so besides matching the HH intensity, we could also choose to match the other two channels, that is, we can have PWF<sub>VV</sub> and PWF<sub>HV</sub>. Therefore, this method is not unique, much less optimum.

In fact, there exists a simple way to make use of the power information in all the polarimetric channels. This is to match the output of the polarimetric whitening filter to SPAN, i.e., to the total power of the polarimetric channels. We will call this PWF<sub>SPAN</sub>. Its output is given by

$$y = \frac{\text{Tr}(\Sigma_X)}{d} x^H \Sigma_X^{-1} x, \quad (8)$$

where  $\text{Tr}(\bullet)$  denotes the trace of a given matrix, and

$$\text{Tr}(\Sigma_X) = E(|S_{HH}|^2 + 2|S_{HV}|^2 + |S_{VV}|^2) = \text{SPAN}.$$

In this paper, we propose a new solution to optimally preserve the power information in the output of a polarimetric whitening filter. Details of our method will be described in Section 3. In Section 4, several previously mentioned power-preserving methods for a polarimetric whitening filter, such as PWF<sub>HH</sub>, PWF<sub>HV</sub>, PWF<sub>VV</sub>, and PWF<sub>SPAN</sub>, will be compared with the new solution, using real PolSAR data.

### 3. The Power-Preserving Polarimetric Whitening Filter

Our modified polarimetric whitening filter is also implemented in two stages:

1. A transformation matrix,  $\mathbf{A}$ , is first applied to  $\mathbf{x}$  to obtain  $\mathbf{y}$ :

$$\mathbf{y} = \mathbf{A}\mathbf{x}, \quad (9)$$

where  $\mathbf{A}$  is a positive-definite Hermitian matrix to be optimized.

2. The polarimetric whitening filter output,  $y$ , is derived by

$$y = \mathbf{y}^H \mathbf{y}. \quad (10)$$

We are next to derive an optimum  $\mathbf{A}$  that can minimize the speckle, and, in the meantime, preserve the power information as much as possible.

Two constraints are added for the above purpose. The first one is still to minimize s/m for maximum speckle reduction. It can be proven that s/m is minimized when the covariance matrix of  $\mathbf{y}$  is  $\Sigma_Y = w^2 \mathbf{I}$ , where  $w$  is a positive number and  $\mathbf{I}$  is an identity matrix [1, 8]. Hence, the first step of the modified polarimetric whitening filter can be regarded as a covariance shaping problem [11], and the solution must be in the form of

$$A = w \Sigma_X^{-1/2}. \quad (11)$$

Second, in order to preserve the power information of the original polarimetric channels, instead of designating  $w = \sqrt{\sigma_{HH}/d}$  as in Equation (5), we propose to choose an optimum  $w$  resulting in a vector  $\mathbf{y}$  that is closest to the original input vector  $\mathbf{x}$  in a mean-square-error (MSE) sense. Mathematically, the model is given by

$$\min_w \{\varepsilon_{MSE}\} = \min_w \left\{ \mathbb{E} \left[ (\mathbf{x} - \mathbf{y})^H (\mathbf{x} - \mathbf{y}) \right] \right\}, \quad (12)$$

$$\text{s.t. } \Sigma_Y = \mathbb{E}(\mathbf{y}\mathbf{y}^H) = w^2 \mathbf{I},$$

where s.t. stands for “subject to.” We refer to Equation (9) as the minimum-mean-square error (MMSE) constraint, and consequently call our method PWF<sub>MMSE</sub>. By substituting Equation (11) into Equation (12),  $\varepsilon_{MSE}$  becomes

$$\varepsilon_{MSE} = \text{Tr}(\Sigma_X) - 2w \text{Tr}(\Sigma_X^{1/2}) + w^2 \text{Tr}(\mathbf{I}). \quad (13)$$

$\varepsilon_{MSE}$  is minimized when

$$\partial \varepsilon_{MSE} / \partial w = 0, \quad \partial^2 \varepsilon_{MSE} / \partial^2 w > 0.$$

Images	Area 1	Area 2	Area 3	Area 4	Area 5
$PWF$	0.4818	0.4814	0.4712	0.4544	0.4589
$PWF_{MMSE}$	0.5577	0.5801	0.5298	0.5179	0.5683
$PWF_{SPAN}$	0.5861	0.6391	0.5478	0.5341	0.6012
$PWF_{HH}$	0.6160	0.6692	0.6142	0.6056	0.6216
$PWF_{HV}$	0.6171	0.6042	0.5969	0.5766	0.5933
$PWF_{VV}$	0.5804	0.6615	0.6139	0.6042	0.5936
$SPAN$	0.9006	1.0275	0.7157	0.7050	1.0169
$HH$	0.9970	1.1533	1.0495	1.0556	1.0720
$HV$	1.0408	1.0161	0.9967	0.9812	1.0238
$VV$	0.9514	1.1599	1.0653	1.0398	1.0388

Table 1. The  $s/m$  values of the original polarimetric whitening filter,  $PWF_{MMSE}$ ,  $PWF_{SPAN}$ ,  $PWF_{HH}$ ,  $PWF_{HV}$ ,  $PWF_{VV}$ ,  $SPAN$ ,  $HH$ ,  $HV$ , and  $VV$ , for the SIR-C/X PolSAR data in the five selected areas.

According to Equation (13), we have

$$\frac{\partial^2 \varepsilon_{MSE}}{\partial^2 w} = 2\text{Tr}(\mathbf{I}) = 2d > 0, \quad (14)$$

$$\frac{\partial \varepsilon_{MSE}}{\partial w} = 2wd - 2\text{Tr}(\Sigma_X^{1/2}) = 0. \quad (15)$$

Finally, by Equation (15), the solution of  $PWF_{MMSE}$  is

$$w = \frac{\text{Tr}(\Sigma_X^{1/2})}{d}. \quad (16)$$



Figure 4. The  $SPAN$  image of the PolSAR data acquired by the SIR-C/X SAR system.

The  $PWF_{MMSE}$  for single-look PolSAR imagery is then

$$\mathbf{y} = \frac{\text{Tr}(\Sigma_X^{1/2})}{d} \Sigma_X^{-1/2} \mathbf{x}, \quad (17)$$

$$y = \mathbf{y}^H \mathbf{y} = \frac{\text{Tr}^2(\Sigma_X^{1/2})}{d^2} \mathbf{x}^H \Sigma_X^{-1} \mathbf{x}, \quad (18)$$

Under the minimum-mean-square-error principle, the  $PWF_{MMSE}$  for multi-look PolSAR imagery can also be derived as follows:

$$y = \frac{\text{Tr}^2(\Sigma_C^{1/2})}{d^2} \text{Tr}(\Sigma_C^{-1} \mathbf{C}), \quad (19)$$

where  $\mathbf{C}$  is the polarimetric covariance matrix [12] of each pixel, and  $\Sigma_C = \mathbb{E}(\mathbf{C})$ . In fact, Equation (18) is a special case of Equation (19) when the rank of  $\mathbf{C}$  is equal to one.

## 4. Experimental Results

The  $PWF_{MMSE}$  was tested on a single-look PolSAR image (acquired in Tien Shan, China, by the SIR-C/X SAR) in our experiment. The  $SPAN$  image is shown in Figure 4.

Since the theoretical  $\Sigma_X$  was unknown, each pixel's  $\Sigma_X$  was estimated adaptively, by, e.g., in our experiment, a  $5 \times 5$  neighborhood window as follows:

$$\hat{\Sigma}_X = \frac{1}{N} \sum_{i=1}^N \mathbf{x}_i \mathbf{x}_i^H, \quad (20)$$

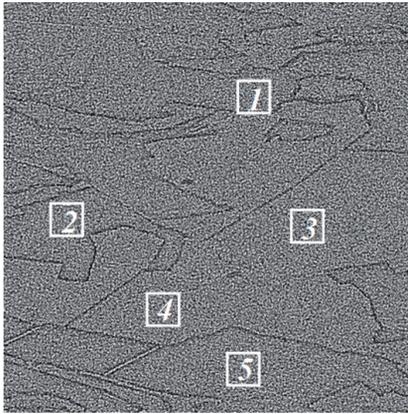


Figure 5. The output image of the original polarimetric whitening filter for the SIR-C/X PolSAR data. Five areas were selected in which to calculate their  $s/m$  values, and these are shown in the second line of Table 1.

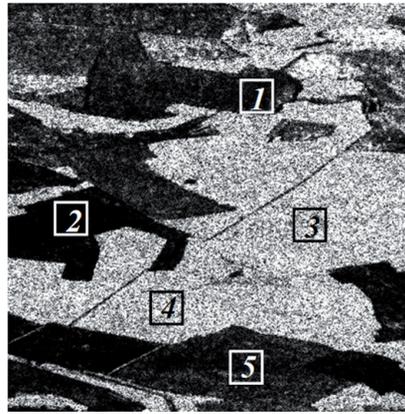


Figure 6. The output image of  $PWF_{MMSE}$  for the SIR-C/X PolSAR data. Five areas were selected in which to calculate their  $s/m$  values, and these are shown in the third line of Table 1.

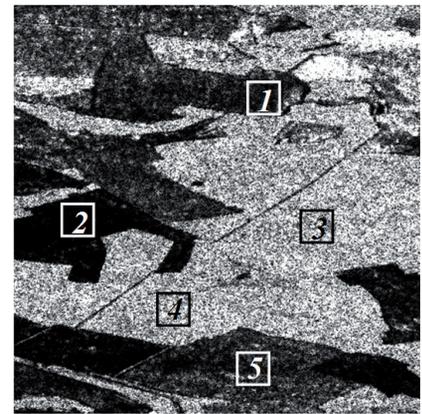


Figure 7. The output image of  $PWF_{SPAN}$  for the SIR-C/X PolSAR data. Five areas were selected in which to calculate their  $s/m$  values, and these are shown in the fourth line of Table 1.

where  $N = 25$ ,  $x_i$  ( $i = 1, 2, \dots, 25$ ) are the polarimetric vectors of the pixels in the  $5 \times 5$  neighborhood window.

The output images of the original polarimetric whitening filter,  $PWF_{MMSE}$ ,  $PWF_{SPAN}$ ,  $PWF_{HH}$ ,  $PWF_{HV}$  and  $PWF_{VV}$ , for the single-look PolSAR data, are shown in Figure 5 to Figure 10, respectively. In order to quantitatively evaluate the speckle-reduction ability of different filters (i.e.,  $PWF_{MMSE}$ ,  $PWF_{SPAN}$ ,  $PWF_{HH}$ ,  $PWF_{HV}$ ,  $PWF_{VV}$ ), five areas marked by the rectangles in Figure 5 to Figure 10 were selected to calculate the standard-deviation-to-mean ratios ( $s/m$ ). The results are shown in Table 1. The  $s/m$  values of the HH, HV, VV,  $SPAN$  image in the corresponding regions are also given in the tables for comparison.

As shown in Table 1, not surprisingly, the  $s/m$  value of the original polarimetric whitening filter was the least (best) among all the ten images. On the other hand, when the power information was added,  $PWF_{MMSE}$ ,  $PWF_{SPAN}$

$PWF_{HH}$ ,  $PWF_{HV}$ , and  $PWF_{VV}$  all suffered certain degrees of performance degradation. However, it could be seen that  $PWF_{MMSE}$  performed better than the other four power-preserving polarimetric whitening filters. In particular, the speckle-reduction performance of  $PWF_{MMSE}$  was better than  $PWF_{SPAN}$ , and  $PWF_{SPAN}$  was better than  $PWF_{HH}$ ,  $PWF_{HV}$ , and  $PWF_{VV}$ . The reason for the performance difference of  $PWF_{MMSE}$ ,  $PWF_{SPAN}$ ,  $PWF_{HH}$ ,  $PWF_{HV}$ , and  $PWF_{VV}$  can be explained as follows. For  $PWF_{HH}$ ,  $PWF_{HV}$ , and  $PWF_{VV}$ , the power terms were estimated using only one of the three trace elements of  $\hat{\Sigma}_X$  (the first element for  $PWF_{HH}$ , the second for  $PWF_{HV}$ , and the third for  $PWF_{VV}$ ), so the estimation accuracy was relatively low. For  $PWF_{SPAN}$ , the power term was estimated using three elements (in the main diagonal) of  $\hat{\Sigma}_X$ , so it had better accuracy. For  $PWF_{MMSE}$ , the power term was estimated using all the information that was provided by  $\hat{\Sigma}_X$ , and thus  $PWF_{MMSE}$  gave the best accuracy. Consequently, the radiometric accuracy of the power terms of different filters accounts for such different speckle-reduction performance.

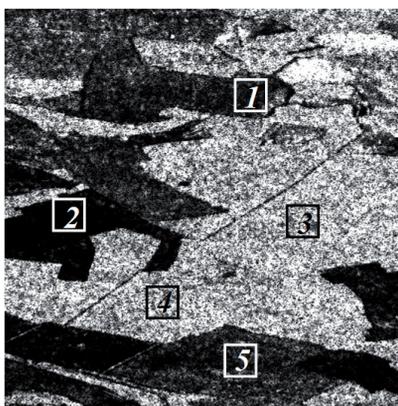


Figure 8. The output image of  $PWF_{HH}$  for the SIR-C/X PolSAR data. Five areas were selected in which to calculate their  $s/m$  values, and these are shown in the fifth line of Table 1.

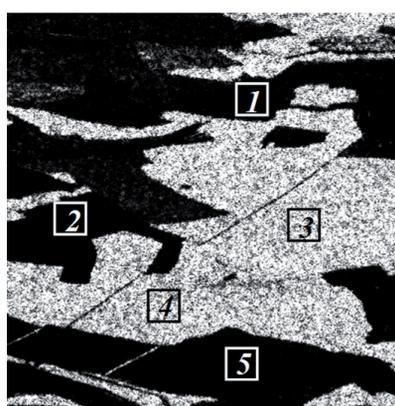


Figure 9. The output image of  $PWF_{HV}$  for the SIR-C/X PolSAR data. Five areas were selected in which to calculate their  $s/m$  values, and these are shown in the sixth line of Table 1.

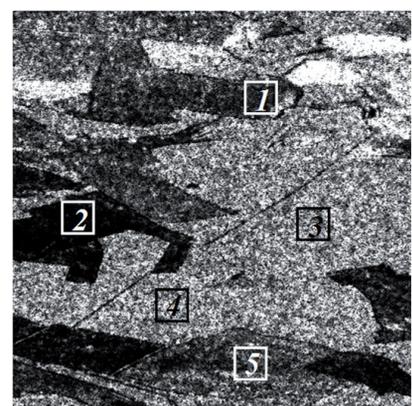


Figure 10. The output image of  $PWF_{VV}$  for the SIR-C/X PolSAR data. Five areas were selected in which to calculate their  $s/m$  values, and these are shown in the seventh line of Table 1.

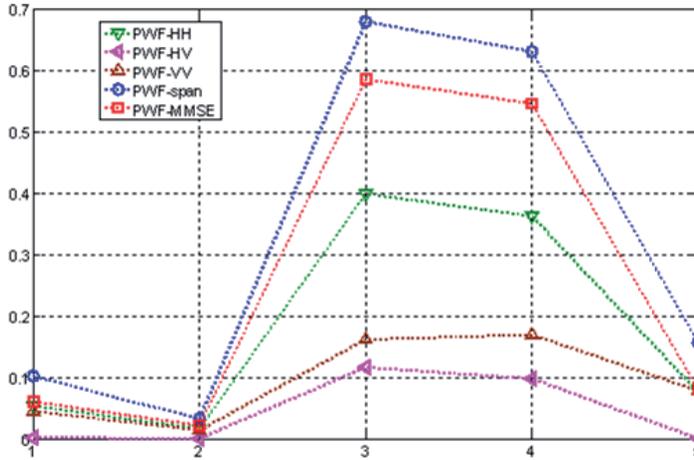


Figure 11. The power relations of  $PWF_{HH}$ ,  $PWF_{HV}$ ,  $PWF_{VV}$ ,  $PWF_{SPAN}$ , and  $PWF_{MMSE}$  in the five selected areas of the respective images.

To reveal the power-preserving abilities, the mean intensity (power) values of the five selected areas were also computed. The power relations of the five selected areas in the outputs of  $PWF_{MMSE}$ ,  $PWF_{SPAN}$ ,  $PWF_{HH}$ ,  $PWF_{HV}$  and  $PWF_{VV}$  are shown in Figure 11. It could be clearly seen from Figure 11 that the power relationship of  $PWF_{MMSE}$  in the five different areas was in strong agreement with that of  $PWF_{SPAN}$ . Specifically, the powers of  $PWF_{MMSE}$  in the selected areas were correspondingly smaller than those of  $PWF_{SPAN}$ . Such a phenomenon can be explained by the eigen-decomposition of  $\Sigma_X$ . As previously stated in Section 3, the power coefficient of  $PWF_{MMSE}$  is  $w = \text{Tr}(\Sigma_X^{1/2})/d$ , which can be rewritten as

$$\frac{\text{Tr}(\Sigma_X^{1/2})}{d} = \frac{\sqrt{\lambda_1} + \sqrt{\lambda_2} + \sqrt{\lambda_3}}{d}, \quad (21)$$

where  $\lambda_1$ ,  $\lambda_2$ ,  $\lambda_3$  are the three eigenvalues of  $\Sigma_X$ . For  $PWF_{SPAN}$ , the power coefficient is  $w = [\text{Tr}(\Sigma_X)/d]^{1/2}$ , which can be rewritten as

$$\left[ \frac{\text{Tr}(\Sigma_X)}{d} \right]^{1/2} = \left( \frac{\lambda_1 + \lambda_2 + \lambda_3}{d} \right)^{1/2}. \quad (22)$$

Since  $\lambda_i \geq 0$ , it is easy to know that  $\text{Tr}(\Sigma_X^{1/2})/d = [\text{Tr}(\Sigma_X)/d]^{1/2}$  holds. As a result, the output of  $PWF_{MMSE}$  is always smaller than  $PWF_{SPAN}$ . However, it should be noted that  $PWF_{MMSE}$  has a strong (if not stronger than  $PWF_{SPAN}$ ) physical justification, in that it represents the total power that is embedded in the intermediate output vector  $\mathbf{y}$ , which is closest to the input vector  $\mathbf{x}$  in a mean-square-error sense.

## 5. Conclusion

Based on the principle of minimum-mean-square-error covariance shaping, a modified polarimetric whitening

filter has been proposed. The power information in the output of the filter is optimally preserved as compared with other methods, such as matching to span or HH channels. The speckle-reduction performance of the polarimetric whitening filter is enhanced by this improvement, which has been demonstrated by an experiment using real PolSAR data.

## 6. Acknowledgement

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# Edge- or Face-Based Electric Fields in FDTD : Implications for Dosimetry



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T. Uusitupa

## Abstract

An alternative method for modeling dielectric interfaces in the Finite-Difference Time-Domain (FDTD) algorithm is presented, and it is applied for computational electromagnetic dosimetry. The alternative method is based on swapping the positions of the electric- and magnetic-field components in the Yee-cell grid. Compared to the standard method, the alternative method is theoretically just as valid a choice, but it may produce differing numerical results. The applicability of the alternative method is first motivated by comparing numerical FDTD results to analytical solutions in a lossy sphere. The implications of the alternative method for SAR calculations in an anatomical human body model are then studied.

## 1. Introduction

The Finite-Difference Time-domain (FDTD) method has become the most widely used tool for solving electromagnetic-dosimetry problems. The numerical specific-absorption-rate (SAR) results are affected by several computational uncertainty factors, such as the discretization error that is connected to the ratio between the step length and the wavelength [1-3]. The error may be made smaller by using a finer-grid step length, which, in turn, requires more computational resources. The step length is also related to the staircasing error that results from forcing curved shapes into the rectangular FDTD grid. At high frequencies (small wavelengths compared to the step length), the choice of SAR algorithm for calculating the SAR in each Yee cell may have a significant effect on the whole-body-averaged SAR [3-5].

This paper investigates one important modeling choice that may have a significant impact on the results. An alternative method for taking into account dielectric interfaces in the FDTD – called the H-cell method, as opposed to the standard E-cell method – was introduced in [6]. The H-cell method is based on swapping the positions

of the electric- and magnetic-field components in the Yee-cell grid. Calculations of small lossy spheres showed that the H-cell method gave significantly more-accurate results than the standard E-cell method in certain cases, but the opposite was true in some other cases. In this paper, the H-cell method is applied for dosimetry in a realistic human-body model. The principle of the method is revisited in the following section. The applicability of the method is then motivated by showing results of the FDTD modeling of plane-wave irradiation of a small lossy sphere. Finally, the implications of the H-cell method for SAR calculations are studied by simulating the plane-wave exposure of a human-body model in the frequency range from 30 MHz to 3 GHz.

## 2. E-Cell and H-Cell Methods

In the original paper by Yee [7], the FDTD update equations included all the electric field,  $\mathbf{E}$ , magnetic field,  $\mathbf{H}$ , electric flux density,  $\mathbf{D}$ , magnetic flux density,  $\mathbf{B}$ , and conductivity current,  $\mathbf{J}$ . Later, it has become customary to write the FDTD update equations such that they include only the electric field,  $\mathbf{E}$ , and the magnetic field,  $\mathbf{H}$ , with permittivity,  $\epsilon$ , conductivity,  $\sigma$ , and permeability,  $\mu$ , e.g. [8]. Electromagnetic media may be modeled by assigning  $\epsilon$ ,  $\sigma$ , and  $\mu$  for each Yee cell, and then defining effective values for  $\epsilon$ ,  $\sigma$ , and  $\mu$  on the edges and faces of the cells. The effective values will depend on how the field components are positioned in the Yee cells [6]. In the following discussion,  $\mathbf{D}_{tot}$  denotes the total electric-flux density, including the conductivity current:

$$\mathbf{D}_{tot} = \mathbf{D} + \int_{-\infty}^t \mathbf{J} dt' \sim \left( \epsilon + \frac{\sigma}{i\omega} \right) \hat{\mathbf{E}}. \quad (1)$$

Field quantities with hats (^) are the complex time-harmonic fields, with time dependence of the form  $A = \text{Re}[\hat{A} \exp(-i\omega t)]$ . The corresponding time-domain fields are denoted without hats.

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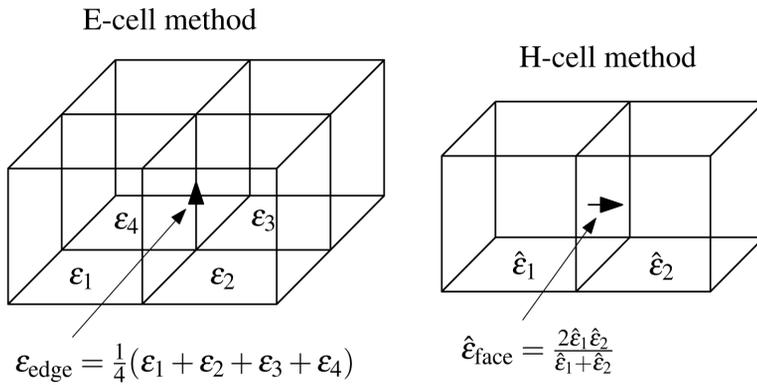


Figure 1. The effective permittivities on the edges of the E cells and on the faces of the H cells.

In the FDTD, the standard method is to position the electric-field components on the edges of the Yee cells. In this paper, this is called the E-cell method. The tangential component of the electric-flux density,  $\mathbf{D}_{tot}$ , is discontinuous over material interfaces, so it might not be well defined on the edges. The solution is to define the value on each edge as the average of the values in the four neighboring cells (Figure 1). Hence,

$$D_{edge} = \frac{1}{4}(\varepsilon_1 + \varepsilon_2 + \varepsilon_3 + \varepsilon_4)E_{edge} = \varepsilon_{edge}E_{edge} \quad (2)$$

$$J_{edge} = \frac{1}{4}(\sigma_1 + \sigma_2 + \sigma_3 + \sigma_4)E_{edge} = \sigma_{edge}E_{edge}. \quad (3)$$

Substituting  $\varepsilon_{edge}$  and  $\sigma_{edge}$  into the FDTD update equations gives the standard method for modeling dielectric materials in the FDTD.

In the alternative H-cell method, the magnetic field,  $\mathbf{H}$ , is located on the Yee-cell edges, and the electric field,  $\mathbf{E}$ , is positioned on the cell faces. According to the electromagnetic boundary conditions, the normal component of the total electric flux density,  $\hat{\mathbf{D}}_{tot} = \hat{\varepsilon}\hat{\mathbf{E}}$ , is continuous on the cell faces, so the normal component of  $\hat{\mathbf{E}}$  may be discontinuous and not well defined. The electric field on the faces should thus be treated as an effective field,  $E_{face}$ , which is defined as the average of the normal components of the electric fields,  $E_1$  and  $E_2$ , in the two neighboring cells:

$$E_{face} = \frac{1}{2}(E_1 + E_2). \quad (4)$$

Using the continuity of the normal component of the total electric-flux density,  $\hat{\varepsilon}\hat{\mathbf{E}}$ , we require

$$\hat{\varepsilon}_1\hat{E}_1 = \left(\varepsilon_1 + \frac{\sigma_1}{i\omega}\right)\hat{E}_1$$

$$= \hat{\varepsilon}_{face}\hat{E}_{face} \quad (5)$$

$$= \left(\varepsilon_2 + \frac{\sigma_2}{i\omega}\right)\hat{E}_2$$

$$= \hat{\varepsilon}_2\hat{E}_2,$$

where  $\hat{\varepsilon}_1$  and  $\hat{\varepsilon}_2$  are the complex permittivities of the two cells (Figure 1). Hence, the complex permittivity on the face is

$$\hat{\varepsilon}_{face}(\omega) = \frac{2\hat{\varepsilon}_1\hat{\varepsilon}_2}{\hat{\varepsilon}_1 + \hat{\varepsilon}_2}. \quad (6)$$

Clearly, the complex permittivity on the face,  $\hat{\varepsilon}_{face}(\omega)$ , is dispersive, so  $\mathbf{D}_{tot}$  can not generally be divided into  $\mathbf{D}$  and  $\mathbf{J}$ , which are needed for the FDTD update equations. However, if we are studying the fields at a single frequency (angular frequency  $\omega_0$ ), which is the case in most dosimetric calculations, we may write

$$\varepsilon_{face} = \text{Re}(\hat{\varepsilon}_{face}) \quad (7)$$

$$= 2 \frac{\varepsilon_1\sigma_2^2 + \varepsilon_2\sigma_1^2 + \omega_0^2\varepsilon_1\varepsilon_2(\varepsilon_1 + \varepsilon_2)}{(\sigma_1 + \sigma_2)^2 + \omega_0^2(\varepsilon_1 + \varepsilon_2)^2},$$

$$\sigma_{face} = -\omega_0 \text{Im}(\hat{\varepsilon}_{face}) \quad (8)$$

$$= 2 \frac{\sigma_1\sigma_2(\sigma_1 + \sigma_2) + \omega_0^2(\varepsilon_1^2\sigma_1 + \varepsilon_2^2\sigma_2)}{(\sigma_1 + \sigma_2)^2 + \omega_0^2(\varepsilon_1 + \varepsilon_2)^2}.$$

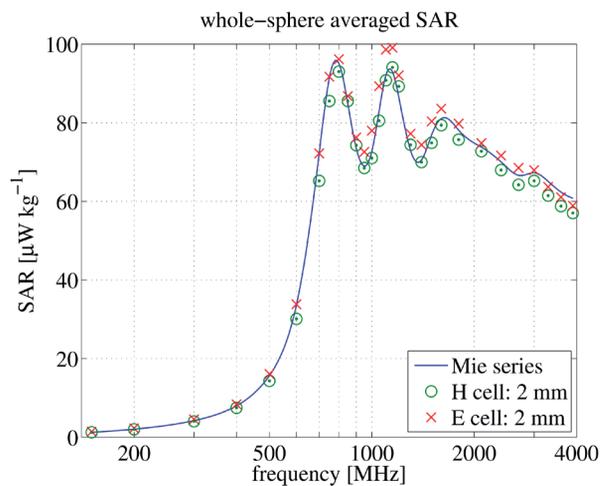


Figure 2. The SAR averaged over the whole sphere.

$E_{face}$ ,  $\sigma_{face}$ , and  $\varepsilon_{face}$  may now be substituted into the FDTD update equations. Parameters  $\sigma_{face}$  and  $\varepsilon_{face}$  must be recalculated at each frequency, but this is not a problem, because in SAR calculations the dielectric properties are different at each frequency, anyway. Essentially, the H-cell method may thus be implemented only by changing how the material parameters at dielectric interfaces are determined for the FDTD update equations. In addition to this, a slight change in post-processing of the FDTD results is needed. Namely, the electric field produced by the FDTD is the face-based non-physical electric field  $E_{face}$ , from which the physical electric fields,  $E_1$  and  $E_2$  may be calculated using Equation (5).

The relationship between the E-cell and H-cell methods may be made clear by the analogy between the FDTD and the time-domain Finite-Element Method (FEM). In the FEM, the E-cell method would correspond to using the edge-based curl basis functions for the electric field,  $\mathbf{E}$ , and the face-based divergence basis functions for the magnetic flux density,  $\mathbf{B}$  [9]. In turn, for the H-cell method, the unknown quantities are the electric flux density,  $\mathbf{D}_{tot}$ , and the magnetic field,  $\mathbf{H}$ , which are modeled with divergence and curl basis functions, respectively. The H-cell method is thus based on essentially the same principle as the original E-cell method, with the basis functions swapped around. Theoretically, the two methods should be equivalently valid. However, they will produce different numerical results. Also, both methods result in identical update equations inside homogeneous media.

### 3. Spherical Example

The motivation behind the H-cell method can be made clear by studying the FDTD modeling of small lossy dielectric spheres. In [6], some examples showing the SAR in small muscle spheres of varying radii were presented, at a fixed 1000 MHz frequency. In this study, a sphere with a fixed 3 cm radius was exposed to plane waves in the

frequency range from 150 MHz to 3900 MHz. The dielectric properties of the sphere were a weighted average (ratio 2:1) of muscle and (not infiltrated) fat [10]. The plane wave was linearly polarized, with amplitude  $1 \text{ Vm}^{-1}$  (rms). In the case of the E-cell method, the SAR values in each Yee cell were determined by the mid-ordinate algorithm [5], i.e., the squared electric field was calculated by averaging the electric field on the edges to the center of the cell, and the absolute value of the average was then squared. For the H-cell method, an equivalent algorithm employing the six electric field components on the cell faces, Equation (5), was used.

Figure 2 shows the whole-sphere averaged SAR (total power absorbed in the sphere divided by the sphere's mass) in the frequency range from 150 MHz to 3.9 GHz. The accurate analytic whole-sphere SAR was been calculated by the Mie series, and the FDTD results were calculated by the E-cell and H-cell methods using a 2-mm cell size. There were several visible peaks in the whole-sphere averaged SAR between 700 MHz and 2000 MHz. These corresponded to the lowest spherical resonance frequencies. There seemed to be certain frequencies where one of the methods gave a clearly better match with the analytic solution. For example, the E-cell method gave very good agreement with the Mie-series solution from 500 MHz to 800 MHz, but the H-cell method seemed to produce significant underestimation of the SAR. On the other hand, the H-cell method produced much more accurate results in the frequency range from 900 MHz to 1500 MHz, where the E-cell method overestimated the whole-sphere averaged SAR.

The differences between the E-cell and H-cell methods may be seen more clearly in Figure 3, which shows a comparison between the FDTD and the analytic whole-sphere averaged SAR for the 2-mm and 1-mm resolutions. It can be seen in the figure that refining the resolution by halving the cell size also seemed to halve the difference from the analytic whole-sphere averaged SAR. Figure 3 also showed that the choice between the E-cell and H-cell

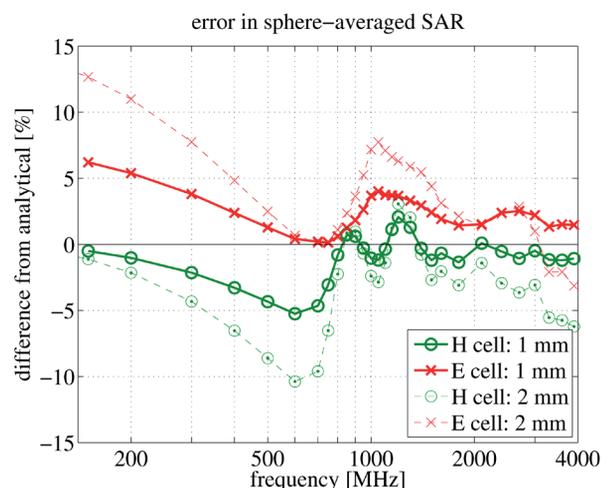


Figure 3. The differences between the E-cell and H-cell methods in whole sphere-averaged SAR.

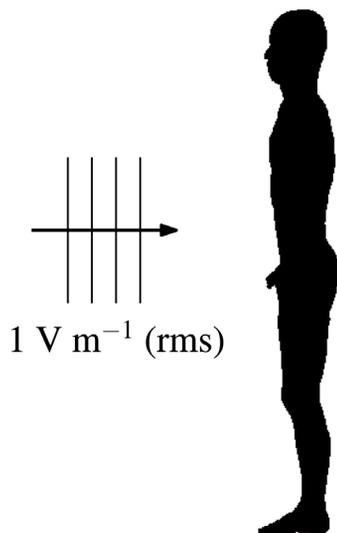


Figure 4. The exposure scenario.

methods may have an even larger effect than the choice of the step length in the resonance region. Using the “correct” method at a certain frequency may produce accurate results even at low resolution, whereas the other method may require refining the resolution to get equally accurate results.

At high frequencies, both methods started to diverge from the analytic solution when the 2-mm resolution was used. This was because of the discretization error affected by the ratio between the wavelength and cell size. In this case, both methods produced underestimation for too-high frequencies. However, for example, if the trapezium algorithm [5] (where the squared electric field is determined by averaging the squared field on the edges/faces) had been used instead of the mid-ordinate algorithm for calculating the SAR, both the E-cell and H-cell methods would have produced overestimation at high frequencies. At low frequencies, the H-cell method seemed to perform significantly better than the E-cell method, which produced a large overestimation. Because of the low frequency, this error was certainly not caused by the discretization error that resulted from the ratio between wavelength and cell size.

The differences between the E-cell and H-cell methods may at least partly have been contributed to by the fairly coarse staircase approximation of the spherical surface. Namely, the H-cell method tended to give smaller SAR values than the E-cell method in the voxels that were located on the surface of the sphere. That was why the H-cell method often gave a smaller whole-sphere averaged SAR compared to the E-cell method. Apparently, at certain frequencies, the spatial field distribution was such that using either the E-cell or the H-cell method may lessen or strengthen the effect of the staircase-approximation error. For example, at low frequencies, the magnitude of the accurate electric field inside the sphere was very small compared to the magnitude outside of the sphere. However, the E-cell method resulted in several spurious hotspots in the voxels just inside the staircased surface, which resulted in large overestimation of the total SAR.

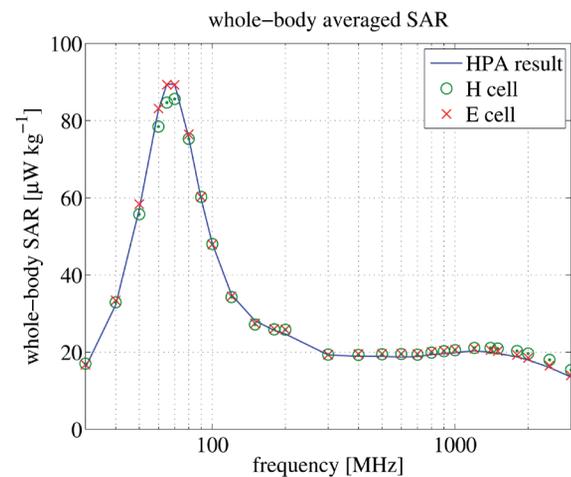


Figure 5. The whole-body-averaged SAR calculated by the E-cell and H-cell methods compared to the earlier results by HPA [4].

## 4. SAR Calculations in an Anatomically Realistic Body Model

The alternative H-cell method was employed for SAR calculations of whole-body models earlier in [11], but in that paper, only two frequencies (900 MHz and 1800 MHz) were studied. Because the choice between the E-cell and H-cell methods is particularly important near the spherical resonances for small spheres, it is interesting to study a wider frequency range, including low frequencies and the whole-body resonance frequency.

In this paper, the Japanese male TARO model [12] was used for the SAR calculations. A vertically polarized plane wave, incident from the front of the model, was used as the exposure source (Figure 4). The amplitude of the plane wave was 1 V/m (rms). The mass of the model was normalized to 65 kg, and the dielectric properties were modeled after [10]. The frequency range was chosen to be from 30 MHz to 3 GHz, and the sample frequencies were the same as in [4], to allow direct comparison of the results. For frequencies smaller than or equal to 300 MHz, the model resolution was down-scaled from 2 mm to 4 mm by the winner-takes-all principle [13]. For frequencies higher than 300 MHz, the original 2 mm resolution model was used.

Figure 5 shows the calculated whole-body-averaged SAR in the whole frequency range on a semi-logarithmic scale. The SAR values calculated by the E-cell and H-cell methods were compared to the earlier results calculated in the Health Protection Agency (HPA), UK [4]. As expected, the standard E-cell method provided a good match with the earlier results.

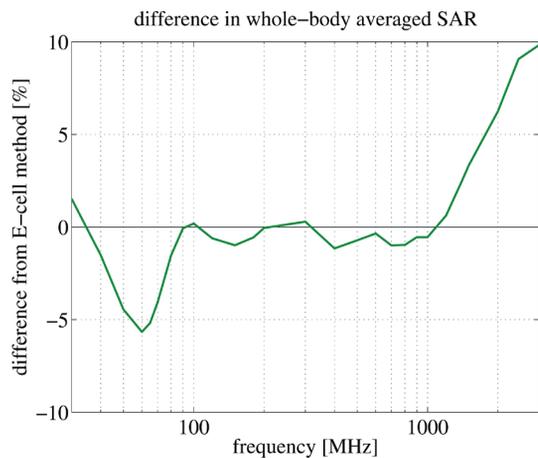


Figure 6. The differences between the E-cell and H-cell methods in whole-body averaged SAR.

Figure 6 shows the comparison between whole-body-averaged SAR calculated by the H-cell and E-cell methods. The difference seemed to be typically about 1%, but there were two interesting frequency ranges where there was a significant difference between the methods. The first interesting frequency range was above 1 GHz, where the E-cell and H-cell methods produced diverging whole-body-averaged SAR with increasing frequency. This divergence was comparable to that caused by different SAR-calculation algorithms [3-5]. In this study, the mid-ordinate algorithm was used for calculating the SAR values, and the behavior above 1 GHz would have changed if some other SAR-calculation algorithm were used. The divergence above 1 GHz was likely caused by the increasing ratio of step length compared to the wavelength, which made the SAR values increasingly uncertain at high frequencies.

Another interesting frequency range was around the whole-body resonance at 65 MHz, where there was a notable difference in the SAR results. The H-cell method resulted in about 6% smaller whole-body averaged SAR compared to the standard E-cell method. For studying which method was more accurate, calculations at 65 MHz were repeated for 8 mm and 2 mm resolutions. The results for the E-cell and H-cell methods are shown in Table 1. The whole-body-averaged SAR calculated with E cells seemed to stay relatively constant with the resolution. On the other hand, the H-cell result slowly increased when the resolution was refined. This suggests that the main whole-body resonance is of the type for which the E-cell method is the more accurate choice.

Step Length	E-Cell	H-Cell	HPA
8 mm	90.52	84.21	N/A
4 mm	89.28	84.65	N/A
2 mm	89.92	86.98	89.44

Table 1. The whole-body-averaged SAR ( $\mu\text{W}/\text{kg}$ ) at 65 MHz for three resolutions. The HPA result is after [4].

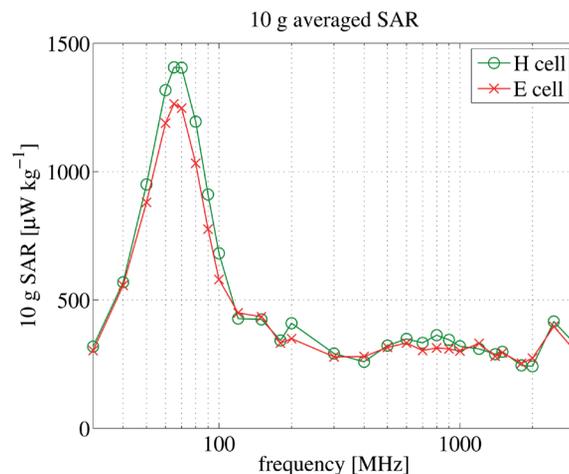


Figure 7. The peak 10 g averaged SAR calculated by the E-cell and H-cell methods. The peak value was calculated over the whole body.

In addition to the whole-body-averaged SAR, the localized SAR values averaged over 10 g were also calculated, using cubical averaging volumes [14]. The mass of each averaging cube was tuned to be exactly 10 g [15]. Figure 7 shows the peak 10 g averaged SAR for both the E-cell and H-cell methods in the whole frequency range. Near the whole-body resonance frequency, the location of the peak value was near the knees, and for the lowest frequencies, the peak value was located in the ankles. For frequencies higher than 100 MHz, the peak was located in the hands. Using the H-cell method instead of the E-cell method resulted in somewhat higher 10 g averaged SAR near the resonance frequency. Above 120 MHz, there was no clear pattern as to which method gave larger peak 10 g SAR values. The differences in peak 10 g SAR between the H-cell and E-cell methods was in the range from  $-0.5$  dB to  $+0.7$  dB.

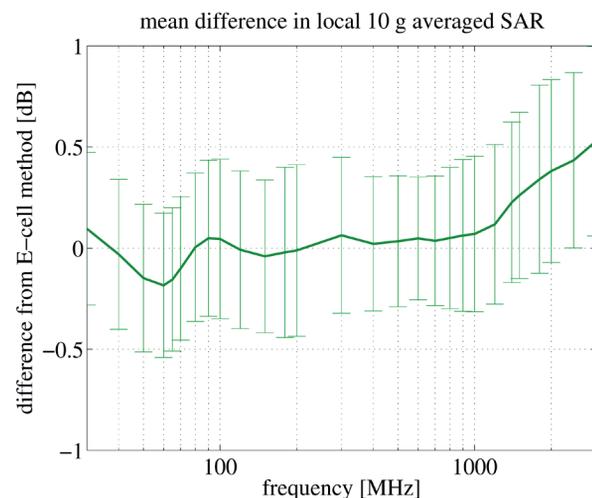


Figure 8. The mean value and standard deviation of the differences between the E-cell and the H-cell methods. The mean value and standard deviation were calculated over all 10 g SAR values that were greater than 1% of the maximum 10 g SAR.

Step Length	E-Cell	H-Cell
8 mm	1391	1506
4 mm	1264	1406
2 mm	1114	1214

Table 2. The peak 10 g averaged SAR ( $\mu\text{W}/\text{kg}$ ) at 65 MHz for three resolutions.

Besides the peak 10 g SAR values, the local 10 g SAR distributions inside the body were also studied. However, there seemed to be no obvious spatial pattern in the differences between the E-cell and H-cell methods. However, the relative difference in the local 10 g SAR seemed to be approximately log-normally distributed (over all cells), i.e., the difference in decibels was normally distributed. Figure 8 shows the mean difference and standard deviation in decibels. It was clear that the differences between the methods in the local 10 g SAR might be much larger than the difference in the whole-body averaged SAR. Also, the peak 10 g SAR values seemed to be more sensitive to the step length, which may be seen in Table 2.

## 5. Conclusions

The alternative H-cell method is based on swapping the positions of the electric and magnetic fields in the FDTD. Implementation of the H-cell method is just as easy as the standard E-cell method. The only difference is in the different way of calculating the material parameters on dielectric interfaces. The validity of the H-cell method was motivated by studying the plane-wave irradiation of a small lossy sphere in a wide frequency range. At certain frequencies, the H-cell method provided accurate results even with a low resolution, whereas the standard E-cell method produced a significant error. Interestingly, the opposite was true at some other frequencies. It was suggested that the difference between the methods was connected to the staircase approximation of the spherical surface.

The H-cell method was applied for SAR calculations in the Japanese male whole-body model in the frequency range from 30 MHz to 3 GHz. The whole-body-averaged SAR values calculated by the H-cell and E-cell methods generally agreed very well (a difference of about 1%), except in two frequency ranges. The first range was above 1 GHz, where the two methods produced diverging whole-body SAR values with increasing frequency. This divergence may be contributed to the increasing ratio of the step length (2 mm) compared to the wavelength. Another frequency range where there was a significant difference between the two methods was around the whole-body resonance frequency at 65 MHz. There, the H-cell method produced up to 6% lower whole-body-averaged SAR, compared to the E-cell method at 4 mm resolution. Repeating the calculations at multiple resolutions revealed that the standard E-cell method seemed to be more accurate at the whole-body resonance frequency. The choice between the E-cell and H-cell methods

had a much larger effect on the 10 g averaged SAR than on the whole-body averaged SAR. Also, the 10 g SAR values were more sensitive to the step length. The computational uncertainty in 10 g averaged SAR values thus seemed to be significantly greater compared to the whole-body SAR even at low frequencies, where there should be no problems with insufficient step length compared to the wavelength.

Compared to the standard E-cell method, the alternative H-cell method is theoretically just as valid a choice, but it may still produce differing results. Generally, it is not clear which method is the more accurate method. The difference between the E-cell and H-cell methods may be used as an indicator of the uncertainty in the FDTD. For instance, a large difference between the methods means that it may be necessary to repeat the calculations with a refined resolution to get good accuracy. Outside of the field of dosimetry, the H-cell method has obvious applications in modeling materials that are both magnetic and dielectric. Namely, on the edges and faces of the Yee cells, one of permittivity or permeability need to be treated with the H-cell method, and the other with the E-cell method.

## 6. Acknowledgments

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# The Relationship between the Leader Progressions and the Charge Distributions



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## Abstract

The Lightning Research Group of Osaka University (LRG-OU) succeeded in visualizing cloud-to-ground (CG) flashes with long horizontal leaders in three-dimensions using a VHF broadband digital interferometer (DITF) during the 2006-2007 field campaign in Darwin. It was concluded that in the case of cloud-to-ground flashes, the negative breakdowns occurred near the boundary regions of graupel and upper snow layers, and the horizontally long negative leaders progressed along the positive-charge regions. When the negative leaders reached the end of the positive-charge regions, the negative leaders changed their progression direction from horizontal into downward. In contrast, in the cases of intra-cloud (IC) flashes, the negatively charged graupel regions blocked the downward development of negative leaders. We also note that positive charge regions could facilitate extension of horizontal negative leaders. This result could be a resource for predicting the next lightning-strike location.

## 1. Introduction

Some cloud-to-ground (CG) flashes with long lightning channels, which extend more than 10 km horizontally before they touch the ground, have been reported. This type of lightning discharge is often frequently observed in the winter thunderstorm season. They are sometimes observed in summer lightning [1, 2]. Yoshihashi et al. (2001) [3] reported that the negative leader traveled horizontally inside the cloud at nearly the same speed as in the following downward expansion in a cloud-to-ground flash. The horizontally long leaders contribute to the difficulty of prediction of the location of the next lightning strike. It is considered that there are causal associations between the leader progressions and the charge distributions near

the lightning channels. Although studies have been made about this relationship, it is still controversial as to why the leader does not extend directly to the ground, but progresses horizontally in clouds before it touches the ground.

It is generally thought that electrifications in thunderclouds occur due to collisions between graupel particles and ice crystals [4], and strong electrifications produce lightning discharges. Ground-based electric-field measurements have traditionally been conducted for studying the charge structure of thunderstorms. The typical thundercloud charge structure is often approximated by three vertically stacked point charges, which have the main positive at the top, the main negative in the middle, and the lower positive at the bottom, respectively [5]. Lund et al. (2007) [6] reported that the majority of lightning initiated in two altitude regions. The lower altitude is near the freezing level on the outside of the updraft location, while the upper altitude is at the updraft locations on the edge of graupel regions. It is generally thought that the lower positive-charge region serves to enhance the electric field (E field) at the bottom of the negative-charge region. The lower positive-charge region thus facilitates the launching of a negative leader toward the ground [7-9]. On the other hand, the presence of excessive lower positive charge has been reported to prevent the occurrence of negative cloud-to-ground flashes, and to facilitate intra-cloud discharges between the main negative and lower positive-charge regions [10]. Nag and Rakov (2009) [11] also reported that the horizontal negative-leader progression before extending downward was caused by positive charge. According to Nag and Rakov, the positive charge was considered to “block” the progression of a descending negative leader from reaching ground. Coleman (2008) [12] reported that a long period of preliminary breakdown and significant horizontal propagation of negative breakdown before the first return stroke (RS) only occurred when there was a potential well for negative charge below the initiation altitude.

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Recently, studies on the relationship between the leader progressions and the charge distributions have been made using both lighting-mapping systems and polarimetric weather radar. The polarimetric radar produces data for estimating precipitation particles. It is an effective method for clarifying the relationship, since the charge distributions are able to be estimated by distributions of precipitation particles. Bruning et al. (2007) [13] observed thunderstorms using the Lightning Mapping Array and polarimetric radar in Oklahoma. The cloud-to-ground flash was initiated above the melting level. A negative leader propagated downward toward the  $ph_v$  minimum, which indicated water-coated ice particles. The leader eventually came to ground on the side of the  $ph_v$  minimum. However, the studies were mainly conducted in mid-latitudes, where the convective activity is not so high.

The Lightning Research Group of Osaka University (LRG-OU) has been developing and improving a VHF broadband digital interferometer (DITF) [14] that locates the impulsive VHF radiation sources caused by lightning with extremely high time resolution in three dimensions. For the purpose of revealing the relationship between the leader progressions and the charge distributions in thunderclouds, we conducted an observation campaign for thunderstorms during the 2006-2007 monsoon season in Darwin, Australia, using the VHF broadband digital interferometer. The Bureau of Meteorology Research Centre C-band polarimetric weather radar also produced data for estimating charge distributions in thunderclouds. Darwin lies in the inter-tropical convection zone (ITCZ), which is the world's largest source of latent heating. Since the tropopause layer's altitude is 15 km or higher, the high convective activity produces large thunderstorms. The scale of electric activity is so large that Darwin is a suitable site for investigating the relationship between the leader progressions and the charge distributions.

## 2. Methods

It is well-known that a lot of VHF impulsive electromagnetic (EM) waves are radiated mainly from the tips of negative breakdowns associated with lightning leader progressions [15]. The VHF broadband digital interferometer receives these VHF impulsive electromagnetic waves and locates their sources. The basic idea of digital interferometry is to calculate the phase difference for various frequency components of a broadband electromagnetic wave detected by a pair of antennas. The VHF broadband digital interferometer at each observation site provides the directions of the radiation sources. Three-dimensional (3D) localization of the radiation sources can be accomplished by a conventional triangulation scheme from the two-dimensional (2D) mappings. A slow antenna with a decay time constant of 10 s was also equipped to measure the E-field change on the ground's surface. The three-dimensional lightning observation campaign, using two VHF broadband digital interferometers, was conducted

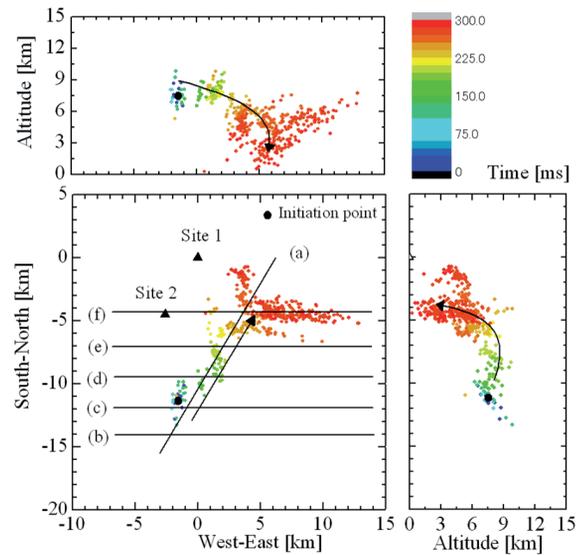


Figure 1. The three-dimensional imaging of Flash A with its projection onto the horizontal and vertical planes. Sites 1 and 2 were located at the origin, and  $(-2.6, -4.5)$ , respectively. The arrow shows the progression direction of the main negative leader, which touched the ground. Lines (b)-(f) are east-west straight lines,  $-14.3$  km,  $-11.8$  km,  $-9.3$  km,  $-6.8$  km, and  $-4.3$  km south from the origin. The colors show the VHF pulse time received at Site 1 in milliseconds. The main negative leader touched the ground at the time of 280 ms after the initiation of the flash.

during the 2006-2007 monsoon season in Darwin, Australia. We set up the VHF broadband digital interferometer at Site 1, and another interferometer with a slow antenna at Site 2. The distance between Sites 1 and 2 was 5.2 km.

## 3. Results

### 3.1 Flash A

Figure 1 shows the three-dimensional imaging of a lightning flash recorded at 07:22:33 UT on December 16, 2006. It was identified as a cloud-to-ground flash by its abrupt E-field change (not shown here). Zero time corresponded to the time when the first electromagnetic pulse associated with this event was received at Site 1. After the negative leader initiation, it progressed northeastward horizontally about 10 km, with at least three branches. The main channel indicated by the arrows in Figure 1 touched the ground and produced the first return stroke. In this paper, we focus only on the main channel. Figures 2a through 2f show the VHF source locations superimposed on vertical cross sections of the hydrometeor classification along Lines (a) through (f) in Figure 1. The spatial resolutions were 2.5 km in the horizontal direction and 0.5 km in the vertical direction. The hydrometeor classifications are shown for the pixels that exceeded 0 dBZ in the radar-reflectivity factors. The black dots show the VHF radiation sources that were located within 1.25 km of each vertical cross section. The arrow in Figure 2a indicates the direction of propagation of the main channel.

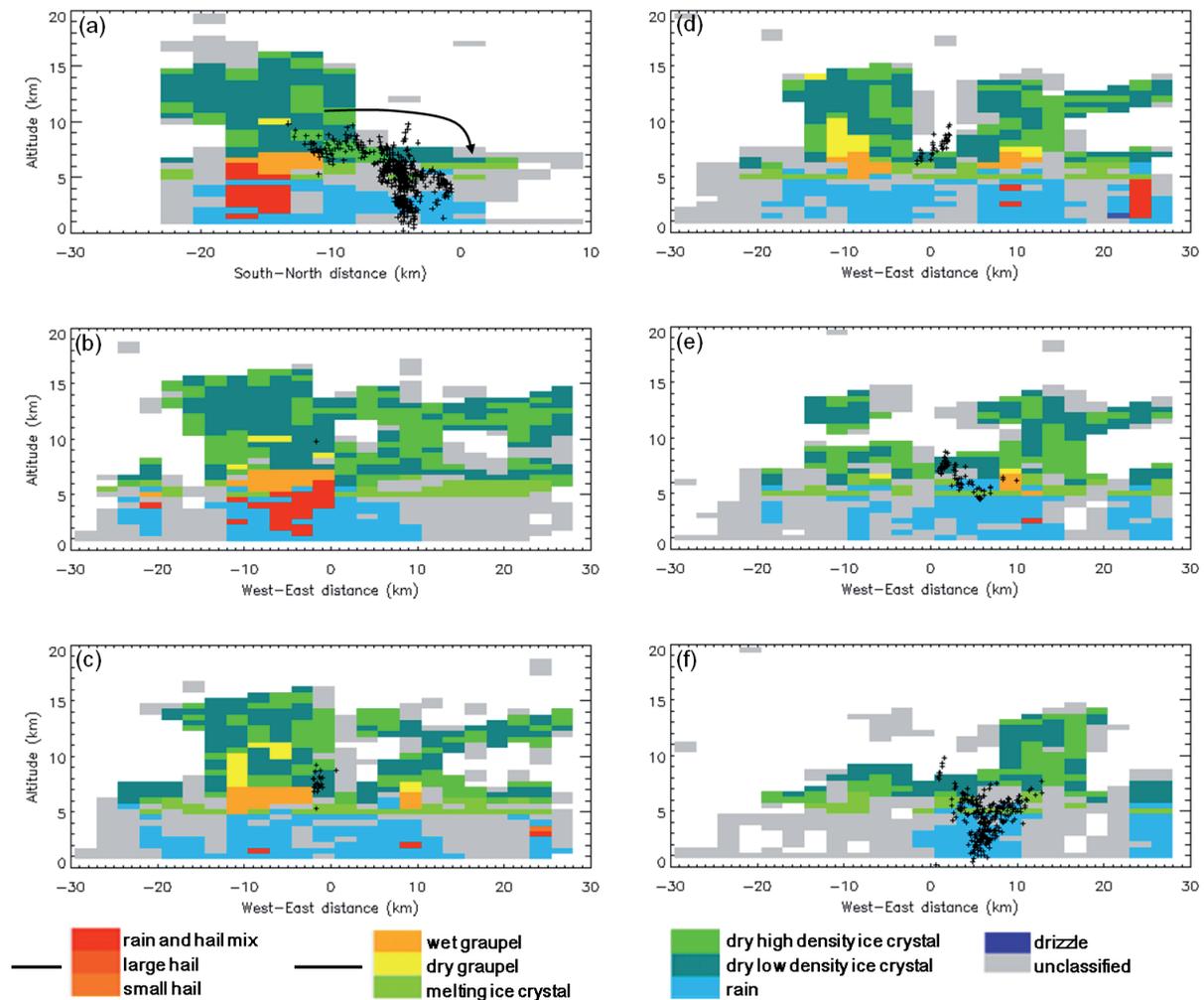


Figure 2. The VHF source locations superimposed on vertical cross sections of hydrometeor classification along Lines (a) through (f) in Figure 1. Figure 2a shows the vertical cross section along the main channel that touched the ground. Figures 2b, 2c, 2d, 2e, and 2f show the vertical cross sections along lines  $-14.3$  km (b),  $-11.8$  km (c),  $-9.3$  km (d),  $-6.8$  km (e), and  $-4.3$  km (f) south from the origin, respectively. The color of each pixel is coded by hydrometeor classification. The arrow in Figure 2a shows the progression direction of the negative leader. The black dots show the VHF radiation sources located within  $1.25$  km of each vertical cross section.

The negative leader was initiated between the graupel and upper ice-crystal layers at about  $7$  km in altitude. The initiation point was in the outer part of the graupel region. A few VHF sources were located in Figure 2b. In Figure 2c, the source of the first VHF pulse received at Site 1 was located. The negative leader propagated continuously within or above the ice-crystal layer in Figures 2c and 2d. The negative leader changed its propagation direction toward the ground as shown in Figure 2e. The region where the negative leader propagated in Figure 2e was composed of low-density ice-crystal and unclassified regions. In Figure 2f, the negative leader propagated downward and reached the ground, resulting in the first return stroke.

### 3.2 Flash B

Figure 3 shows the three-dimensional imaging of an intra-cloud flash recorded at  $09:20:54$  UT on December 13, 2006. Figure 4 shows the VHF source locations superimposed

on the vertical cross section of the hydrometeor classification along the direction of the propagation (Line (a)) of the intra-cloud flash. Although the negative leader was initiated at about  $7$  km between the graupel and upper ice-crystal layers at the same altitude as the leader of Flash A, the initiation point was located several kilometers from the side edge of the graupel region, unlike the case of Flash A. The graupel layer was covered with the upper ice-crystal layer. The negative leader proceeded horizontally, and then developed into the upper ice-crystal layer.

### 3.3 Thunderstorm Analysis

Figure 5a shows the three-dimensional imaging of eight intra-cloud flashes and one cloud-to-ground flash, recorded between  $08:55:00$  and  $09:05:00$  on December 13, 2006 (UT). Figures 5b and 5c show the VHF source locations superimposed on the vertical cross sections of hydrometeor classification by Lines (i) and (ii) in Figure 5a, respectively.

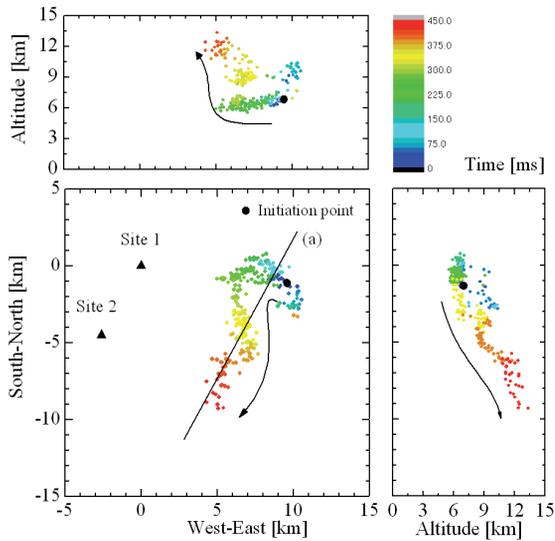


Figure 3. The three-dimensional imaging of Flash B with its projection onto the horizontal and vertical planes same as in Figure 1. The arrow shows the progression of the main negative leader. The plot color transits from cold to warm with time from the time that the first VHF pulse was received at Site 1. The main negative leader progressed for 417 ms. The vertical cross section of the VHF source locations and hydrometeor classification along the Line (a) is shown in Figure 4.

The cloud-to-ground flash was initiated at a location a few kilometers away from the region where most intra-cloud flashes occurred.

The negative leader of the cloud-to-ground flash moved further away from the region where the VHF sources associated with the eight intra-cloud flashes were located. The initiation points of the intra-cloud flashes were located in the inner part of the region between the graupel and upper ice-crystal layers, with the graupel layer beneath the region where the intra-cloud flashes were initiated. Meanwhile, the cloud-to-ground flash was located in the outer part of the same region. The negative leaders associated with intra-cloud flashes did not progress to the ground but to the upper ice-crystal layer, as observed in Flash B. In contrast, the negative leader of the cloud-to-ground flash progressed horizontally for about 6 km at its beginning, and then changed its direction toward the ground after it reached the outer edge of the ice-crystal layer, as observed in Flash A.

#### 4. Discussion

In the case of Flash A, the negative breakdown progressed horizontally along the snow layer about 10 km. When the negative leaders reached the end of the snow layer, the negative leaders changed their direction of progression from horizontal into downward. According to the most-popular non-inductive thundercloud-electrification mechanism [4], the collisions between graupel and ice crystals make precipitation particles electrified when the ambient temperature is between  $-10^{\circ}$  and  $-20^{\circ}$  isotherms. In the collisions, the graupel particles acquire a negative

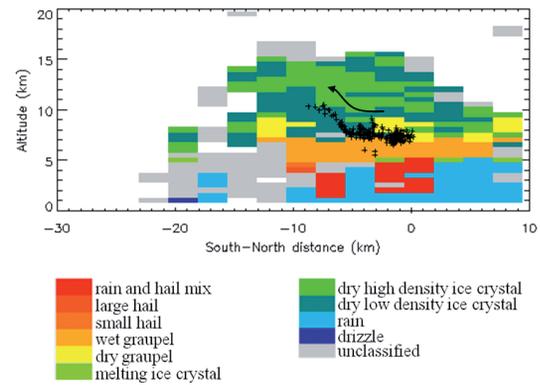


Figure 4. The VHF source locations superimposed on vertical cross sections of hydrometeor classification of Flash B

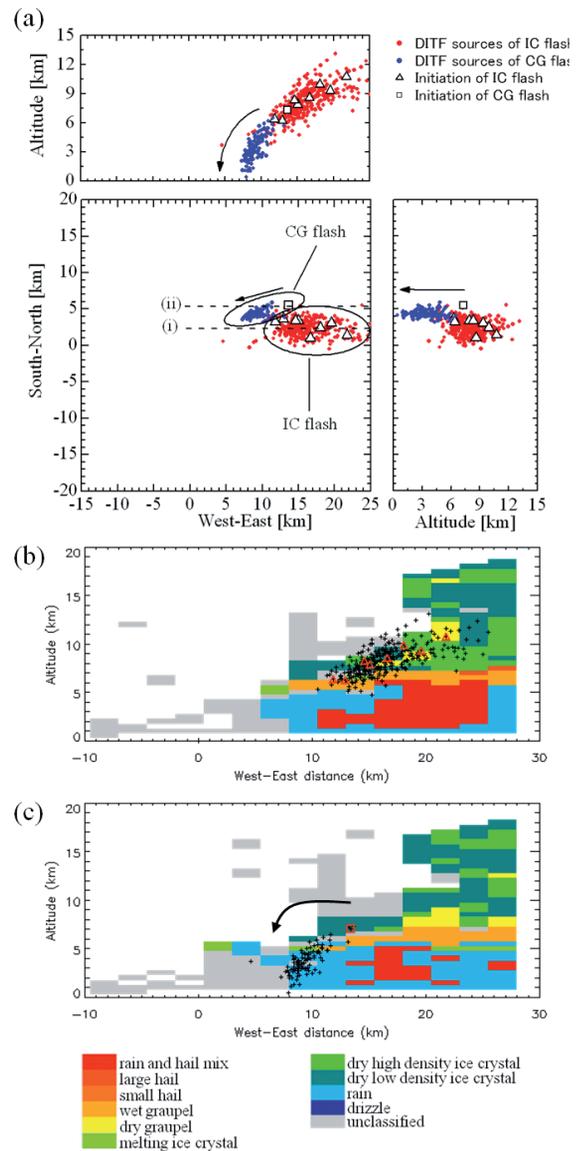


Figure 5. The three-dimensional imaging of flashes recorded during 0855:00 to 0905:00 with (a) the projection of the intra-cloud and cloud-to-ground flashes onto the horizontal and vertical planes, (b) vertical cross sections of hydrometeor classification along Lines (i), and (c) vertical cross sections of hydrometeor classification along Line (ii)

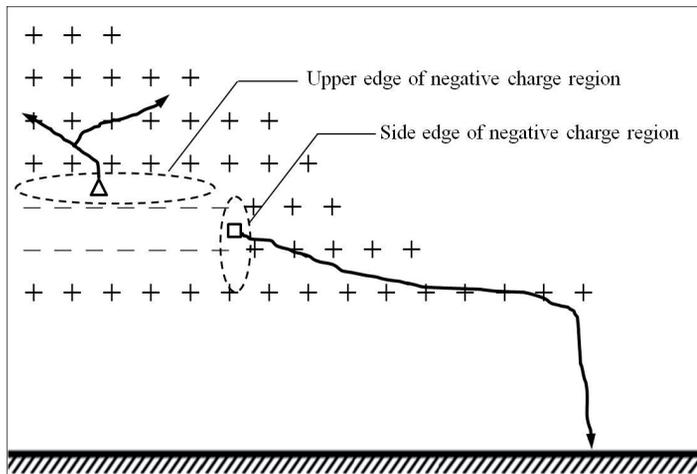


Figure 6. A diagram illustrating the relationship between negative leader channels and charge distribution in thunderclouds. The ice-crystal and graupel regions were considered to be positively and negatively charged regions, respectively.

charge. It is therefore assumed that the ice-crystal and graupel regions are positively and negatively charged regions, respectively. Taking into account these facts, the negative breakdown is initiated between the negatively charged and upper positively charged regions, where the E field is quite high, as reported in the previous literature [16]. The negative breakdown progresses horizontally, neutralizing the positive charge. When it reaches the edge of positively charged region, it changes direction of progression from horizontally into downward. The breakdown progresses in the bottom of the slope structure of the positive charge, due to the induced positive charge on the ground. In the case of Flash B, the initiation point was not near the edge of the negatively charged graupel region. The snow formed a layer uniformly above the initiation point. The negative breakdown was considered to progress toward the upper snow layer to neutralize the positive charge. Similar patterns, typified by Flashes A and B, have also been recognized in thunderstorm analysis. Nag and Rakov (2009) [11] reported that the horizontal negative breakdown progression before extending downward was caused by positive charge. The positive charge was considered to “block” the progression of the descending negative leader from reaching ground. Our observation results basically agree with them. However, considering the cases of cloud flashes, it may be appropriate that the positive charge is considered to “lead” rather than “block” the progression of negative breakdown. In the case of the flashes for which the initiation points were on the upper edges of the graupel regions, what blocked the progression of the descending negative leader seemed to be not so much positive charge as negative charge that are graupel regions. We also consider that the negative leaders of the cloud-to-ground flashes showed a tendency to be initiated in the outer part of the graupel region. Unlike the cases of the cloud-to-ground flashes, the negative leaders of the intra-cloud flashes showed a tendency to be initiated around the inner part of the region between the graupel and the upper ice crystals. Our observation results suggest that the location of flash initiation and the surrounding charge distribution would determine what the flash types will be, as illustrated in Figure 6. We also observed six more cloud-to-ground and 85 intra-cloud flashes with the same

features in 30 minutes after 9:05 on December 13, 2006. These results indicated that the location of flash initiation and the surrounding charge distribution would determine the flash type.

## 5. Conclusions

LRG-OU conducted a lightning-observation campaign during the 2006–2007 monsoon season in Darwin, Australia, using the VHF broadband digital interferometer. The flashes were initiated in and near the boundary regions between the graupel and upper snow layers. If the initiation points were near the edge of the graupel layer, the breakdowns progressed horizontally. The negative breakdowns progressed along the snow layer, where the positively charged region is considered to be. It was also found that the negative breakdown progressed along the horizontally spread positively charged region. When the negative breakdown reached the end of the snow layer, the negative breakdowns changed their direction of progression from horizontal into downward. In other words, the negative breakdowns changed their direction when the breakdowns reached the regions where positive charge did not exist. On the other hand, in the case of cloud flash, the flash initiated far from the edges of the negatively charged graupel layer. Taking into account the results obtained from the digital interferometer, it was also indicated that we could predict the next lightning-strike locations from the structure of precipitation particles by radar data in thunderclouds.

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# Errors in Channel Prediction Based on Linear Prediction in the Frequency Domain : A Combination of Frequency-Domain and Time-Domain Techniques



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Akira Hirose

## Abstract

Channel prediction is one of the most important issues in dealing with a fading environment. If a future channel response is predicted, adaptive techniques, such as pre-equalization and beamforming, can be employed before transmission in order to avoid degradation of the quality of the communication. This paper proposes a highly accurate method for predicting time-varying channels by using a linear prediction of Fourier-domain channel parameters. The method combines frequency-domain and time-domain techniques. Simulation assuming a time-division duplex (TDD) system demonstrates that the proposed method very accurately predicts varying channels. The paper also presents the dependence of the prediction error on the length of the observation window, and on the distance between scatterers. It is found that our method reduces the prediction error even when the scatterers are located very closely together.

## 1. Introduction

Communication quality is degraded by time-varying fading in mobile communications. There are a number of techniques for reducing a fading-channel effect, such as space diversity and error coding. However, they require a large receiver size and/or heavy calculation costs. Another potential technique is to avoid the fading by pre-equalization or beamforming, which requires the prediction of future channel characteristics. This direction opens the possibility of higher-performance adaptive communications with mitigated fading effects.

In recent years, much research has been reported concerning the topic of channel prediction. Many researchers

have used variations of the autoregressive (AR) modeling method [1-4], high-resolution methods such as ROOT-MUSIC [5] and ESPRIT [6], and the time-domain linear-prediction method [7, 8]. The autoregressive and high-resolution methods can realize highly accurate prediction. However, they usually require very high calculation costs, which lead to difficulty in implementation for real-time processing with power-limited devices. On the other hand, the linear-prediction methods require only low calculation costs, but the prediction is less accurate and more sensitive to noise.

This paper proposes a combination of frequency-domain and time-domain techniques. That is, we employ linear prediction for frequency-domain parameters to realize highly accurate prediction of time-varying channels. We use the chirp-Z transform (CZT) to convert the signal into the frequency domain. Since we regard the channel as a summation of discrete Doppler paths, we predict the channel's state by estimating all dominant-path parameters in the Doppler spectrum. We then linearly predict a set of future path parameters to reduce the inaccuracy caused by the variation of parameters over time.

## 2. Linear Prediction of Frequency-Domain Parameters

### 2.1 Channel Model

A fading channel can be modeled as a summation of sinusoids, which correspond to the multipath rays caused by reflection and scattering. A signal path,  $m$ , among a set of paths can be characterized by the following path parameters: the amplitude,  $a_m$ ; phase shift,  $\theta_m$ ; and Doppler frequency,

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$f_m$ . The channel characteristic,  $c(t)$ , is the summation of these  $M$  complex signal paths, expressed as

$$c(t) = \sum_{m=1}^M a_m e^{j(2\pi f_m t + \theta_m)}, \quad (1)$$

where  $j$  denotes the imaginary unit. This model suggests that the Fourier transform of the estimated channel response will show signal paths as amplitude peaks at their respective Doppler frequencies in the Doppler spectrum. The path parameters of respective dominant signal paths can thus be obtained in the frequency domain by searching the amplitude peaks.

We use the chirp-Z transform (CZT) to calculate the Doppler spectrum to estimate the path parameters, because of its lower cost of calculation and higher accuracy, compared to the normal fast Fourier transform (FFT) [9, 10]. However, the chirp-Z transform (or FFT) data represent channel characteristics averaged over the chirp-Z transform (or FFT) window. This is a serious weak point of the frequency-domain method when the channel parameters vary with time. We then propose linear-parameter prediction to obtain current path parameters to be used to predict the channel in the future.

## 2.2 Proposal of Linear Prediction of Frequency-Domain Parameters

In general, a window function weights the most at the middle of the window, paying more attention to the central part. On the other hand, since the path parameters are changing in the window, it is better to pay larger attention to the last part for future prediction. Alternatively, the window should be set over the future region, which is impossible. To solve this problem, we propose the linear prediction of frequency-domain path parameters. We also analyze the prediction performance in terms of window size and the spacing of the scatterers.

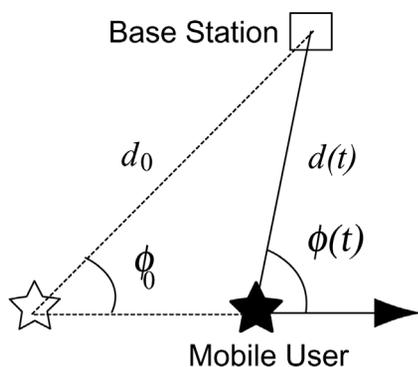


Figure 1. The angle and distance to a base station of a moving user.

Figure 1 shows a schematic diagram, showing a Doppler situation. The star symbol represents a mobile user having velocity  $v$ , and a square represents a base station. When a mobile user is moving relative to the base station, the angle between the movement direction and the base-station direction,  $\varphi(t)$ , is changing. The Doppler frequency,  $f(t)$ , is thus also changing:

$$f(t) = \frac{f_c}{c} v \cos[\varphi(t)], \quad (2)$$

$$\varphi(t) = \arctan \left[ \frac{d_0 \sin(\varphi_0)}{d_0 \cos(\varphi_0) - vt} \right], \quad (3)$$

where  $c$ ,  $d_0$ , and  $\varphi_0$  denote the speed of light, the initial distance between the base station and the user, and the initial angle, respectively.

Figure 2 explains the simplified linear parameter-prediction method. It includes some sets of parameters,  $a_m$ ,  $\theta_m$ , and  $f_m$ , for a single signal path, although our method linearly predicts all the path parameters for all

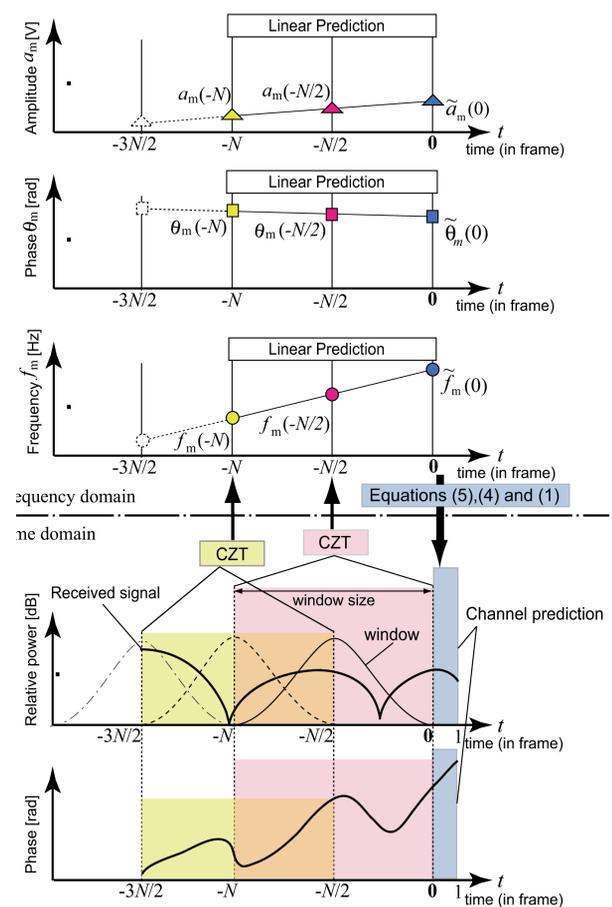


Figure 2. A schematic diagram of linear-path-parameter prediction, using parameters obtained in two overlapping windows to predict those at the current time ( $t = 0$ ).

dominant signal paths. In our method, two overlapping chirp-Z transform windows, each  $N$  frames long, produce two path-parameter sets:

$$\left[ a_m(-N/2), f_m(-N/2), \theta_m(-N/2) \right],$$

and

$$a_m(-N), f_m(-N), \theta_m(-N),$$

focusing on frames centered at  $-N/2$  and  $-N$ , respectively. These past parameter sets are used to linearly predict the path parameter set at frame zero:  $\left[ a_m(0), f_m(0), \theta_m(0) \right]$ . The predicted path parameters represent the predicted channel at frame zero better than the parameters focusing only on  $-N/2$  because the path parameters are varying with time.

The linear prediction uses the Newton backward-difference interpolation to predict the parameters at the current time ( $t=0$ ). The first-order linear parameter prediction is described as

$$\begin{cases} \tilde{f}_m(0) = f_m(-N/2) + \Delta f_m(-N/2) \\ \tilde{a}_m(0) = a_m(-N/2) + \Delta a_m(-N/2), \\ \tilde{\theta}_m(0) = \theta_m(-N/2) + \Delta \theta_m(-N/2) \end{cases} \quad (4)$$

$$\begin{cases} \Delta f_m(-N/2) \equiv f_m(-N/2) - f_m(-N) \\ \Delta a_m(-N/2) \equiv a_m(-N/2) - a_m(-N) \\ \Delta \theta_m(-N/2) \equiv \theta_m(-N/2) - \theta_m(-N) \end{cases} \quad (5)$$

The predicted parameters,  $\tilde{\bullet}_m$ , for each signal path,  $m$ , are the addition of the previously estimated parameter,  $\bullet_m(-N/2)$ , focused at frame  $-N/2$ ; and the backward difference,  $\Delta \bullet_m(-N/2)$ , focused at frame  $-N$ . This

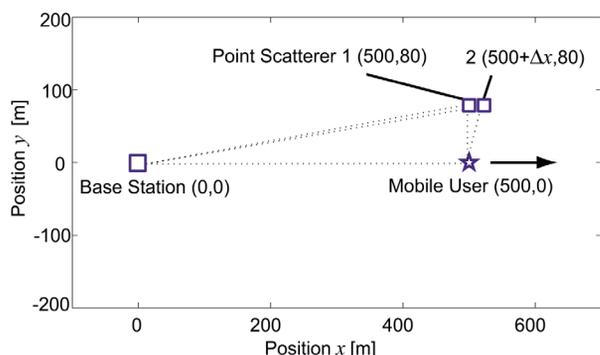


Figure 3. The geometric positions of the base station, the mobile user, and two scatterers.

Parameter	Value
Carrier frequency	2 GHz
Symbol rate	500 k symbol/s
Frame length	2500 symbols (= 5 ms)
Number of paths	3
User speed	14 m/s (= 50.5 km/s)
Max. Doppler frequency	93 Hz
Observation window length	$N (= N \times 5 \text{ ms})$

Table 1. The simulation parameters

is the difference between the two previously estimated sets of parameters focused at frame  $-N/2$  and  $-N$ . The future channel response in the time domain can thus be predicted based on the predicted path parameters  $\tilde{a}_m$ ,  $\tilde{\theta}_m$ , and  $\tilde{f}_m$ .

### 3. Evaluation Results

The time-selective fading channel in a TDD system was simulated. The general simulation conditions are detailed in Table 1. The unit frame length was 5 ms, i.e.,  $N$  frames corresponded to time  $t = N \times 5$  ms.

Figure 3 shows the geometric positions of the base station, mobile user, and two scatterers. To show the effectiveness of the linear parameter-prediction method in a close-scatterer condition, we first simulated a channel that had two point scatterers close to the mobile user, at an initial distance of 80 meters and an initial angle of  $90^\circ$  relative to the mobile user's direction of motion. The distance between the two scatterers was  $\Delta x$ . In this simulation, noiseless conditions and perfect reflection were assumed.

Figure 4 shows a typical example of the (a) power and (b) phase prediction results of a simulated channel response

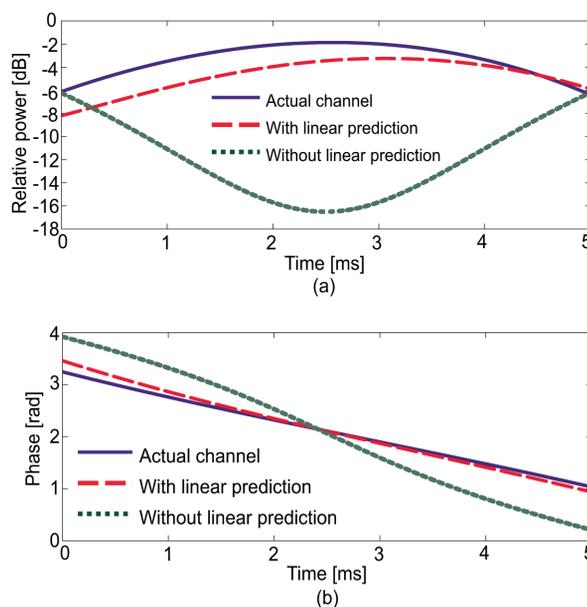


Figure 4. Typical examples of prediction results for (a) power and (b) phase.

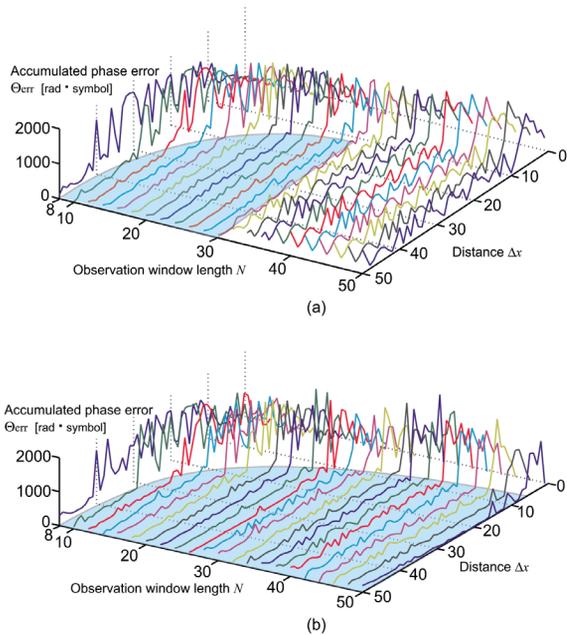


Figure 5. The phase-prediction error,  $\Theta_{err}$ , as a function of the distance between two scatterers,  $\Delta x$  for various observation-window lengths,  $N$ , (a) without and (b) with the proposed linear prediction of frequency-domain parameters.

in a single future frame. The observation frame number  $N$  was set to 14 ( $= 70$  ms). It was clear that the future channel response (solid line) could be predicted more accurately with the proposed linear-parameter prediction (dashed line) than for the case without it (dotted line).

For extraction of the channel parameters, the spectral peaks were tracked in the frequency domain. That is, the number of spectral peaks gives the number of dominant propagation paths. In the conventional method without linear prediction [10], the system often yields a less-accurate output when Doppler peaks – corresponding to different signal paths – cross each other in the frequency domain. It is often observed that multiple spectral peaks with similar Doppler frequencies may suddenly combine into a single peak, and then break into multiple peaks. Such an event causes the apparent vanishing and/or emergence of channel paths, and hence hinders the acquisition of appropriate channel parameters. However, in the present simulation using the linear prediction, even when Doppler peaks cross each other, the prediction error did not increase, because of our prediction using the past data before the peaks were approaching each other.

Figure 5 shows the evaluation results (a) without and (b) with the parameter prediction. The curves show the summation of absolute values of the phase-prediction error,  $|\theta_{err}|$ ,  $\Theta_{err} = \sum |\theta_{err}|$ , at symbol points in the predicted single frame (2500 symbols,  $2 \mu\text{s}$  interval, when we assumed a 500 k symbol/s communication system) as a function of the distance between two scatterers,  $\Delta x$ , in the range from 1 to 50 m, for various observation-window lengths,  $N$ , from

eight to 50 (time,  $t$ , from 40 ms to 250 ms). For these phase-error values, we could introduce a criterion to evaluate a system, as follows. Assuming the highest-level modulation, 64QAM, in the adaptive modulation in IEEE802.20, we can roughly estimate the acceptable phase-error value as  $\Theta_{err} < \frac{\pi}{2} \frac{1}{\sqrt{64}} = 2500 \approx 250$  rad symbol. The dark areas in Figures 5a and 5b show the acceptable error regions.

In Figure 5a, without the proposed method, it was found that the prediction error depended on the observation window's length. We could observe low errors in a region of  $N < 30$  frames and  $\Delta x < 12$  m. However, in the region of longer window lengths, the prediction error increased to larger than 250 rad symbol. In other words, the conventional method possesses an inherent tradeoff between the predictability of instantaneous parameter values, requiring a short window, and the Fourier-transform resolution, which needs a long window.

On the other hand, Figure 5b shows the evaluation result for our method. We found that the low-phase-error region (the dark area) extended to larger  $N$  and smaller  $\Delta x$  directions. For example,  $\Delta x = 6$  m when  $N = 50$  frames. The availability of longer  $N$  improved the Fourier resolution. It also realized the use of long-past parameters, effective for prediction even when Doppler peaks were crossing each other at around the current time. These advantages also reduced the phase error in the smaller  $\Delta x$  region.

When we continued the simulation for larger  $N$ , we found that the phase-error value gradually increased at about  $N = 100$  frames, at which the low-error region extended down to  $\Delta x \approx 3$  m. In actual applications in a crowded urban area, we may have room for improvement in the extension to smaller  $\Delta x$  direction. A higher-order prediction, instead of the linear prediction, would be effective. We can very easily extend our proposal into such a higher-order prediction with almost no increase in calculation cost.

## 4. Conclusion

We have proposed a channel-prediction method using the linear prediction of frequency-domain parameters in time-varying fading channels. The method combines time-domain and frequency-domain techniques. With our proposal, the prediction error was reduced even when scatterers were located close to each other. We can use the prediction results in pre-equalization and/or beamforming to mitigate time-selective fading. It has been shown that the proposed method extends the low-error parameter region to a smaller scatterers' distance of 6 m at a longer window size of 50 frames.

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*This report was prepared by Professor K.J. Langenberg, Commission B Chair 2008-2011.*

### 1. GA 2008, Chicago

The URSI Board approved the election of Karl Langenberg, Germany, as Chair and Giuliano Manara, Italy, as Vice-Chair for the period 2008 – 2011

### 2. International Symposium on Electromagnetic Theory 2010

This triennial Symposium was held in Berlin, Germany, August 16 – 19, 2010; it attracted about 260 participants. The scientific program was set up by a Technical Program Committee consisting of the national Commission B Chairs supported by a Technical Advisory Board formed by well-known radio scientists. Topics included the conventional topics of the Commission B terms of reference as well as special sessions proposed by respective conveners. A memorial session for the late Femke Olyslager was organized by Daniel De Zutter and Ludger Klinkenbusch. The local arrangements for the Symposium including preparation of the abstract booklet and the proceedings and maintenance of the website was in the hands of the Local Organizing Committee headed by Ludger Klinkenbusch. A highlight of the Symposium was by no doubts the Banquet that was held in the glass courtyard of the Jewish Museum.

URSI symposia carefully maintain the tradition that is also true for the General Assemblies to support Young Scientists. The Berlin Symposium received 49 applications satisfying the criteria that the applicant must be the first author, and that he must be younger than 35.

Consuetudinarily, for the Commission B Symposia the Vice-Chair of the Commission, presently Giuliano Manara, is responsible to handle the program. With the help of reviewers he proposed 21 nominees, and, as a matter of fact, due to the financial support of URSI and several sponsors, all 21 could be supported meaning that their registration fee was waived, and that they received a per diem and an invitation to the Banquet; those from developing countries also received a financial travel support.

Two more sponsors – the software company CST and the consulting company NavCom – arranged for a Young Scientist Best Paper Award: first prize Euro 1000, second

prize Euro 750, third prize Euro 500. To select potential awardees from the Young Scientists reviewers proposed 6 nominees who, in addition to their oral paper, had to prepare a poster that was evaluated by a selection committee. Finally, the awardees were announced during the Banquet: 1. Yan Kaganovsky from Israel, 2. Alireza Kazemzadeh from Sweden, 3. Giorgio Carluccio from Italy.

### 3. International URSI Commission B Symposia 2013 and 2016

The 2013 Symposium will be held in Hiroshima, Japan, May 20 – 23. A pre-announcement flyer has been distributed during the Berlin Symposium. Questions about the Symposium and its technical program can be directed to the present URSI Commission B Vice-Chair.

For the 2016 Symposium the site will be chosen during the Commission B Business Meeting during the GASS 2011; the present Chair has received a bid by the French Commission B to hold the Symposium in Versailles, France.

### 4. GASS 2011

With the help of Conveners Commission B has been able not only to fill its allocated slots for invited and submitted oral papers, but a substantial number of evenly high-ranking papers had to be moved to the two Poster Sessions. The Commission B Tutorial will be given by Richard W. Ziolkowski, USA, on Metamaterials. Commission B Member Ehud Heyman, Israel, will be awarded the Balthasar van der Pol Gold Medal.

### 5. Vice-Chair Election 2011 – 2014

Five nominations have been received by the Commission by March 1, 2011:

Ayhan Altintas, Turkey,  
Kazuya Kobayashi, Japan,  
Ari Sihvola, Finland,  
Donald Wilton, USA,  
Man-Fai Wong, France.

Unfortunately, Man-Fai Wong passed away on April 3. The appropriate ballot forms have been sent out by

URSI. The final election will take place during the first Commission B Business Meeting during GASS 2011 that has to be subsequently approved by the URSI Board.

## 6. Publication Matters

Papers presented during the 2010 International Commission B Symposium on Electromagnetic Theory will be published by IEEEExplore.

Upon suggestions of session chairs and conveners authors have been invited to contribute to a Special Section of Radio Science; submitted papers are presently under review.

For what concerns the tutorials for the Radio Science Bulletin, a paper on "On Body Communications" has been published in the December 2010 issue. The paper is co-

authored by Prof. Peter Hall, University of Birmingham, UK, and Prof. Yang Hao, Queen Mary University of London, UK. Several other contributions have been invited, but it seems not so easy to obtain submissions. However, three papers should be received in a short time, so that we will try to have them published in the June or September issue.

## 7. Global URSI Symposium to Complement the GASS

During a Business Meeting in Berlin members of Commission B strongly opposed the establishment of such an additional symposium; instead, Commissions should try hard to come up with similar triennial symposia as Commissions B and F.

# COMMISSION D

*This report was prepared by Professor F. Kaertner, Commission D Chair 2008-2011*

## 1. Conferences supported by Commission D

- EMC2009 VIII International Symposium and Exhibition on Electromagnetic Compatibility and Electromagnetic Ecology, St Petersburg, Russia, June 2009
- META'10, 2nd International Conference on Metamaterials, Photonic Crystals and Plasmonics, 22-25 February, 2010, Cairo, Egypt.
- ISSSE 2010, International Symposium on Signals, Systems and Electronics, 16 - 19 September, 2010, Nanjing, China.
- ICEAA10, International Conference on Electromagnetics in Advanced Applications, September 20-24, 2010, Sydney, Australia.
- AP-RASC2010 Asia-Pacific Radio Science Conference, September 22-26, 2010, Toyama, Japan.
- APMC 2010 Asia-Pacific Microwave Conference, December 7-10, 2010, Yokohama, Japan.

## 2. Program of Commission D for URSI GASS 2011 in Istanbul

### 2.1 D01: RFID Technology and Applications

Conveners: S. Tedjini, Prof Grenoble-inp/lcis, France

Even if the RFID concept was introduced many decades ago, it still very attractive and fertile in terms of R&D and new applications. Today, RFID is seen as

a very enabling technology and it is under consideration for thousands of applications covering a large variety of domains among them : ID papers, security, access control, toll road, ticketing, pharmacy, logistic, manufacturing, gambling, sensors, etc.. RFID is an enabling technology for identification by means of radiofrequency signals. RFID tags may be located on or in almost anything and RFID is used for a very wide variety of purposes in an extremely wide variety of locations. This session focus on the advances on RFID. It will cover all the aspects of RFID, from Tag technology to application like Internet Of Things

### 2.2 DB1: Modeling of High Frequency Devices and Circuits

Conveners : Peter Russer, TU Munich, Germany and Irsadi Aksun, Koç University, Turkey.

The development will be characterized by a further increase of integration density, higher frequencies, lower power consumption and enhanced functionality. Wireless technology and vehicular technology and the need for high-speed digital circuits are major drivers for the increased demand for high-frequency and optoelectronic devices. On a long-term time scale also quantum information processing will come into consideration. The main characteristics of new technologies include nanoelectronic devices with structure dimensions from below 100 nm down to atomic structures, low-cost materials, low power electronics, and fast design cycles. Circuit elements will not only be connected via traditional wiring but also will directly interact via field coupling. In the near future nanoelectronics will be dominated by CMOS technology and the trends will include mixed signal techniques, systems on a chip, and systems in package. Long term research and development will go beyond CMOS and involve novel materials as graphene,

carbon nanotubes, magnetic materials and superconductors, novel technologies as nanoimprint lithography and novel device concepts based on these materials and technologies. As the basis for the development of future high-frequency and optoelectronic nanoscale devices and circuits and systems based upon these devices advanced analytic and numerical modeling and simulation tools are required. These tools include the modeling of electromagnetic, electron transport and other phenomena in a multiphysics environment. This session reviews the latest developments in this area.

### **2.3 D03: Lasers**

Conveners: Alphan Sennaroglu, Koç University, Turkey and U. Morgner, University of Hannover, Germany

This topic includes, but is not limited to laser sources covering all wavelength ranges from THz to the x-ray region. Lasing media comprise semiconductors, solid-state materials, fibers, gases or free electrons. The generated waveform may range from continuous waves to ultrashort pulses. Also high speed modulation of lasers, novel laser structures, amplifiers, laser applications and modeling are of interest.

### **2.4 DBC: Signal Processing Antennas**

Conveners: S. Tedjini, Prof Grenoble-INP/ICIS, France and Heinz J. Chaloupka, Microwave & Antenna Engineering, Germany.

For many RF systems the antenna is the most important device and its performance will determine the overall characteristics of, for example, a wireless communication system. This session will focus on the evolution of the antenna function, which increasingly integrates electronics, sensors and signal processing. These new capabilities are transforming the original passive antenna to signal processing antenna (SPA). Signal-processing antennas combine a multiple-antenna-structure e.g. an array with signal-processing capabilities to enable adaptive and knowledge aided processing in space and time. By sensing the spatial and spectral properties of the electromagnetic environment SPAs can adaptively optimize the spatial and temporal signal processing operations in order to enhance system relevant performance metrics like the spectral efficiency in wireless communication systems and the probability of detection in radar. Furthermore, limits of adaptive SPAs can be overcome by combining prior knowledge with measured data (knowledge-aided processing).

### **2.5 DB2: Plasmonics**

Conveners : F. de Fornel and Nader Engheta

Surface plasmons are interfacial electromagnetic modes that can be exploited to control the propagation and local oscillation of electromagnetic energy. This topical conference will explore fundamental and applied plasmonic concepts, the control and manipulation of local and propagating surface plasmons, plasmon dynamics, and novel plasmonic nanostructures.

### **2.6 DT: RFID Technology and Applications**

Session Chair: Franz Kaertner

M. M. Tentzeris, et al., "Inkjet-printed paper/polymer-based RFID and wireless sensor nodes, Georgia Tech, USA.

### **2.7 DB3: Metamaterial Applications**

Conveners: C. Caloz, R. W. Ziolkowski, and N. Engheta

In the last decade, there has been a renewed interest in using fabricated structures at various length scales to develop composite materials that mimic known material responses or that qualitatively have new, physically realizable response functions that do not occur, or may not be readily available, in nature. Researchers have studied the exotic physics associated with these metamaterials and the potential use of their properties for interesting engineering applications, including lenses, cloaking, antennas, small waveguides and cavities, and other devices at microwave, millimeter-terahertz and optical frequencies. We have two sessions dedicated to this topic. This joint DB session on metamaterials, as a companion to another joint BD session, is intended to review and to present recent research advances in the applications of metamaterials.

### **2.8 D07: Micro and Nano Photonics**

Convener: M. Watts, mwatts@mit.edu

High index contrast micro- and nano-photonics devices, photonic crystals, plasmonics, electronic and photonic integration. High density integrated photonics based on group IV as well as group III-VI semiconductor materials, metals and dielectrics. Passive and active devices and a combination thereof, design tools, or micro and nano-fabrication techniques. Nonlinear effects in micro and nano devices, linear and nonlinear effects enhanced by high index contrast waveguides, photonic crystals and plasmons.

## 2.9 D08: Nonlinear Optics and Guided Wave Devices

Conveners: Omer Ilday, Bilkent University, Turkey and G. Steinmeyer, Max-Born-Institute, Germany

This topic includes, but is not limited to, nonlinear wavelength conversion, optical parametric processes, QPM components and devices; wave mixing, stimulated scattering, self- and cross-phase modulation; nonlinear propagation and instabilities, continuum generation, filamentation and optical solitons; nonlinear optics in waveguides and fibers; novel nonlinear materials and structures; nonlinearities in gain media; nonlinear effects in nanostructures and semiconductor microstructures; methods and applications of nonlinear spectroscopy; novel optical applications of nonlinear phenomena; nonlinear optics of metamaterials; nonlinear optical effects in laser damage.

## 2.10 DAF1: Enabling technologies for Millimeter and THz wave applications I

Conveners: Rene Beigang, University of Kaiserslautern, Germany, Sami N. Gopalsami, Argonne National Laboratory, US; Hakan Altan, METU, Turkey and Tadao Nagatsuma, Osaka University, Japan

The latest developments in millimeter-wave and terahertz-wave devices for signal generation, transmission and detection including photonic/electronic devices and materials, metamaterials, MEMS, transmission media, etc. will be discussed, including their implementation to measurement and sensing systems.

## 2.11 DAF2: Enabling technologies for Millimeter and THz wave applications II

Conveners: Rene Beigang, University of Kaiserslautern, Germany, Sami N. Gopalsami, Argonne National Laboratory, US, Hakan Altan, METU, Turkey and Tadao Nagatsuma, Osaka Univ., Japan

The topic includes recent progress in real-world and/or industrial applications of millimeter and THz waves in non-destructive testing, security, medicine/biology communications, spectroscopic and sensors.

## 2.12 DF: Hyperspectral Sensing and Lidar

Conveners: E. Schweicher

Hyperspectral sensors (HS) may offer significant improvement over existing sensors in detecting camouflaged and hidden targets. HS is the paradigm of all multispectral sensors, because of its high spectral (or wavelength) resolution and, thereby, with the advent of high performance staring arrays, is potentially able to defeat any CCD (Camouflage, Concealment and Deception) measure! LIDAR (also termed LADAR or Laser raDAR) is an acronym for Light Detection and Ranging. Contributions may address: humanitarian demining by HS & LIDAR, camouflage removal by HS & lidars, various corrections and thematic algorithms for HS, whiskbroom and pushbroom scanning HS, various kind of lidars: mechanical scanning, electronic scanning, coherent (laser vibrometry) and incoherent, 2-D, 3-D & n-D, sensing of atmospheric aerosols by LIDAR, air data systems (aircraft flow fields), pollution monitoring, chemical agent detection, biological (pathogen) agent detection, Differential Absorption Lidar (DIAL) as example of incoherent LIDAR, coherent processing by LIDAR: Atmospheric flow field mapping, wind sensing, ballistic wind determination; underwater detection & imagery & bathymetry; spectral signature data bases for HS, fishing zones and other sorts of monitoring (like novice, applications of HS in agriculture, geology, health, management of resources, urban zone management, soil practicability & traffic ability, coastal zone bathymetry, pollution detection, maritime applications of HS, like oil spills & discerning objects and organisms below the sea surface, military applications of HS like target identification & target mitigation.

## 2.13 AD: Low Noise Microwave Generation

Conveners: M. Tobar, University of Western Australia, Franz X. Kärtner, Massachusetts Institute of Technology, USA

Topics include, but are not limited to, low noise microwave oscillators based on electrical or dielectric resonators, optoelectronic oscillators, cryogenic technologies for low noise oscillators, optical techniques for low noise microwave generation, microwave frequency references.

## 2.14 AD: Optical Frequency Metrology

Conveners: F. Hong, AIST, Japan and T. Schibli, University of Colorado, USA

Topics include optical devices, instruments, and technologies for precision measurements of time and frequency; optical frequency standards; optical clocks; lasers, supercontinua, and broadband sources for optical metrology; frequency-comb generation, control, and

applications; conversion between optical and microwave frequencies; instrumentation and devices for optical frequency metrology, including precision interferometry and other novel measurement methods, optical transmission of metrology signals, including reference-frequency and pulsed transmission and remote measurements.

## 2.15 BD: Metamaterial Theory

Conveners: R. W. Ziolkowski, C. Caloz, and N. Engheta

In the last decade, there has been a renewed interest in using fabricated structures at various length scales to develop composite materials that mimic known material responses or that qualitatively have new, physically realizable response functions that do not occur, or may not be readily available, in nature. Researchers have studied the exotic physics associated with these metamaterials and the potential use of their properties for interesting engineering applications, including lenses, cloaking, antennas, small waveguides and cavities, and other devices at microwave, millimeter-terahertz and optical frequencies. We have two sessions dedicated to this topic. This joint BD session on

metamaterials, as a companion to another joint DB session, is intended to review and to present recent theoretical research advances in metamaterials.

## 2.16 Commission D Poster Sessions:

DP1 – Poster : RFID and Signal Processing Antennas

DP2 – Poster: High frequency Devices and Multiphysics Techniques

DP3 – Poster: Photonics

DP4 – Poster: Metamaterials and Microwave Techniques

## 3. Papers contributed to RSB by Commission D

S. Tedjini and E. Perret, “ RFID system and advances in Tag design.”

# COMMISSION E

*This report was prepared by Prof. C. Christopoulos, Commission E Chair 2008-2011*

## 1. Terms of Reference

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

- a) Terrestrial and planetary noise of natural origin, seismic associated electromagnetic fields;
- b) Man-made electromagnetic environment;
- c) The composite noise environment;
- d) The effects of noise on system performance;
- e) The effects of natural and intentional emissions on equipment performance;
- f) The scientific basis of noise and interference control, electromagnetic compatibility;
- g) Spectrum management.

## 2. Commission E Working Groups

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

## 2.1 E1: Terrestrial and Planetary Electromagnetic Noise Environment

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

This working group deals with the electromagnetic noise environment on the Earth and on other planets. The main interests and activities of E1 during the last three years is summarised as follows: (1) study of the characteristics and generation mechanisms of ionospheric/magnetospheric electromagnetic noise by means of satellite observations; (2) study of global and local lightning distributions and characteristics by means of ground- and satellite-based observations; (3) study of electromagnetic and plasma phenomena associated with earthquakes and volcano eruptions.

Especially a lot of progress has taken place in the field of lightning. Lightning is recently regarded as a new and fundamental topic in physics because it includes particle acceleration and its significant effects onto the mesosphere (transient luminous events) and ionosphere. In addition, a lot of convincing evidence has accumulated on seismo-electromagnetics effects. In particular, a statistically significant correlation between the ionospheric perturbations

as detected by sub-ionospheric VLF/LF propagation and earthquakes (large magnitude and shallow) was obtained from long-term data.

## **2.2 E2 : Intentional Electromagnetic Interference**

Co-Chairs: M. Bäckström (Sweden), and W. Radasky (U.S.A)

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

## **2.3 E3 : High Power Electromagnetics**

Co-Chairs: C.E. Baum (U.S.A) (deceased), and R.L. Gardner (U.S.A)

The subject of this working group is the physics and engineering associated with electromagnetic sources for which nonlinear effects associated with high-field regions must be avoided or included in the analysis and design. This includes (but is not limited to) EMP simulators, high-power narrowband and mesoband sources and antennas, and hyperband (impulse) sources and antennas. It also includes the environment near lightning channels and in nuclear EMP source regions. In some cases it includes the high-field regions on, or in targets.

First, it is with great regret that the Commission E community reports that the long time chairman of the High-Power Electromagnetics Working Group, Dr. Carl E. Baum passed away early this year. Those working in the field will miss his leadership and his pioneering work.

The purpose of the High-Power Electromagnetics Working Group is to encourage research in electromagnetics, which is of sufficient power to show nonlinear effects in at least part of the problem. Such problems often involve the response of air or surrounding dielectrics subject to breakdown level fields. Consequently, Maxwell's Equations are often augmented by various plasma physics equations in addition to the usual boundary value problems. Working Group efforts are informal and are often in cooperation with the Permanent NEM Committee, US National Committee Commission E and other similar organizations supporting the general subject of electromagnetic compatibility.

Much of the work associated with the EUROEM and AMEREM series of meetings was dedicated to the understanding of high-power electromagnetics and applications. During this triennium, meetings were held in Lausanne, Switzerland in 2008 and Ottawa in 2010. These meetings, along with all other NEM, AMEREM and EUROEM Meetings were held in formal cooperation with URSI.

Sessions on HPE were also organized at the URSI General Assembly in Chicago in August 2008 and at the US National Radio Science Meetings in 2009, 2010 and 2011. Contributions in the form of lightning papers and related coupling papers were given at PIERS 2009 in Hangzhou and will be given at PIERS 2011 in Marrakech.

Each of the International Conferences on Electromagnetics in Advanced Applications has had a session dedicated to the understanding of high-power electromagnetics. While these sessions were labelled “Intentional Electromagnetic Interference”, the subject matter was that of high-power electromagnetics. During this triennium, sessions were held in Turin in September 2009 and in Sydney in 2010. Finally, members of this working group have held a series of short courses on high-power electromagnetics. During the triennium a course was held in Chateau d'Oex, Switzerland in 2009. During that course, 26 new scientists were introduced to high-power electromagnetics.

## **2.4 E4 : Lightning Discharges and Related Phenomena**

Chair: Z. Kawasaki (Japan), V. A. Rakov (USA)

## **2.5 E5 : Interaction with, and Protection of, Complex Electronic Systems**

Co-Chairs: F Sabath (Germany) and J-P. Parmentier (France)

## **2.6 E6 : Spectrum Management**

Chair: T. Tjelta (Norway).

The spectrum management working group has since the last GA in 2008 organised one session on spectrum management at a conference and planned a session at the upcoming general assembly.

An URSI Comm. E spectrum management session was organised as part of the EMC Europe conference held 13-17 September 2010 in Wroclaw, Poland. The session included five presentations addressing general spectrum management in the context of market mechanisms and free utilisations, called “commons”, the recent interest in “white space” in the UHF bands, a study showing almost

negligible interference from new mobile systems in the 800 MHz bands for TV households in lower bands, an introduction to spectrum management for radio systems dealing with climate data addressing climate change issues, and radiowave propagation and utilisation of spectrum in West Africa.

The planned spectrum management session at URSI GA addresses effective utilisation of the radio spectrum. It covers presentations on sound scientific spectrum management methods such that services are available in an interference-free environment, collaboration and interoperability between various spectrum users, and more recent ideas of sharing spectrum in a dynamic manner. There will be presentations on the following themes:

- Spectrum needed to fulfil ambitions of broadband access for everyone in the world
- Modern approaches to spectrum sharing
- Broadband mobile and fixed convergence and traditional ITU-R radio regulations
- Perspectives and problems of opportunistic and dynamic spectrum management
- Conservation of spectrum for scientific services
- Overview: physical, technical/practical, economical, and regulatory approaches to spectrum management

## **2.7 E7 : Geo-Electromagnetic Disturbances and their Effects on Technological Systems**

Chair: A. Viljanen (Finland)

## **2.8 E8 : Electromagnetic Compatibility in Wire and Wireless Communication Systems**

Co-Chairs: J. Gavan (Israel), and A.Zeddani (France)

## **2.9 Commission E: Joint Working groups**

### **Inter-Commission working group on Solar Power Satellites**

Chair: H. Matsumoto (Japan)

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

### **EGH. Seismo Electromagnetics (Lithosphere-Atmosphere-Ionosphere Coupling)**

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

## **3. Commission E Related National Activities**

During the triennial period a large number of events linked to Commission E took place in many cases directly

sponsored by URSI. Listed below is a selection of national activities to show the breadth of Commission E-based events:

### **3.1 France**

For the last two three years, the scientific activities of the Commission E have been represented during the 15<sup>th</sup> international and exposition symposium on EMC which took place at Limoges (April 7-9 2010). There was an increase to the number of participants (260); 107 communications were presented during three sessions in parallel and a poster session (22 posters). This large number of articles and the growing number of PhDs underlines the importance and the interest of academic, industrial and young scientists in EMC problems. The success of this symposium was amplified by the participation of about fifteen exhibitors (private companies) which indicates strong partnerships with the EMC research teams.

Many communications addressing advanced numerical models and new characterization methods were presented on the topic of “EMC interaction on complex systems” (more than 34 papers), with a focus on cable networks and applications in aerospace and automotive systems. Numerical modeling for EMC applications represents again an important activity of the research teams. The other topics presented were measurement techniques (12 papers and 4 papers about MSRC), communication systems (4 papers), power systems (5 papers), and integrated circuits (10), protection systems (4 papers). It can be noted that the biological effects community (Commission K) shows good interaction with Commission E, in particular for the study of exposure systems (12 papers).

### **3.2 Italy**

During the past triennium, the Italian contribution to the URSI Commission E scientific activities can be summarized as follows.

The members of the Department of Electrical Engineering of La Sapienza (M. D’Amore, S. Greco, M.S. Sarto, A. Tamburrano) work on the technology of EM shields transparent at optical frequencies, on numerical modelling and on transient waveforms of electric and magnetic fields.

The Telecom Lab TILAB (M. Giunta) works on the evaluation of coupling between Power Line Communication and VDSL2 links and on VDSL2 simulation parameters. In order to ensure reliable operation in the distribution of broadband services around homes, suitable noise models were developed.

A joint activity which brings together the Department of Information Engineering of the University of Padova, the Industrial Electronic Research Centre and the National Institute of Metrology Research, is currently analyzing in depth and developing improved adapters for the accurate

calibration of LISN input impedance, and studying the uncertainty evaluation and reduction in air electrostatic discharge tests.

The main activity of the EMC Group of the Politecnico di Torino includes the creation of modelling tools and verification techniques for the Electromagnetic Compatibility of transportation systems, the modelling of cable networks and the study of parameter variability effects on the performance of electronic devices. A statistical assessment of good-but-imperfect Reverberation Chambers has also been conducted. The members of the “Department of Biomedical Engineering, Electronics and Communications” and the “Antennas and EMC Group” of the Università Politecnica delle Marche provide expertise in reverberation chambers, in particular in FDTD technique analysis, in the efficiency of cable shielding and in techniques of electronic stirring. Their contributions also include the study of the simulation of cardiac stimulators on the human body and the study of plasma columns.

The activity of the EMC Group at Politecnico di Milano is mainly focused on the characterization of interference effects in wiring structures (lines and cables), and development of innovative experimental procedures and optimized setups for EMC assessment at the unit/system level. In particular, Group activity over the past three years includes development of statistical EMC prediction models for field-to-wire coupling and crosstalk, analysis of noise effects in time-domain measurement systems, development of optimized measurement systems for EMC assessment of high-speed railway systems, and characterization of the power-line communications (PLC) channel frequency-response for different channels and different applications of the PLC technology.

An URSI Italy meeting was held in Parma in June 2009, where the activities of all Commissions were illustrated. Commission E presented an overview of the activities of various research groups and Prof. Paolo Corona of Parthenope University in Naples delivered an invited speech on “Digital telecommunications and Electromagnetic Compatibility” which focused on the need for having new procedures, parameters and evaluation methods which take into account the frequency impact of new multiple access systems.

### 3.3 Netherlands

Commission E related activities include, three annual joint conferences with NERG (Dutch Institute of Electronic and Radio Engineers), yearly joint symposium with the Belgian national URSI committee, EMC project research funded by Ministry of Economic affairs IOP-EMVT and EU FP7 (ILDAS, Marie Curie, HIRF-SE), Lightning related research funded by the Dutch Technology Foundation STW ([www.stw.nl](http://www.stw.nl)) and various activities sponsored by the Dutch EMC Foundation ([www.emc-esd.nl](http://www.emc-esd.nl)) such as knowledge market, EMC on Tour etc.

### 3.4 Portugal

Relevant activities include the 2<sup>nd</sup> Congress of the Portuguese Committee of URSI (20-21 Nov 2008) devoted to the theme of “Electromagnetic Compatibility and New Radio Communications Services” <http://www.anacom.pt/render.jsp?contentId=704949&languageId=1>;

The 3<sup>rd</sup> Congress of the Portuguese Committee of URSI (3-4 Nov 2009) with several papers presented on the topics of Commission E <http://www.anacom.pt/render.jsp?contentId=704949&languageId=1>;

The 4<sup>rd</sup> Congress of the Portuguese Committee of URSI (23-24 Sept 2010) with several papers presented on the topics of Commission E <http://www.anacom.pt/render.jsp?contentId=1048655&languageId=1>

### 3.5 South Africa

Several activities related to Commission E business are organised in collaboration with other scientific societies. In June 2009 an IEEE joint EMC chapter along with AP/MTT were started. The 2011 South African IEEE combined AP/MTT/EMC chapter conference will be held in Stellenbosch on 14 and 15 April 2011. Engineers from both the South African industry and academia in the fields of Antennas and Propagation, Microwave Theory and Techniques and Electromagnetic Compatibility will be brought together. The conference will host approximately 40 technical papers, all invited, which will cover the whole spectrum of antennas, microwave and radar engineering activity in South Africa. This includes research activities centred around the South African Square Kilometre Array (SKA) radio-astronomy project, active and passive microwave devices, computational modelling, and Electromagnetic Compatibility. The department of EE Engineering at Stellenbosch has an extensive group tackling RFI mitigation and EMC for SKA demonstrator systems.

South Africa’s TC73 has made sustained submissions to CISPR sub-committee concerning PLT systems and legislation. In expressing extreme caution, South Africa promoted the inclusion of the “in some countries” clause. South Africa’s electricity utility, ESKOM, has meanwhile been contemplating its own response to PLT and is drafting a standard, NRS 094, which is a code of practice for utilities to use in their engagement with third party PLT operators wishing to use their ‘last mile’ infrastructure. In its present final draft form it does not deal with EMC issues directly, but alerts the electricity utility to the co-existence /lack of co-existence issues that can arise. This is particularly relevant because of the evolving applications in ‘smart metering’ where many electricity utilities need to communicate with their customers’ electricity meters (e.g. through PLC over the LV networks). ESKOM has also produced the NRS083 standard which is a comprehensive code of practice for the application of EMC standards and guidelines in electricity networks – its part 2 concerns substation design and equipment installation practices.

## 3.6 Sweden

Commission E in Sweden holds two meetings per annum a total of six over the triennium. Of these, three meetings are held jointly with the IEEE EMC Chapter. The attendance at these meetings ranges between 10 and 50. The Swedish Commission E has 28 members.

Of the many publications on international conferences and in scientific journals that were published by commission members we would like to highlight one that received the “2009 Richard Schultz Transaction Paper Award” for the best paper during 2008 in the IEEE Transactions on EMC. The title of this paper is “Vulnerability of European Rail Traffic Management System to Radiated Intentional EMI”.

## 3.7 United Kingdom

### International collaboration in Radio Science

In September 2008 the UK representative for Commission E gave the invited lecture *Partial discharge: noise or signal?* at the Recife headquarters of Companhia Hidro Eletrica do Sao Francisco in Recife, Brazil. This lecture outlined the potential information available in the noisy electromagnetic environment of an electricity substation and how this information may be used for condition monitoring of power system plant. The UK Commission E member was subsequently appointed under a 12-month sabbatical arrangement to the full-time post of CAPES Visiting Professor of Radio Science at the Universidade Federal de Campina Grande (UFCG), Brazil. This international collaboration in Radio Science resulted in several further outputs and activities related to Commission C, E and F activities:

### UK Festival of Radio Science

Commission E played a full role in IET-URSI UK Festivals of Radio Science held at the University of Birmingham on 15 December 2009 and the University of Leicester on 12 January 2011. These events organised by the UK URSI panel cover all URSI commissions and are specifically designed to promote Radio Science by giving an opportunity for Research Students and early career researchers to present their work to an audience consisting of senior Radio Scientists. Commission E related work was well-represented at both events.

## 3.8 United States of America

The US National Committee (USNC) of URSI Commission E has promoted new organized and special sessions since Jan. 2009 and this resulted in increased attendance (more than double) compared to three years ago. The sessions were organized at the US National Radio

Science meeting, which occurs every year in the month of January, and at the joint IEEE International Symposium on Antennas and Propagation with USNC/URSI. In particular, in Jan. 2010 it was the turn of USNC/URSI Comm. E to organize one of the plenary talks at the National Radio Science Meeting. The title of the talk was “Computer modeling tools for EMC engineers” and the presenter was Prof. Todd Hubing of Clemson University.

The following sessions relevant to Commission E were organised: 2009 National Radio Science meeting, Boulder, Colorado, USA (High Power Electromagnetics); 2009 IEEE Intl. AP-S Symposium/USNC-URSI, Charleston, SC, USA (Electromagnetic Environments and Interference: High-Power, Transients, and Spectrum Management); 2010 National Radio Science meeting, Boulder, Colorado, USA (High-Power Electromagnetics: Environments and Sources; EM Interference: Effects and Cyber Threats); 2010 IEEE Intl. AP-S Symposium/CNC/USNC-URSI, Toronto, Ontario, Canada (Research directions for future radar systems: perspectives from the DoD R&D community; EMI modeling, interference and coupling); 2011 National Radio Science meeting, Boulder, Colorado, USA (Waveform Diversity: Multidisciplinary Approaches to Different Sensing Modalities; Radar-Communication Spectrum Issues: Management, Allocation, and Compatibility; Radio Frequency Interference Mitigation and Spectrum Usage)

## 4. Meetings

A large number of meetings took place in the review period as outlined in section III. In addition, Commission E sponsored a number of international meetings which are listed in the attached table which also indicates expenditure.

## 5. Reviews of Radio Science

The following papers were contributed to the Radio Science bulletin:

1. “EMC in Space Systems: Current Practices and Future Needs-The ESA Perspective”, A. Ciccolella, F. Marliani, Radio Science Bulletin, No 328, March 2009, pp 9-19.
2. “Man-made Noise in Our Living Environments”, F. Leferink, F. Silva, J. Catrysse, SA. Batterman, V. Beauvois, A. Roc’h, Radio Science Bulletin, , No 334, Sept. 2010, pp 49-57.

## 6. Website

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

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

## Balance sheet of Commission E

Budget 2008-2011: EUR 9,000

code	details meeting	mode	allocation in Euro
090112EK	EMC Zurich 2009 - 20th International Zurich Symposium on Electromagnetic Compatibility, Zurich, Switzerland, 12-16 January 2009	A	EUR 0
090611E	EMC Europe Workshop "Materials in EMC Applications", Athens, Greece, 11-12 June 2009	B	EUR 500
090622BCE	ISTET'09 - International Symposium on Theoretical Electrical Engineering, Luebeck, Germany, 22-24 June 2009	A	EUR 0
090720CE	EMC'09 Kyoto, 2009 International Symposium on Electromagnetic Compatibility, Kyoto, Japan, 20-24 July 2009	A	EUR 0
090912BCDEFH	ICEAA'09 - International Conference on Electromagnetics in Advanced Applications, Torino, Italy, 14-18 September 2009	A	EUR 0
100329JE	RFI 2010 - RFI Mitigation Workshop, Groningen, The Netherlands, 29-31 March 2010	A	EUR 0
100412BE	Asia Pacific EMC Symposium, Beijing, China, 12-16 April 2010	A	EUR 0
100621BEF	OCOSS 2010 - Ocean and Coastal Observation: Sensors and observing systems, numerical models and information systems, Brest, France, 21-23 June 2010	A	EUR 0
100817BCEG	Nordic Shortwave Conference HF10 and Longwave Symposium LW10, Farö (north of the island of Gotland in the Baltic), 17-19 August 2010	A	EUR 0
100920BDEFGJ	ICEAA'10 - International Conference on Electromagnetics in Advanced Applications, Sydney, Australia, 20-24 September 2010	A	EUR 0
100922ABCDEFHJK	AP-RASC'10: 3rd Asia-Pacific Radio Science Conference, 22-25 September 2010, Toyama, Japan	B	EUR 500
100913E	EMC Europe, Wroclaw, Poland, 13-17 Sept. 2010		
110912ACEFGHJK	ICEAA-APWC 2011, Torino, Italy, 12-17 September 2011	A	EUR 0
110926EB	EMC Europe 2011, York, UK, 26-30 September 2011	A	EUR 0
Total :			EUR 1,000
Balance :			EUR 8,000
Budget (fixed in Euro) :			EUR 9,000

# COMMISSION G

*This report was prepared by Dr. M.T. Rietveld, Commission G Chair 2008-2011*

## 2. Chair's Comments

### 1. In Memoriam

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

- . Helmut Kopka (Germany)
- . Jules Aarons (USA)
- . Vitold Belikovitch (Russia)
- . Ernie Smith (UK)
- . Bill Gordon (USA)
- . Ian Axford (New Zealand)
- . Henry Rishbeth (UK)
- . Paul Kintner (USA)
- . Keith Cole (Australia)
- . John Titheridge (New Zealand)
- . Bill Ellis (Australia)

### 2.1 General

I would like to thank the GA conveners and WG leaders for their help, and to thank my vice-chair John Mathews and my immediate past-chair Paul Canon for their helpful advice.

I feel that Commission G is an active commission as the reports below show, albeit with an increasing age profile.

URSI wishes to revitalize the contacts between International Telecommunications Union (ITU) and URSI and Commission G should certainly be involved here but I have not succeeded in making progress here. There will be a workshop at the 2011 GASS where URSI scientists who have experience in dealing with ITU, could brainstorm how best to organize a renewed interaction between URSI and ITU.

## 2.2 Funding

The URSI board provides to the Commission Chairs a sum of money at the start of each triennium, to be administered for the good of the community. During this triennium a sum of EUR 9000 was made available. Approximately EUR 7500 was spent in supporting various meetings, typically with 500 or 1000 Euros. The remaining EUR 1500 is being used to support scientists, from a number of countries, to attend the General Assembly – this being our flagship meeting.

In addition 3000 EUR were made available to support the attendance of students at the meeting. After consultation, the Chair is deciding how to allocate these funds, with those students who submitted to the Student Paper Competition having high priority.

## 2.3 Electronic Communication

The Commission website hosted by URSI <http://www.ursi.org/G/Homepage.htm>, is basic but hopefully sufficient – it is at least easy to maintain and keep up-to-date. My thanks go to Inge Heleu at URSI for posting updates as required.

Commission G also has an electronic mailing list, maintained by Dr Wilkinson ([ursi-commission-g@ips.gov.au](mailto:ursi-commission-g@ips.gov.au)). Any member of the community can post to this mailing list. The mailing list membership is moderated by the Commission Chair and is used fairly often but hopefully not too much so that people would start to regard it as SPAM. Currently, there are 507 addresses in the mailing list (includes some 5-10% multiple addresses for the same person), which is a welcome increase from ~410 from the report three years ago.

## 2.4 Istanbul GASS

Programme: Commission G has ~220 papers at the GA – an excellent turn out. It is slightly less than at the last GA but the largest number of any commission. One of the three general lectures is to be given by Prof. Asta Pellinen-Wannberg on “The Radio Physics of Meteors: High Resolution Radar Methods offering new Insights”, an interesting and active Commission G field. The Commission G tutorial paper is to be given by Dr Martin Füllekrug, on the subject of “Sprites and Energetic Radiation above Thunderstorms”, another rapidly developing and exciting area for our community.

Paper Submission Process: The same centralised paper submission process that was used as last time. This has worked well on the whole. The only complication from our view is that caused by the 4-page paper request, which we generally use as an extended abstract, together with a short (<100 word) summary also being required.

## 2.5 URSI Long Range Planning Committee

One of the working documents of the LRPC is a “Review of URSI’s Technical Domains, Interactions with Other Societies and Emerging Topic Areas”. The Chair, Co-Chair and National Representatives of Commission G helped in a comprehensive update of this document, with the Remote Sensing, Telecommunication and Navigation added to Propagation as our primary areas of interest. Important emerging issues remain in two categories, Applied Science and Systems, and Science. The former include radar remote sensing from space and in space, high integrity GNSS navigation systems, assimilative models of electron density and scintillation, and engineering out the affects of the ionosphere in low frequency radio astronomy. The Science topics include increased emphasis on planetary ionospheres, anthropogenic effects (ionospheric modification by HF heaters and climate change), and plasmaspheric physics and models. As usual, significant opportunities for interaction exist with Commission F, H, and J.

## 2.6 Working Groups

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

All WGs are active and recommend that they continue, with the possible exception of WG4, where the Chair thinks it is not active enough and he would like to resign.

## 3. Vice-Chairs Comments

The primary responsibility of the commission vice-chair is soliciting, and editing papers for the Radio Science Bulletin. In this triennium two papers have been published and a third is promised. This is a minimum number, averaging nearly one per year, and a greater number of papers is clearly desirable. Approximately one in three solicited authors agreed to prepare a paper so some redundancy is needed. The support of the wider community is required to suggest topics and authors to the next vice-chair. Thanks go to Dr Ross Stone (Editor) and to Dr Phil Wilkinson, (Senior Associate Editor) for the final preparation of the papers.

The papers published were: “Meteoric Ionization: The Interpretation of Radar Trail Echoes” by J. Baggaley, RSB No 329, June 2009 and “EISCAT\_3D: A Next-Generation European Radar System for Upper-Atmosphere and Geospace Research” by U.G. Wannberg et al., RSB No. 332, March 2010.

## 4. Working Groups Reports

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

### 4.1 G1: Ionosonde Network Advisory Group

Chair (2008-2010): L-A McKinnell (SA), Acting Chair (2010-2011): I.A. Galkin (USA), INAG Bulletin Editor: P. Wilkinson (Australia)

INAG has maintained a constant membership of around 280. Common media for INAG member interaction remain its Bulletin and email announcement list. During the last three years three Bulletins (INAG-69, 70 and 71) were produced, with a total of 14 articles. A new tradition for INAG, first introduced in 2008, has become its annual meetings between the URSI General Assemblies, arranged during the US National Commission URSI Conferences in Boulder, CO.

Most of the INAG activities in 2008-2011 concerned its positioning as a global observatory for real-time monitoring of the ionospheric conditions with online public access to the full resolution raw data and derived products. In the past, online access has been commonly provided to the retrospective data, with increased attention to the native-format raw ionogram archiving capabilities at WDC-A and UMLCAR. With advent of the INAG-inspired Global Ionospheric Radio Observatory (GIRO) and its agreements with 42 network sounders to release their data to GIRO within a few minutes of their measurements, a new community of now-casting instruments with publicly distributed sensor data has emerged. With a word of appreciation, INAG welcomes new real-time GIRO participants from Russia, Brazil, China, Korea, and Nigeria, as well as acknowledges long-time participants in the USA, Europe, and South Africa.

Given the real-time capability of the ionosonde network, the triennium is marked by an increased interest in the assimilative modelling and prediction using ionogram-derived data. A Forecasting Ionospheric Real-time Scintillation Tool (FIRST) has become operational at NGDC based on low-latency feeds from Jicamarca and Kwajalein ionosondes. The International Reference Ionosphere (IRI) has started a new project of building an assimilative IRI using GIRO data. The USAF Weather Agency (AFWA) has begun its network-wide NEXt IONosonde (NEXION) program to update their ionosonde instruments that contribute their real-time data to the Global Assimilative Ionospheric Measurements (GAIM) model. The NEXION program plans fielding a total of 30 new 4D ionosonde systems over the next few years. An important step forward for the ionosonde community was the acceptance of the URSI-endorsed standard data model for ionosonde data exchange,

SAO.XML (DIAS), and the upcoming Near-Earth Space Data Infrastructure for e-Science (ESPAS) program. The SAO.XML data model was fully accepted in 2008, based on the metadata model engineered for long-term electronic archival of science data.

There has been a continuing development and deployment of new generation ionosondes featuring digital transceivers. In 2011, DSTO in Australia developed a new mono/bistatic FMCW ionosonde which is joining the family of fully-digital ionosondes that also include VIPIR (2008) and Digisonde 4D (2006). With improved precision of the new generation ionosondes comes their capability to conduct synchronized oblique sounding experiments.

### 4.2 G2: Studies of the ionosphere using beacon satellites

Chair: R. Leitinger (Austria), Vice-Chairs: P. Doherty (USA), P.V.S. Rama Rao (India) and M. Hernandez-Pajares (Spain)

Studies of the Ionosphere using Beacon Satellites  
Vice-Chairs: P. Doherty (USA); P.V.S. Rama Rao (India) and Honorary Chair: R. Leitinger (Austria)

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

The Working Group was active in its traditional fields, namely compilation, exchange and dissemination of information, communication and exchange of experience with various organizations of relevance (the European COST Actions, augmentation systems for GPS based satellite navigation, international and national advisory bodies, GPS data retrieval and archiving organizations, the Institute of Navigation, IHY and IPY activities and others), providing advice on request. The work was partly carried out by correspondence, and partly through attendance at conferences and other meetings.

Among the most important activities of the BSG are the Beacon Satellite Symposia. After a forerunner organized 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. Keeping the three year rhythm the 18th meeting is planned for 2013. There are three proposed venues including the University of Bath in the UK, the University of Warmia and Mazury in Olsztyn, Poland and Boston College in the US. The chairs of the BSG are in the process of consulting with group members to decide on a final destination.

The most recent Beacon Satellite Symposium held in June 2010 at the Universitat Politècnica de Catalunya, UPC/gAGE, in Barcelona, Spain was a great success. The

local chair for this symposium was Dr. Manuel Hernandez-Pajares. The symposium was attended by over 150 scientists from more than 20 countries. There were 17 sessions covering topics that included TEC Measurements and Models, Scintillation, Space Weather Effects using Beacon Satellite Signals, Ionospheric Imaging Techniques and Results, GPS Radio Occultation Techniques and Studies, Multi-Instrument Ionospheric Techniques and New Science Initiatives with Beacon Satellites.

During the opening ceremony the participants were welcomed by Dr. Manuel Hernandez-Pajares and the BSG chairs, Patricia Doherty and Prof. P.V.S. Rama Rao. P. Doherty also extended a message from Dr. Leitinger to the group. Dr. Leitinger continues to recover from a stroke that he suffered in 2006.

The presentations were of excellent quality and they included some of the latest techniques and analysis results for beacon satellite studies. To showcase these papers, a special issue of *Radio Science* is in progress. Dr. Manuel Hernandez-Pajares and Patricia Doherty are serving as associate editors of *Radio Science* for this issue. It is expected that this issue will be released later in 2011. It is important to note that this is the first time that the Beacon Satellite Symposium papers have been showcased in a special issue of a peer reviewed journal.

The Beacon Satellite Group is grateful for the generous support from our sponsors including the Universitat Politècnica de Catalunya, the Spanish Government, Boston College, NSF and the FAA. These supporting funds made it possible to waive registration fees for students and young scientists, and to provide travel support for nearly 20 participants from developing countries.

The Working Group wishes to continue its activities as an URSI Commission G Working Group in the future and has endorsed its present leadership at the 2010 symposium. 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.

### **4.3 G3: Incoherent scatter Working Group**

Chair: I. Häggström (Sweden), Vice-Chair: M. McCready (USA)

#### **4.3.1 Introduction**

The global network of incoherent scatter radars (ISR) provides observations of fundamental properties of the atmosphere, ionosphere, and magnetosphere. Coordinating World Day (WD) experiments conducted by the ISRs and associated instrumentation is the major activity of the URSI Incoherent Scatter Working Group (ISWG). The ISWG publishes schedules of the World Days as part of the

International Geophysical Calendar. Links to the current and previous schedules may be found at <http://www.eiscat.se/Members/ingemar/skedule>.

This report will include general information about World Days, the procedure to request World Days, and descriptions of the experiments carried out since the last report and planned for the remainder of 2011.

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

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

The use of the ISRs is open to all qualified scientists, and the data are freely disseminated to a broad community of users for research and in the development and validation of models and instrumentation via prompt submission to the CEDAR, Madrigal, and/or other databases as appropriate. In view of the ongoing activities in this field, we ask URSI to keep this working group active.

#### **4.3.2 Process for Requesting World Day experiments**

Radar observing time is allocated (1) to individuals or groups through either formal or informal requests to the institutions responsible for operating the facilities, and (2) for World Day observations coordinated through a plan developed annually by the URSI Incoherent Scatter Working Group (ISWG). The high demand for ISR observations, in particular for extended and multi-radar operations, requires certain procedures to help ensure that the highest priority scientific research is addressed by the coordinated World Day schedule within the limits imposed by the costs and technical restrictions of ISR operations.

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

### 4.3.3 Observations

A description of the coordinated incoherent-scatter radar runs that were performed during the last three years are given here, with a brief description of their goals. During **2009**, the World Day observations totaled 560 hours for all the ISRs, and an additional 136 hours for the polar radars. They are listed here.

**IPY** (International Polar Year), three 32-hour runs performed by the EISCAT mainland, ESR, PFISR and Sondrestrom radars to complete the two-years of extra measurements that provided extensive coverage for the International Polar Years, March 2007 through February 2009.

ISRs needed: Polar (EISCAT Mainland, ESR, Sondrestrom, PFISR).

Contacts: A. van Eyken, J. Sojka.

**StratWarm** (Stratospheric Warming), a 10-day run during a one-month alert window to measure neutral winds and electron and ion temperatures in the lower thermosphere before and during sudden stratospheric warming, and to examine the mechanisms responsible for variations in lower thermospheric dynamics and temperatures. This run was not performed because there was not a stratospheric warming event during the one-month window.

ISRs needed: All, although the response at Arecibo and Jicamarca may be weak.

Contacts: L. Goncharenko, P. Hoffman, S. Azeem, W. Ward.

**QP TIDs** (Quasi-Periodic Medium-Scale Travelling Ionospheric Disturbances), three 40-hour runs to determine whether gravity-wave induced medium-scale travelling ionospheric disturbances consistently observed at high geomagnetic latitudes under quiet geomagnetic conditions, are related to the continuum of quasi-periodic thermospheric waves observed at both Arecibo and Millstone, and perhaps at PFISR.

ISRs needed: All except Jicamarca.

Contacts: J. Mathews, F. Djuth, D. Livneh, I. Seker, M. Sulzer, C. Tepley, S. Smith, W. Bristow, J. Foster, M. Nicolls.

**Synoptic**, a 32-hour run to provide measurements of standard ionospheric parameters.

ISRs needed: All.

Contacts: W. Swartz, J. Sojka.

**Meteors** (Global Measurements of the Meteor Input Function), one 24-hour run to study the sporadic meteor distribution throughout the hemisphere near solstice, and to add to the study of the geographical, season and diurnal behaviour.

ISRs needed: All.

Contacts: J. Plane, D. Janches.

**PMSE** (Polar Mesospheric Summer Echoes), a 40-hour measurement of this polar phenomenon.

ISRs needed: Polar (EISCAT Mainland, ESR, Sondrestrom, PFISR).

Contact: I. McCrea.

**Wind Reversal**, a 10-day run during a one-month alert window to measure the temporal development of the equinoctial wind reversal and temperature changes to help examine the factors responsible for circulation change.

ISRs needed: All.

Contacts: L. Goncharenko, P. Hoffman.

**TEC Mapping** (Total Electron Content), a six-day run of ISR/GPS coordinated observations of electron density variations to study the latitudinal variation of the ionosphere and the plasmasphere boundary layer behavior.

ISR needed: All.

Contacts: S.-R. Zhang, A. Coster.

**Solar Wind Effects** (Terrestrial effects of solar wind processes), to study the effect of equatorial solar coronal holes, fast solar streams, CMEs and solar flares. This request was combined with the TEC Mapping run.

ISR needed: All.

Contacts: A. Rouillard, C. Davis, I. Finch, I. McCrea.

During **2010**, the World Day observations totalled 653 hours and are listed here.

**StratWarm** (Stratospheric Warming), a 10-day run during a one-month alert window to measure neutral winds and electron and ion temperatures in the lower thermosphere before and during sudden stratospheric warming; to compare variations in temperature and winds to average variations observed by ISRs during the winter; to compare variations in temperatures and winds to mesospheric response as given by MF and meteor radars and lidars; to extend studies of stratospheric warming effects to the lower thermosphere and investigate possible coupling with the ionosphere; and to examine the mechanisms responsible for variations in lower thermospheric dynamics and temperatures.

ISRs needed: All, although the response at Arecibo and Jicamarca may be weak. Contacts: L. Goncharenko, P. Hoffman, S. Azeem, W. Ward.

**QP TIDs** (Quasi-Periodic Medium-Scale Travelling Ionospheric Disturbances), one two-day run to determine whether gravity-wave induced medium-scale travelling ionospheric disturbances consistently observed at high geomagnetic latitudes under quiet geomagnetic conditions are related to the continuum of quasi-periodic thermospheric waves observed at both Arecibo and Millstone, and perhaps at PFISR.

ISRs needed: All except Jicamarca.

Contacts: J. Mathews, F. Djuth, D. Livneh, I. Seker, M. Sulzer, C. Tepley, S. Smith, W. Bristow, J. Foster, M. Nicolls.

**Solar Min** (Synoptic), six 32-hour synoptic runs to capture the extended solar minimum of the current cycle.

ISRs needed: All.

Contacts: A. van Eyken, J. Sojka, I. Häggström.

**Topside**, three two-day runs to investigate the latitudinal variability of F-region topside parameters, capitalizing on new data acquisition and analysis schemes. In addition, study of the latitudinal coupling of the topside region on

closed field lines, and ion upflow in the high latitude region. ISRs needed: All.

Contacts: F. Rodrigues, M. Nicolls.

During **2011**, the World Day observations will total 515 hours and are listed here.

**Synoptic**, two three-day runs to measure basic ionospheric parameters and to capture the end of the extended solar minimum.

ISRs needed: All.

Contacts: J. Sojka, I. Häggström.

**Meteors** (Global Measurements of the Meteor Input Function), two two-day runs to study the sporadic meteor distribution throughout the hemisphere, and to study sporadic *E*-layer fluctuations not influenced by strong meteor flux variations. ISRs needed: All.

Contacts: A. Pellinen-Wannberg, C. Szasz, J. Kero, D. Meisel, I. Häggström.

**Planetary Waves**, a 10-day run to investigate planetary-scale waves in the ionosphere. This will include measurements of the neutral wind throughout the mesosphere-lower thermosphere region, the response of the *F* region to atmospheric waves, and examining the mechanisms responsible for modulating the global-scale structure of the ionosphere at low and middle latitudes.

ISRs needed: All.

Contacts: S. England, Q. Zhou, G. Liu.

## 4.4 G4: Ionospheric Research to support radio systems

Chair: M. Angling (United Kingdom); Vice-Chair: D. Knepp (USA)

URSI Commission G Working Group 4: Ionospheric Research to Support Radio Systems was formed at the Maastricht General Assembly. The intention was that the group should have wide objectives, and should seek to maintain an overview of ionospheric research related to radio systems. A website for the working group is located at: <http://www.ips.gov.au/IPSHosted/wg4/index.html>. In addition to a general information role, the group has attempted to sponsor two projects that were felt of general importance. The areas selected were data assimilation and propagation predictions for digital radio.

The data assimilation project aimed to provide a consistent set of input and test data that could be used to facilitate comparative testing between models. There has been little uptake of this idea. Indeed it has proven to be very hard to get different groups to participate in comparative testing of any sort. Some progress has been made by QinetiQ by testing against openly published data. Progress has also been made by AFRL – anonymized results will be published at IES 2011. A comparative testing collaboration has also been proposed by the IRI group, but has not proceeded.

With regards the other project, a model of ionospheric scatter has been formulated and a method developed to estimate the effect of multipath and Doppler on digital waveforms. The model is largely based in existing ITU recommendations applicable to self-interference. The model has now been included in the current version of ITU-R P.Rec533 (10/09). This has been achieved largely through the personal efforts of Les Barclay with some assistance from IPS and QinetiQ.

The group has not been as active as hoped and it is not clear that this is likely to change in the near future. This may be due to the engineering focus – in contrast to the Beacon Satellite Group or INAG.

## 4.5 GF: Middle atmosphere

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

International Schools on Atmospheric Radar (ISAR) were held in November 2008, 2009 and 2010 at the National Central University (NCU) in Chung-Li, Taiwan. One observes a continuing demand for such schools and training courses, which is proved by the generally large number of students' applications and a reported success, proved by examinations and responses of students. The National Central University has consequently again decided that the next school ISAR-NCU-2011 shall be held over ten days 14-23 November 2011. The venue will again be the National Central University in Chung-Li, Taiwan, which is also the main sponsor of this school.

These schools are aiming to graduate and PhD students, young postdoctoral research scientists and engineers having background or work in the fields of atmospheric or ionospheric science, radar and radio system development and experimental applications. In particular methods applying different ground-based lower, middle and upper atmosphere and ionosphere radar and radio methods are addressed.

All these schools ISAR-NCU were performed under the international heading of the SCOSTEP (Scientific Committee on Solar Terrestrial Physics) program CAWSES (Climate and Weather of the Sun-Earth System) and the URSI Working Group GF on Middle Atmosphere (International Union of Radio Science), co-chaired by C.H. Liu and J. Röttger.

## 4.6 GH: Active experiments in Space plasmas

Co-Chair for Commission G: K. Groves (USA), Co-Chair for Commission H: B. Thide (Sweden)

The 2008-2011 period marked a number of new results using high frequency high power radio waves to actively

perturb the natural ionosphere despite the generally low solar flux which limited the electron densities available for experimentation. Perhaps the most dramatic new results obtained during the reporting period were observed at the High-Frequency Active Auroral Research Program (HAARP) HF facility near Gakona, Alaska. For the first time artificial ionization layers have been generated by high power HF radio waves. Initially such layers were believed to be confined to magnetic zenith and vertical heating geometries. Subsequent experimentation has since established that the layers can occur over a broad range of pointing angles (up to 20° zenith angle) by HF frequencies at least as high as the 4<sup>th</sup> harmonic of the fundamental electron cyclotron frequency. The layers can now be produced reliably using frequency stepping techniques designed to match the resonant frequency as a function of altitude as the layers typically descend, sometimes by 100 km or more, from the initial HF interaction altitude. Nominally it is believed that local ionization of neutrals by accelerated electrons within the interaction region is responsible for extreme increases in electron density. The effects of reduced recombination and/or other chemical processes in the heated environment are not known. Current activities are focused on maintaining the layers in a stable configuration to extend the lifetime beyond a typical period of a few minutes. The results are consistent with numerous DMSP and GPS observations of enhanced electron density on field lines connected to the HF interaction region and more exciting work remains to be done to fully understand the phenomena.

Active investigations of ELF/VLF generation using the “polar electrojet antenna” have been conducted and much progress has been made towards understanding the nature of the source region both from ground- and space-based sensors. An exciting new development is the first demonstration of ELF signals generated by HAARP without the presence of the electrojet, via F-region heating using the so-called Ionospheric Current Drive (ICD) concept. Strong signals at frequencies between .5-50 Hz have been detected at sites near HAARP as well as far sites located at Homer and Poker Flat in the absence of electrojet currents. The implication is that HF sites far from the auroral electrojet region can possibly generate ELF radiation. In fact this has now been reported from the mid-latitude Sura Facility near Vasilsursk, Russia.

Additionally extensive new studies at HAARP utilizing the flexibility of the HF phased array antenna have generated interesting new waveforms and beam polarizations to exert more control over the nature of the HF perturbations. New stimulated electromagnetic emissions (SEE) have been identified as well, improving our understanding the HF interactions and enabling extremely accurate determination of local plasma parameters.

The EISCAT HF facility at Tromsø continues to be used extensively between 2008 and 2011 with at least 200 hours per year by groups from China, Finland, Germany, Japan, Norway, Portugal, Sweden, Russia, Ukraine, UK and USA. The facility has been upgraded with new RF

generation hardware and control software allowing for more flexible frequency and other parameter changes and better monitoring. In addition a radar receiving mode has been added using one of the three antenna arrays purely for reception. Mesospheric and magnetospheric radar experiments are being performed. The facility remains unique in having multiple co-located incoherent scatter radars as a main diagnostics.

Experiments have been performed in the following areas: Langmuir turbulence using the VHF and UHF incoherent scatter radars. Upper-hybrid phenomena like the excitation of striations (meters to tens of meter scale irregularities) were studied using coherent HF backscatter radars and the electron heating and artificial ion upwelling with incoherent scatter radar. Particularly the dependence of the various phenomena on geometry of the heating and radar beams with respect to the geomagnetic field continues to be investigated. Surprising effects were found from X-mode heating. ELF/VLF generation experiments were performed for the Demeter and other satellites. Mesospheric physics including PMSE and PMWE echoes are being studied using artificial heating of the mesospheric electrons and three different wavelength radars as diagnostics. Some experiments, particularly optical ones continued to be hampered by the effects of solar minimum, but this situation is now improving.

A number of new studies were carried out at the Sura HF Facility near Vasilsursk, Russia during the 2008-11 period. A method for controlled excitation of a magnetospheric maser through the production of artificial density ducts by high - power HF radio emission from the Earth's surface has been proposed and implemented in an in-situ experiment. Artificial density ducts allow one to affect the maser resonator system and the excitation and propagation of low-frequency electromagnetic waves in a disturbed magnetic flux tube. The characteristics of electromagnetic and plasma disturbances at outer-ionosphere altitudes were measured in situ by the DEMETER satellite as it passed through the magnetic flux tube connected to the region of intense generation of HF-induced artificial ionospheric turbulence.

In 2011 artificial ULF signals were generated by SURA facility in night time conditions without current modulation. The signals were detected at each modulation frequency from 2 to 20 Hz. Such ULF signals have been generated in separate cases when the SURA operation frequency was below and above the F-layer critical frequency.

A new method of electron density determination at E-region heights is under development at the “Sura” facility. The method is based on creating artificial periodic irregularities (API) with two spatial scales (by using two powerful radio-waves at different frequencies) and sounding the API by probe radio waves. The electron density is determined using a relation of relaxation times of the API with different scales.

During pump wave frequency sweeping near fourth and fifth harmonics of the electron cyclotron frequency  $f_{ce}$ , it was established that the different spectral features of the stimulated electromagnetic emission (SEE) are quenched near the multiple gyro resonance at the same frequency coinciding with the pump frequency at which the total SEE intensity is minimal, and, according to the model, to the double resonance (multiple gyro and double resonance) frequency. This allows one to determine magnetic field strength, plasma density and double resonance height in the ionosphere with high accuracy.

During F-region O-mode pumping facility it was found that, depending on the state of the ionosphere, either amplification or quenching of the 630 nm airglow occurred. This enabled studies to separately investigate the role of electron acceleration and ohmic electron heating effects.

The comparison of the measured SEE inverse decay times with calculated plasma wave damping rates allowed to determine characteristics of plasma waves mostly contributing to the SEE generation, such as wave numbers and the angles between the wave vectors and geomagnetic field, and the altitude region of the SEE source. It was shown that plasma (upper hybrid) waves with “moderate” wavenumbers  $\sim 0.10 - 0.15$  inverse gyro radii propagating at angles  $\sim 60-70^\circ$  to the magnetic field, most probably provide the primary contribution to the intensity of plasma waves responsible for SEE generation, at least for the pump wave near 4<sup>th</sup> gyroharmonics.

A new HF facility is under construction at the Arecibo Observatory in Puerto Rico. The transmitter building has been completed, the transmitters have been moved into it, and the antenna modeling work has been completed. This facility is designed to transmit a high-power, high-frequency wave into the Earth’s ionosphere with high reliability and safety, using surplus equipment when possible. The Arecibo 305-m dish provides the required necessary large effective aperture. A feed using dipoles and a subreflector is being constructed to illuminate the dish efficiently. The high-power transmitters and transmission lines have been obtained surplus.

Several key engineering issues had to be solved in order to design and construct this HF facility. The first problem was to find an antenna geometry to feed the 305-m dish with an efficient illumination pattern. A useful solution must allow other feeds, especially the two 430-MHz feeds used for the incoherent scatter radar, to operate simultaneously. A practical constraint is that the feed system must not load the suspended platform. Any solution must be modeled accurately to assure proper operation with a minimum of construction and test time. The design needed to use available surplus transmitters and incorporate them into the system in an economical way.

The unique design uses a Cassegrain subreflector and six pairs of crossed dipoles (three operating in each of two

frequency bands). The sub-reflector will be a light square mesh constructed from 1/16-inch stainless steel cables (with larger support cables). The sub-reflector will be supported from the three main towers, not the platform. The dipoles will be located approximately one half wave length above the 305-meter dish (and will use it as a reflecting surface) and radiate upwards to the subreflector. The subreflector will direct the RF to the main dish. The facility will operate at 5.1 and 8.175 MHz.

The facility is expected to be ready for testing and initial use by the end of 2011. Use of the facility will require a proposal to be submitted following the usual guidelines at the NAIC web site.

## 4.7 URSI/COSPAR on International Reference Ionosphere (IRI)

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

During the reporting period (2008 – 2011) annual meetings were held by the URSI/COSPAR joint working group on the International Reference Ionosphere (IRI). The working group is extremely active with regular contributions from members that assist towards the improvement of the model and general understanding of ionospheric behaviour and the applications for such a global model.

A 2-day session on the Updating of Ionospheric Models with Ground and Space Data was held by the IRI working group during the 2008 Scientific Assembly of the Committee on Space Research (COSPAR) in Montreal, Canada. The session was divided into oral and poster sessions with the oral sub-sessions being focused on ‘Updating Ionospheric Models’, ‘TEC Data and Models’, ‘F-peak Mapping’, ‘Topside Modelling’, ‘Storm Modelling’, ‘New Inputs for IRI’, and ‘Solar Cycle Effects’.

The IRI 2009 workshop was held in Kagoshima, Japan from 2 - 6 November 2009. The special emphasis of the 2009 Workshop was on (1) regional modelling of the ionosphere and (2) ionosphere/atmosphere/geosphere coupling studies for improvement of IRI. Other topics of interest for the workshop included comparisons of IRI with other models and with satellite/ground observations, proposed changes to the IRI models for improved performance and accuracy, and applications of the model in the many areas of interest. The workshop received financial support from the following sponsors: COSPAR, URSI, Kagoshima Prefecture, Kagoshima City, Hokkaido University, Japan Aerospace Exploration Agency (JAXA), Kagoshima University, National Institute of Information and Communications Technology (NICT), US Air Force Office of Scientific Research, Society for Promotion of Space Science, Hombo Shoten Company, Ltd. The workshop was a great success

with 113 participants from 20 countries including many students and several first time IRI contributors from Japan, China, Taiwan, Thailand, Malaysia, and Phillipines. The 117 presentations were grouped into one poster session and three oral sessions covering the topics “Structure and Dynamics of the Ionosphere”, “Solar and Geomagnetic Variability of the Ionosphere”, and “Ionosphere-Thermosphere Coupling”. A Final Discussion session reviewed the presented results and came up with proposals for future improvements of IRI.

A two-day session on the ‘Representation of the Auroral and Polar Ionosphere in the International Reference Ionosphere (IRI)’ was held during the 38<sup>th</sup> Scientific Assembly of the Committee on Space Research (COSPAR) in Bremen, Germany. A total of 42 presentations were given which were grouped into 5 topical areas: IRI at High Latitudes, GNSS Observations and IRI, Representation of the Topside Ionosphere in IRI, Improving the Description of Solar Forcing in IRI, and New Inputs to IRI. A hallmark of IRI sessions is the wide variety of data sources used to check and improve the model. The Bremen meeting was no exception and included presentation that were based on satellite measurements from TIMED, TOPEX, Jason, GPS, COSMIC, CHAMP, Alouette, ISIS, ACTIVE, APEX, CORONOS-I, AE-E, and OGO-5, and on ground based measurements from the global network of ionosondes, and on incoherent scatter radar observations from EISCAT, Kharkov, and Arecibo. The majority of presentations were focused on the performance of the IRI model at high latitudes and possible improvements. A new committee for the IRI working group was elected during the COSPAR session.

The 2010 version of the International Reference Ionosphere will include a number of significant improvements including new models for the electron and ion densities in the lower ionosphere, auroral boundaries varying with magnetic activity, solar cycle variations of electron temperature, and the impact of precipitating electrons on the auroral E-region densities. Progress towards this goal was discussed during the COSPAR-2008 IRI session, the 2009 IRI Workshop in Kagoshima, Japan, and the COSPAR-2010 IRI session in Bremen. A special task force activity was started in 2009 that focuses on producing a Real-Time IRI model through data assimilation and model updating. A first task meeting was held at the US Air Force Academy in Colorado Springs in April 2009. The IRI model is the widely used standard for ionospheric densities and temperatures and is now also recognized by the International Standardization Organization in its Technical Specification TS 16457. Comparison with IRI is often one of the first tasks of a satellite or rocket science team and helps to identify critical times and regions for follow-on studies and for data evaluation efforts. IRI is the benchmark against which other models are compared in community model evaluations like the recent Electrodynamics Thermosphere Ionosphere (ETI) challenge of the CEDAR community.

Papers from the 2007 IRI Workshop have been published in two issues of *Advances in Space Research*:

- . Bilitza D., Jan Laštovička, B. Reinisch, (eds.), *Ionosphere - Modelling, Forecasting, and Telecommunications I*, *Advances in Space Research*, Volume 43, Number 11, Pages 1595-1846, 2 June 2009.
- . Reinisch, B., Bilitza D., Jan Laštovička, (eds.), *Ionosphere - Modelling, Forecasting, and Telecommunications II*, *Advances in Space Research*, Volume 44, Number 6, Pages 641-774, 2 June 2009.

The papers from the Kagoshima Workshop will be published in a special issue of “Earth, Planet, Space” (EPS), and selected papers from the Bremen session will be published in *Advances in Space Research*.

The IRI working group will hold their 2011 annual workshop in Hermanus, South Africa during the period 10 – 14 October 2011. The workshop will be hosted by the South African National Space Agency (SANSA).

In view of the ongoing activities in this field we ask URSI to keep this working group active.

## 4.8 Other Working Groups

Other Working Groups in which Commission G is active are reported on the lead Commission reports. These include:

### **Inter-commission Working Group on Solar Power Satellites**

Co-Chair for Commission G: K. Schlegel (Germany)

### **EGH: Seismo Electromagnetics (Lithosphere-Atmosphere-Ionosphere Coupling)**

Co-Chair for Commission G: S. Pulinetz (Russia)

### **FG: Atmospheric Remote Sensing using Satellite Navigation Systems**

Co-Chairs for Commission G: Dr. Cathryn Mitchell (G)

### **URSI/IAGA Inter-union working group on VLF/ELF Remote Sensing of the Ionosphere and Magnetosphere (VERSIM)**

Co-Chair for URSI Commissions G and H: Janos Lichtenberger (Hungary)

## 5. Sponsored meetings

### 5.1 Mode A sponsorship

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

- . MST12 - 12th Workshop on Technical and Scientific Aspects of MST Radars, London, Ontario, Canada, 17-23 May 2009

- . EMC 2009, VIII International Symposium and Exhibition on Electromagnetic Compatibility and Electromagnetic Ecology, St Petersburg, Russia, 16-19 June 2009
- . Nordic Shortwave Conference HF 10, Longwave Symposium LW 10, Fårö, August 17-19, 2010
- . VERSIM workshop 2010, Prague, Czech Republic, 13-17 September 2010
- . 2011 Ionospheric Effects Symposium (IES2011), Alexandria, Virginia, USA, 17-19 May, 2011
- . 3rd International Colloquium on Scientific and Fundamental Aspects of the Galileo Programme, Copenhagen, 31 Aug-2 Sept 2011
- . ICEAA - APWC, Torino, Italy, 12-17 September 2011.
- . IHY-Africa/SCINDA 2009 workshop, Livingstone, Zambia, 7-12 June 2009
- . IRI2009 Workshop, Kagoshima, Japan, 2-7 November 2009.
- . Sixth European Space Weather Week, Brugge, Belgium, 16-20 November, 2009
- . 8th International Nonlinear Waves workshop, La Jolla, CA, USA 1-5 March 2010
- . SCOSTEP - STP12, Berlin, Germany, 12-16 July 2010
- . COSPAR Scientific Assembly, Bremen, 18-25 July 2010
- . Space weather, Nairobi, Kenya, 19-23 July 2010
- . ICEAA'10-International Conference on Electromagnetics in Advanced Applications, Sydney, Australia, 20-24 September 2010

## 5.2 Mode B sponsorship

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

- . 3rd VERSIMURSI-IAGA workshop, Tihany, Hungary, 15-20 September 2008
- . ISAR-NCU 2008 meeting, Chung-li, Taiwan, 6-18 October 2008
- . Asia-Pacific Radio Science Conference (AP-RASC'10), Toyama, Japan, September 22-26, 2010
- . Seventh European Space Weather Week7 (ESWW7), Brugge( Belgium), 15-19 November 2010
- . IAGA/ICMA/CAWSES - II workshop on Vertical coupling in the Atmosphere-Ionosphere System, Prague, Czech Republic, 14- 18 February 2011.
- . IconSpace2011, Malaysia, 12 to 13 July 2011.

# COMMISSION H

*This report was prepared by Professor Y. Omura, Commission H Chair 2008-2011*

## 1. In Memoriam

**Wynne Calvert** died at his home in Iowa on 10 November 2009 at the age of 72. He made pioneering contributions in the field of ionospheric and magnetospheric radio propagation, particularly in the interpretation of signals received by space-borne radio receivers and ionospheric topside sounders, and to our understanding of the generation of auroral kilometric radiation. He enjoyed lively scientific interactions at URSI General Assemblies and enthusiastically conveyed his passion for science to students in colleges and universities in the USA and Japan.

**Robert Helliwell**, emeritus professor of electrical engineering at Stanford University, died at his Palo Alto home on May 2, 2011 at the age of 90. He was one of the first to recognize and then exploit the great potential of whistler-

mode waves to remotely probe both the dense thermal component as well as the tenuous energetic component of the Earth's magnetospheric plasma. In early work he observed wave emissions triggered through non-linear interactions of energetic electrons with whistler-mode transmitter signals, and he later established a successful program of controlled wave injection experiments from Siple Station, Antarctica. With his students he led major advances in knowledge of the propagation of naturally occurring and man-made whistler mode waves, in understanding of resonant wave-particle interactions in space, and in studies of ionospheric perturbations caused by wave induced precipitation of particles from the radiation belts.

## 2. Meeting Support

During the triennium, 9000 Euro is allocated to each Commission to be spent for the support of meetings and the attendance at the GASS of tutorial lecturers or invited scientists. Commission H supported the following meetings

financially (mode B) with a contribution between EUR 500 – 1500:

- . 3rd VERSIMURSI-IAGA workshop, Tihany, Hungary, 15-20 September, 2008
- . 12th Workshop on the Physics of Dusty Plasmas, Boulder, CO, USA, 18-20 May 2009
- . IHY-Africa / SCINDA 2009 Workshop, Livingstone, Zambia, 7-12 June 2009
- . IRI 2009 Workshop, Kagoshima, Japan, 2-7 November 2009
- . 8th International Nonlinear Waves workshop, La Jolla, CA, USA, in February 2010
- . 4th VERSIMURSI-IAGA workshop, Czech Republic, 13-17 September 2010.
- . AP-RASC'10: 3rd Asia-Pacific Radio Science Conference, 22-25, September 2010, Toyama, Japan
- . ESWW7 - Seventh European Space Weather Week, Brugge, Belgium, 15-19 November 2010
- . International Symposium on Recent Observations and Simulations of the Sun-Earth System (ISROSES-II) in Borovets, Bulgaria, 12-16, September 2011

Commission H also provided support in mode A (non financial aid), which means they can use the URSI badge to help promote the meeting, for the following meetings:

- . Microwave-08, Jaipur, India, in late November 2008
- . International Workshop on Chorus Plasma Waves, La Jolla, California, USA, 8-11 or 18-20 February 2009.
- . MST12 - 12th Workshop on Technical and Scientific Aspects of MST Radars, London, Ontario, Canada, 17-23 May 2009
- . EMC 2009, VIII International Symposium and Exhibition on Electromagnetic Compatibility and Electromagnetic Ecology, St Petersburg, Russia, 16-19 June 2009
- . ISSS-9 - 9<sup>th</sup> International School for Space Simulations, Paris, France, 3-10 July 2009
- . ICEAA'09-International Conference on Electromagnetics in Advanced Applications, Torino, Italy, 14-18 September 2009
- . META'10 – 2<sup>nd</sup> International Conference on Metamaterials, Photonic crystals and Plasmonics, Cairo, Egypt, on 22-25 February 2010
- . SCOSTEP - STP12, Berlin, Germany, 12-16 July 2010
- . COSPAR Scientific Assembly, Bremen, Germany, 18-25 July 2010
- . ICEAA-APWC 2011, Torino, Italy, 12-17 September 2011

### 3. Publications

The following review and tutorial papers on various topics of Commission H have been published in the Radio Science Bulletin over the last three years.

- . H. G. James, Understanding Solar-Terrestrial Plasmas at a Distance with the Haselgrove Equations, RSB, No 327, (December, 2008), pages 17-21.
- . I. Kimura, A Review of Whistler-Mode Ray-Tracing Techniques Originated from the Work by J. Haselgrove, RSB, No 327, (December 2008), pages 22-25.
- . D. M. Walker, Ray Tracing in the Magnetosphere, RSB, No 327, (December 2008), pages 26-38.
- . R. L. Dowden et al., World-Wide Lightning Location Using VLF Propagation in the Earth-Ionosphere Waveguide, RSB, No 327, (December 2008), pages 39-53.
- . Shing F. Fung, The Virtual Wave Observatory (VWO): A Portal to Heliophysics Wave Data, RSB, No 332 (March 2010), pages 89-102
- . Robert F. Benson, Four Decades of Space-Borne Radio Sounding, RSB, No 333 (June 2010), pages 24-44
- . Gordon James, A Review of the Major Developments in Our Understanding of Electric Antennas in Space Plasmas, RSB, No 336 (March 2011), pages 75-94

The Vice Chair of Commission H, Ondrej Santolik, has been working as the associated editor of RSB, and he is expecting 6 reviews to come on the following topics.

- . Wave Distribution Functions in Magnetospheric Physics,
- . Role of ULF waves in radiation belt dynamics
- . Collisionless shocks in space plasmas
- . Spacecraft-plasma interaction in space
- . Review on active sounding
- . Wave Acceleration and Loss Processes at the Earth and Planets

### 4. Working Group Activities

#### HEJ: Supercomputing in Space Radio Science

Co-Chair for Commission H : Y. Omura (Japan) and B. Lembège (France)

URSI has been supporting a series of meetings known as the International School / Symposium for Space Simulation (ISSS) since the 1<sup>st</sup> meeting in Kyoto in 1982. During the last three years the 9<sup>th</sup> ISSS was held in Paris to train the next generation of the space scientists. The 10<sup>th</sup> ISSS is scheduled to be held in Canada in 2011.

#### URSI/IAGA: VLF/ELF remote Sensing of the Ionosphere and Magnetosphere (VERSIM)

Co-Chair for Commission H and G: J. Lichtenberger (Hungary)

The 4th workshop of the URSI/IAGA Joint Working Group on VLF/ELF Remote Sensing of the Ionosphere and Magnetosphere (VERSIM) took place in Prague, Czech

Republic, on 13-17 September 2010. The workshop was organized by the Institute of Atmospheric Physics, Prague, Czech Republic and by Charles University, Faculty of Mathematics and Physics, Prague, Czech Republic. The scientific sponsorship and financial support for this workshop has been provided by the International Association of Geomagnetism and Aeronomy (IAGA) and by the Union Radio-Scientifique Internationale (URSI). More details can be found on the workshop website (<http://www.ufa.cas.cz/versim10/>).

## 5. Long Range Planning Committee

A meeting of the Long Range Planning committee was held in Belgium in April, 2010. Commission H identified emerging scientific issues as follows.

- 1) Space Weather - impact of the Sun on the Earth's magnetic field and charged particles  
Particle acceleration, transport and loss in the radiation belts cause damage to spacecraft, interruption to satellite operations, and services, delayed satellite launches and space insurance claims amounting to hundreds of millions of \$. Also disruption to defence related security systems. Understanding the basic physics will help build models to forecast warnings, and evaluate extreme events.
- 2) Space Radiation Environment  
Electron acceleration in solar flares and interplanetary shocks, and acceleration of cosmic rays, which cause a hazard to spacecraft, astronauts and aviation, particularly aircrew and avionics in high flying aircraft on polar routes, and which may affect the atmosphere. Understanding the basic physics will help provide warning and evaluation of extreme events.
- 3) Exploration of planetary environments  
Fundamental science of wave-particle interactions at the Moon, Mars, Jupiter and other planets and other smaller bodies in the Solar System
- 4) Artificial plasma wave excitation in the magnetosphere  
Active experiments with transmitters and lab plasmas provide a basic test of fundamental science with applications to deplete radiation belt electrons to protect spacecraft on orbit from a high altitude nuclear threat.

## 6. URSI General Assembly, Istanbul, 2011

### 6.1 Scientific Sessions

Commission H has arranged

**H01** – Nonlinear Waves and Turbulence in Plasmas

**H02** – Micro/macro-scale Kinetic Processes at Boundary

Layers in Terrestrial and Planetary Environments  
**H03, H04** – Wave-particle Interactions and Their Effects on Planetary Radiation Belts  
**H09** – Laboratory Simulation of Space and Dust-related Phenomena  
**H10** – Waves as Signatures of Inflowing Plasma Interaction with Solar System Bodies  
**HG1, HG2** – Radio Sounding in Ionospheres and Magnetospheres and Associated Plasma Phenomena  
**HG3, HG4** – Active Experiments in the Ionosphere and Magnetosphere  
**H11** – Open session

Other Related Sessions:

**CHGBDJK** – Solar Power Satellites and Wireless Power Transmission

**EGH** – Terrestrial and Planetary Electromagnetics

**GHE1, GHE2** – Lightning Induced Effects in the Ionosphere and Magnetosphere

**GHE3** – Electromagnetic Effects in Lithosphere-Atmosphere-Ionosphere Coupling

**HP1, HP2** – Poster Session

### 6.2 Papers

Commission H accepted 144 papers (86 oral papers + 58 poster papers). The number of papers in each session is indicated in the parenthesis after the session name.

H01 (7), H02 (10), H03 (11), H04 (3), H09 (7), H10 (9), H11 (7), HG1 (6), HG2 (9), HG3 (11), HG4 (6), HP1 (31), HP2 (27)

### 6.3 Tutorial Lecture

Commission H tutorial lecture is given by H. G. James with a title: Major developments in our understanding of electric antennas in space plasmas.

### 6.4 Young Scientist Award

The young scientist awards were given to 8 young scientists from Commission H: Taisei MOTOMURA, Masafumi SHOJI, Brant E. CARLSON, Natalya M. SHMELEVA, Brett DELPORT, Marlie M. VAN ZYL, Nicholas L. BUNCH, Morris B. COHEN. Three of these young scientists received an additional grant from URSI to cover part of their travel.

### 6.5 Student Paper Competition

Five student papers were submitted through Commission H (three papers from the USA, one from Russia, and one from India). After the review process, one of these papers has been selected for the final round of the competition where the students from ten commissions present their work just before the GA.

## 6.6 Commission H Travel Support for Young Scientists

At the General Assembly in Chicago, the URSI Council voted for an additional per-commission support of 3000 Euro, to be spent to bring graduate students to the URSI GA 2011. Commission H supported ten students and young scientists, who applied for the Young Scientists Awards, but were not awarded in spite of good quality of their submitted papers.

## 7. Vice Chair Election

The call for nominations for new Vice Chair was sent out in early February 2011. Two excellent candidates have now been nominated and postal voting is in progress. One candidate will be elected at the first Commission H business meeting, which will be held on the first Monday evening of the GA in Istanbul.

I would like to take this opportunity to thank the Vice Chair Ondrej Santolik, for his valuable advice and support, and wish him every success in the coming triennium.

# COMMISSION J

*This report was prepared by Professor S. Ananthakrishnan, Commission J Chair 2008-2011*

## 1. Commission J Statement of Accounts

Budget: €9000 (for 2008-11 triennium)  
 €3000 (special grant for travel support to the General Assembly)  
 Expenditure: €2350 Mode B meeting support  
 €9650 travel support to General Assembly, distributed to 11 scientists.  
 Balance carried forward: € 0

## 2. Meeting Support

Three meetings were given financial support by Commission J during the triennium as below:

## 3. Publications in the Radio Science Bulletin

1. "The Square Kilometer Array (SKA) Radio Telescope: Progress and Technical Directions", Hall, P.J., Schilizzi, R.T., Dewdney, P.E.F and Lazio, T.J.W., Radio Science Bulletin, No. 326, pp 3, Sept., 2008.

## 4. URSI General Assembly, Istanbul, August 2011

### 4.1 Scientific Sessions

A full program of talks and posters has been prepared on the following topics: A total of 134 papers have been distributed amongst oral and poster sessions.

code	details meeting	mode	allocation in Euro
100317J	3rd Workshop on RFI Mitigation in Radio Astronomy, Groningen, The Netherlands, 17-19 March 2010	B	EUR 750
100922ABCDEFHJK	AP-RASC'10: 3rd Asia-Pacific Radio Science Conference, 22-25 September 2010, Toyama, Japan	B	EUR 1,000
110712CJ	IconSpace2011 'Towards Exploring The Equatorial' - 2011 International Conference on Space Science & Communication, 12-13 July 2011 Malaysia	B	EUR 600
<b>Total : EUR</b>			<b>2,350</b>

J01: Low Frequency Radio Astronomy I–(LOFAR, LWA, MWA, GMRT, any other) 7  
 J02: Low Frequency Radio Astronomy II 7  
 J03: Technology Development for the SKA Program 11  
 J04: Space and Moon Science and Technology 6  
 J05: Sun and Solar System Science 6  
 J06: Signal Processing, Calibration and Imaging in Radio Astronomy 10  
 J07: Observatory Reports 21  
 J08: Spectrum Management Issues and RFI Mitigation 7  
 JG: Ionospheric Calibration for Radio Astronomy 3  
 J10: Mm and Sub-mm Science and Technology with a Special Focus on ALMA 11  
 J11: New Observations and Results 7  
 JP: Poster sessions 38  
 JT: Tutorial J 1

While oral presentations have remained roughly the same, there is a significant drop in the poster presentations in Istanbul, as compared to Chicago 2008 GA.

Thanks are due to the Conveners for excellently organizing the sessions and thanks to Prof. Justin Jonas for his help in organizing the poster session.

Dr. Aaron Parsons will give the tutorial lecture in JT session on “Exploring the Epoch of Reionization (EoR) with Low Frequency Radio Telescopes”.

## 4.2 Medals and Awards

This year, the Grote Reber Medal is being awarded to Prof. Jocelyn Bell Burnell. Congratulations to this distinguished scientist!

## 4.3 Young Scientist Support

Following a call for proposals for travel support, eight young scientists were selected from Commission J to receive grants supporting their travel to the General Assembly.

## 5. Inter Union Committee for the Allocation of Frequencies, IUCAF (Chair: Masatoshi Ohishi)

### 5.1 Introduction

IUCAF (The Scientific Committee on Frequency Allocations for Radio Astronomy and Space Science) was formed in 1960 as the “Inter-Union Commission on Frequency Allocations for Radio Astronomy and Space Science” by its sponsoring Scientific Unions, URSI, the IAU, and COSPAR. It operates as an ICSU inter-disciplinary committee, and is a Sector Member of the International Telecommunication Union (ITU). The International

Telecommunication Union (ITU)<sup>1</sup> is an international organization under the United Nations, which establishes and maintains international rules on frequency use. Each national radio act is based on the decisions made by the ITU.

IUCAF participates directly and independently in ITU groups and studies. Its main goal is to represent the international astronomical community at the ITU, to ensure the protection of radio frequencies allocated to astronomy and passive space sciences and minimize interference to these scientific observations and measurements.

## 5.2 Membership

At the end of 2010 the membership for IUCAF was:

### URSI

S. Ananthakrishnan (Com J), India  
 S. Reising (Com F), USA  
 I. Häggström (Com G), Sweden  
 A. Tzioumis (Com J), Australia  
 W. van Driel (Com J), France

### IAU

H. Chung, Korea (Republic of)  
 H.S. Liszt (Vice Chair), USA  
 M. Ohishi (Chair), Japan  
 K.F. Tapping, Canada  
 A. Tiplady, South Africa

### COSPAR

Y. Murata, Japan

### at large:

W.A. Baan, the Netherlands  
 D.T. Emerson, USA

IUCAF also has a group of Correspondents, in order to improve its global geographic representation and for issues on spectrum regulation concerning astronomical observations in the optical and infrared domains.

## 5.3 ITU-related Meetings

During the period of August 2008 to April 2011, IUCAF participated in 18 international meetings related to many ITU working parties, space frequency coordination meetings, spectrum management, IAU GA, etc.

## 5.4 Protecting Radio Astronomy and Passive Space Sciences

At the ITU, the work in the various Working Parties of interest to IAU was focused on the relevant agenda items that were adopted in 2007 for WRC-12 of the ITU, the World Radiocommunication Conference in 2012, as well as on the creation and maintenance of various ITU-R Recommendations and ITU-R Reports.

A WRC-12 agenda item which is most relevant to radio astronomy concerns is the use of the radio spectrum between 275 and 3 000 GHz. This frequency range is used for radio astronomy observations of important spectral lines and continuum bands used in studies to understand the Universe. New receiver technology and new instruments (both ground-based and space based) being used in the 275 – 1 000 GHz region are helping to refine the results of radio astronomy observations in this spectrum range, while similar developments in the 1 000-3 000 GHz range are leading to a better understanding of specific spectral lines and atmospheric windows that are of interest to radio astronomers.

Significant infrastructure investments are being made under international collaboration for the use of these bands between 275 and 3 000 GHz. For example, the Atacama Large Millimeter/submillimeter Array (ALMA), a facility currently under construction in northern Chile, will provide new insights on the structure of the universe through observations in the 30 - 1 000 GHz range. Space-based highly sensitive telescopes observe spectral lines from a variety of molecules and atoms and continuum thermal radiation from very small particles (cosmic dust).

No frequency allocations for the use of this frequency range will be made at WRC-12, but the radio astronomy community has to identify a list of specific bands of interest. This list was established in close collaboration with the IAU Working Group on Important Spectral Lines, and a new ITU-R Recommendation RA.1860 (Preferred frequency bands for radio astronomical measurements in the range 1-3 THz) was published on February, 2010. Terrestrial use of frequencies in this range is strongly constrained by the Earth's atmosphere. This is especially true above 1 000 GHz, where atmospheric absorption at sea level sites can exceed thousands of dB per km due to the effects of water vapor and oxygen. A new Report ITU-R RA.2189, which was published in 2010, utilized these physical conditions and reports that this frequency range can be used both by the passive (receive-only) and active (transmitting) radio services with little possibility of interference.

Power Line Communications (PLC) utilizing the 2-30 MHz frequency range is a technology to send electrical signals through power lines for communication purposes. This technology enables broadband Internet access and home LAN by means of "existing" power lines. Since the power lines are designed and installed to carry current at 50/60Hz only, there has been serious concern that the electromagnetic field radiated by the power lines may cause harmful interferences to the radio communication services such as broadcasting, communication, and radio astronomy observations. In this regard radio astronomers submitted to ITU-R Working Party 1A (spectrum management) several contribution papers containing measurement results of actual harmful interference from PLC and theoretical analyses. These study results were welcomed by the ITU-R Working Party 1A, and were adopted as a part of the ITU-R Report

SM.2158 (Impact of power line telecommunication systems on radiocommunication systems operating in the LF, MF, HF and VHF bands below 80 MHz).

It should be noted that the disturbance caused by PLC systems has been an issue in Com. E of URSI.

## 5.5 The 3rd IUCAF-Summer School

The 3rd IUCAF summer school on spectrum management for radio astronomy was held between May 31st and June 4th, 2010, at the Mitaka campus of the National Astronomical Observatory of Japan (NAOJ), located about 20 km from central Tokyo.

There were 44 participants from 13 countries: Japan (21), Germany (3), UK (2), Denmark (1), the Netherlands (2), Portugal (2), USA (5), China (2), South Korea (2), Australia (2), Malaysia (1) and Nigeria (1). There were about 10 young (under 35 years old) people that were new to the spectrum management and seven regulators from Japan, China and Europe.

The summer school program covered introductions to radio astronomy and Earth observations, radio science and related technologies and procedures on how to use (allocate) frequency resources. This includes the structure and role of the International Telecommunication Union (ITU) and regional telecommunities (CEPT, CITEL, APT); the roles of science bodies to protect radio astronomy and Earth observations (IUCAF, CRAF, CORF, RAFCAP); interference mitigation techniques; and radio interference topics such as Power Line Telecommunications (PLT), RFID, Ultrawideband (UWB) devices, Software-Defined Radio (SDR), Cognitive Radio Systems (CRS), and others.

There was also a lecture on the SKA project and radio quiet zones for future radio astronomy. The summer school program and the presentation files used at the summer school are available from the IUCAF's web page at [http://www.iucaf.org/SSS2010/presentations/SS2010\\_presentations.htm](http://www.iucaf.org/SSS2010/presentations/SS2010_presentations.htm).

It should be noted that the summer school was supported financially by IUCAF, CRAF, CORF and RAFCAP.

The summer school was run in a very friendly atmosphere and excellent weather, and the participants, especially young students, actively asked questions. In the middle of the summer school, the participants enjoyed a half-day tour to the Nobeyama Radio Observatory of NAOJ, where the 45-m millimetre-wave telescope, the Nobeyama Millimeter Array, and the Nobeyama Radio Heliograph are located.

It can be concluded that the 3rd IUCAF summer school was quite successful, and that the participants were able

to learn many topics to be utilized to ensure the protection of radio astronomy and Earth observations towards better understanding of the Earth and the Universe.

## 5.6 Contact with the Sponsoring Unions and ICSU

IUCAF maintains regular contact with its supporting Scientific Unions and with ICSU. The Unions play a strong supporting role for IUCAF and the membership is greatly encouraged by their support.

Pursuing its brief, IUCAF continued its activities towards strengthening its links with other passive radio science communities, in particular in space science, and defining a concerted strategy in common spectrum management issues.

The preparation towards the next URSI General Assembly and Scientific Symposium (GASS), to be held in August 2011 in Istanbul, is ongoing, led by the Chair of URSI Commission J (radio astronomy), S. Ananthakrishnan, who is also an IUCAF member. Several session proposals were submitted, and a session on spectrum allocation and use issues (session J08) will be held during the URSI GASS. Many IUCAF members have already submitted papers to be presented at this GASS. IUCAF members also actively participated in national URSI meetings, such as AP-RASC 2010 held in Toyama, Japan and the USNC-URSI National Radio Science Meeting in Boulder, CO, USA.

IUCAF member W. van Driel has been appointed president of IAU Commission 50 (Protection of existing and potential observatory sites). Two IUCAF members, A. Tzioumis and M. Ohishi, have joined the Organising Committee of IAU Commission 50. IUCAF member, A. Tzioumis, was Chair of the Working Group on Radio Frequency Interference of IAU Division X (radio astronomy) until August 2009, and IUCAF member, W.A. Baan, has been appointed as the new chair of this Working Group. IUCAF chair, M. Ohishi, chairs the Working Group on Astrophysically Important Spectral Lines of Division X. The IUCAF chair, M. Ohishi, has also been appointed the president of IAU Commission 5 on Documentation and Astronomical Data. He is also appointed the official liaison between the IAU and the ITU.

IUCAF has been recognized in the ICSU as an international body, however, it has been categorized into "Data and Information" group, which has not been correct. The chairman contacted the ICSU several times, and is now categorized into a "Thematic Organization".

See at <http://www.icsu.org/about-icsu/structure/interdisciplinary-bodies-1>.

## 5.7 Conclusions

The WRC-12 is scheduled from January 23 to February 17, 2012 to be held in Geneva, Switzerland. Several radio astronomers are expected to participate in the WRC-12.

IUCAF interests and activities range from preserving what has been achieved through regulatory measures or mitigation techniques, to looking far into the future of high frequency use, giant radio telescope use and large-scale distributed radio telescopes.

Current priorities, which will certainly keep us busy through the next years, include the use of powerful radars and satellite down-links close in frequency to the radio astronomy bands, the coordination of the operation in shared bands of radio observatories and powerful transmissions from downward-looking satellite radars, the possible detrimental effects of ultra-wide band (UWB) transmissions at around 24/79 GHz regions and high-frequency power line communications (HF-PLC) on all passive services, the scientific use of the 275 to 3 000 GHz frequency range, and studies on the operational conditions that will allow the successful operation of future giant radio telescopes.

IUCAF is grateful for the moral and financial support that has been given for these continuing efforts by ICSU, COSPAR, the IAU, and URSI during the recent years.

IUCAF also recognizes the support given by radio astronomy observatories, universities and national funding agencies to individual members in order to participate in the work of IUCAF.

## 6. Global Very Long Baseline Interferometry Working Group (Chair: Steven Tingay)

Discussions in the early part of this triennium identified the GVWG as struggling to play a role of relevance in the modern world of global VLBI. A conclusion of this discussion was that, rather than the GVWG continue to exist but be an unused forum, the GVWG should be disbanded under both URSI and IAU umbrellas. This was a consensus view of the GVWG members. Thus, actions to disband the GVWG within URSI were initiated and the GVWG will be formally closed as an URSI Working Group at the August 2011 URSI meeting in Istanbul. The GVWG members recognized the substantial important work that the GVWG had undertaken over the years, particularly related to assisting to coordinate assets for the VSOP Space VLBI Programme.

## 7. Reports from National Committees

### 7.1 Triennial report from China (Yihua Yan)

The Five hundred meter Aperture Spherical Telescope (FAST) in 0.3-5.1GHz range, with a sky coverage of 40 degrees from the zenith, was formally approved by the National Development and Reform Commission of China in 2008. On Dec 26, 2008, a foundation laying ceremony was held on the construction site. Nanshan 25m station is contributed IVS, EVN, Russian VLBI network as a member participating regularly VLBI observations, also take part in the Chinese VLBI Network (CVN). Some observations of about 10 pulsars at S band with MARK 5B system using 40m radio telescope at Yunan Observatory have been made. Radio Science Receiver is being developed and installed in VLBI stations to track the open-loop Doppler of lunar and other planetary spacecrafts. It has been test in Chinese Lunar mission of Chang'E-1/2, etc. A Single Station-Single Frequency (SSSF) observing system was set up recently at the 25 m radio telescope in Urumqi Astronomical Observatory. The data acquisition and processing systems were developed. Some sources were observed at 18 cm during 2008 - 2009, and partly published [1, 2]. A new Single Station-Dual Frequency (SSDF) observing system has been developed and in commissioning late 2010 at the 50 m radio telescope in Miyun Observatory, which will be the only SSDF mode system for IPS working at S/X and UHF in China. A 3x3 w-band (85-115GHz) focal plane array heterodyne receiver has been built for Delinha 13.7m millimeter telescope in Qinhai China. The Fourier transform spectrometer has been developed for site testing in Dome-A Antarctica. It was installed in Dome-A in 2009 and has been successfully operated remotely for one year[3]. The Shanghai 65m radio telescope is with a shaped Cassegrain configuration, covering a wide frequency range (from 1.4 GHz to 43 GHz) with a total of 8 receivers. The primary active surface will be installed to improve the efficiency at high frequencies. It will be in full operation in 2015 with the first commissioning observations in 2012. The Chinese Spectral Radiograph (CSRH) is being built at Mingantu town in Inner Mongolia of China[4]. The project was approved to start construction in the autumn of 2008. At the end of 2010, the first phase of CSRH (CSRH-I, 0.40-2.00 GHz) finished the installation of the 40 antennae with 4.5 m. According to the schedule, the first test-observation of CSRH-I will be carried out in the summer of 2011, and CSRH-II, at frequency of 2.00 – 15.00 GHz will start to construct from the autumn of 2011 and complete in 2013. The 21 Centimeter Array (21CMA) has been formally in operation since 2007 in Xinjiang, west China and starts to collect the weak 21 cm background signals. The array consisting of 81 pods along two perpendicular arms (6km+4km) allows us to reach an angular resolution of 4 arc-min and a sensitivity of about 1 mK per day. Detection of 21 cm emission / absorption signatures of neutral hydrogen at  $z=6-50$  against cosmic

microwave background will provide a unique tool for study of formation of first stars/QSOs in the universe, for understanding of re-ionization histories and for mapping of 3D matter distribution at high red-shifts.

### 7.2 Triennial Report from France (Andre Deschamps )

The main URSI-France activity this year 2011 was the scientific Workshop “ The Next Radio Telescope Generation”. The benefits from the worldwide development of projects and from the application of the most advanced technologies are shared with all radio sciences.

The Millimeter Array located in Plateau de Bure (French Alps) is the French part of IRAM. The next generation of spectroscopy array receivers will allow the study of galactic low column density CO, and further the samples mapping of nearby galaxies in 13CO, HCN, and HCO+. The arrival of ALMA calls for a competitive equivalent on the northern hemisphere (NOEMA project). The goal is to double the number of 15 m antennas from 6 to 12, extend the baseline from 0.8 to 1.6 km and increase the IF bandwidth from 8 GHz to 32 GHz.

Located in the center of France, the Radio Telescope of Nancay is the French historical site, and one of the EMC cleanest sites in Europe. The French LOFAR station (FR606) was installed in Nancay, it has been tested and used both as a standalone instrument as well as a part of ILT. Nancay is working on a concept “LOFAR Super Station” which consists in analog phased arrays of about 20 antennas increasing the sensitivity by a factor of 10. Nancay station is concerned with SKA by developing R&D projects as SKADS and PrepSKA. Using a huge range of antennas from 200 m to single dishes, Nancay is developing a large field of radio science: cosmology, quasars, pulsars, cosmic rays, the sun, magnetic fields in the galaxy, ...

Developments at LERMA range from R&D activities in the submillimeter to Terahertz domain (SIS, HEB and Schottky) and receiver design for space projects (EJSM-JGO mission, CIDRE balloon-borne 2.7THz, EUFAR meteorological airborne instrument)

### 7.3 Triennial report from India (Ishwara Chandra)

A major focus over the last three years has been the upgrade of the GMRT. The upgraded GMRT will have an instantaneous bandwidth of 400 MHz, a substantial increase from the 32 MHz that is currently available. The feeds and front ends will also be replaced to provide near seamless coverage between 150 MHz and 1450 MHz. The servo system will be upgraded to replace the current brushed motors with brushless DC motors. Each antenna will have a 0-2GHz dual channel analog optical fiber link for direct transport of the RF signal from the antenna to the central

control building as well as gigabit ethernet connections for monitor and control. A new hybrid (FPGA, CPU/GPU) is also being developed for processing the 400 MHz bandwidth. In addition the existing GMRT ASIC based 32 MHz correlator has now been replaced by a much more flexible pure software based correlator.

The ORT is also being upgraded to substantially increase its bandwidth and field of view. Regular observations with the GMRT continue in parallel with the upgrade activities. Typically between 70- 80 proposals are received for each six month scheduling cycle, with the over subscription rate being about 2.5. A wide range of programs including solar observations, observations of extra solar planets, ISM and pulsar studies, HI observations of nearby galaxies, studies of AGN, halos and relics in galaxy clusters etc. have been carried out. Major programs during this period include observations of the Epoch of Reionization and an all sky 150 MHz survey.

The Indian Institute of Astrophysics is in the process of modifying its existing radiotelescope at the Gauribidanur radio observatory near Bangalore in India to probe the solar corona with higher angular resolution and better sensitivity. In its new configuration, the array will have a maximum baseline length of about 3 km, yielding an angular resolution of about 2 arc min at 150 MHz. This is Phase-I of the expansion programme. In Phase-II, the array length will be extended to 10 km. For comparison, the upcoming Murchinson Widefield Array (MWA) in Australia is expected to have a resolution of about 4 arc min at the same frequency. While the MWA is expected to observe over the band 80-300 MHz, the GRH observations are over 30-150 MHz. No other radio telescopes for dedicated observations of the solar corona are in operation in this low frequency range close to the limit of radio observations from the ground.

A 3m Submillimeter Telescope Prototype (3mSTeP) is being built at the Raman Research Institute. The primary goal is to demonstrate the utility of a novel optical arrangement presented in 2004 (MNRAS 354, 1189B) to realise large submillimeterwave telescopes economically. - An 8 GHz wideband hybrid FFT spectrometer is under construction for use with 3mSTeP. Sampling speed and other aspects of the system has been optimised to reduce the overall cost per GHz of spectral processing. A Thomson X-ray polarimeter has been developed for a small satellite mission has been developed at RRI. This instrument works in the 5-30 keV band and has a sensitivity to detect 3% polarisation in a 50 mCrab X-ray source in a million second exposure. A space qualified unit is under fabrication, that can be launched in about two years. About 50 hard X-ray sources like accretion powered pulsars, binary black holes etc. will be observed with this instrument. A new class of extragalactic radio sources without obvious active galactic nuclei and jets in them was formed based on low-frequency observations. Multi-frequency observations of halos and

relics in galaxy clusters were carried out to study particle acceleration in these systems with implications to cluster merger activities. RRI is a partner institution in a major effort that involves the Murchison Widefield Array (MWA), concentrating on the 80-300 MHz frequency range, under construction in the radio-quiet area of Western Australia. This project is an international collaborative effort involving the MIT Kavli Institute and the Harvard-Smithsonian Center for Astrophysics in the U.S., a group of universities and research institutions in Australia, and the Raman Research Institute in India. The activities at RRI focuses on digital receiver system, imaging the EoR signal and also transients. Design and development of an instrument to detect global signature of EoR is under development at RRI.

## 7.4 Triennial Summary for Ireland (Anthony Murphy)

A number of university groups in Ireland are pursuing both instrumental and observational research in radio astronomy. Examples include research at University College Cork focused on Very Long Baseline Interferometry studies of relativistic jets emerging from Active Galactic Nuclei, and at the Dublin Institute for Advanced Studies (DIAS) on jets and ionized winds from low mass young stars using observations with e-MERLIN in C and K band, as well as LOFAR and AMI. Radio continuum observations of small clouds and cores show anomalous cm emission, presumably due to spinning dust. DIAS is also part of a collaboration using the Mopra Telescope and NANTEN/NANTEN2 to map TeV gamma-ray sources, while observations have been carried using ATCA of disks around young stars. Instrumentation projects include Maynooth's contribution both to the optical design, analysis and calibration of the HIFI instrument for the Herschel Space Observatory as well as Bands 5 and 9 of the Atacama Large Millimeter Array. Maynooth has also been involved in a number of cosmic microwave background experiments including the ESA Planck satellite, QUaD, an experiment located at the South Pole designed specifically to image the CMB polarisation and QUBIC, a proposed bolometric interferometer instrument dedicated to specifically to B-Mode polarisation.

## 7.5 Triennial Summary for Netherlands (Arnold van Ardenne)

It was with great sadness that the Dutch National Committee had to acknowledge the withdrawal of its key member Prof. Brussaard as URSI President for personal reasons so soon after taking up this important role with great enthusiasm.

Radio astronomy's national flagship LOFAR expanded its border to become an International LOFAR Observatory while e.g. Space and SKA related activities and excellent university based radio science programs supported the interest in national radio science. The National Committee took it serious to stipulate the importance of Radio Science

to/for Society at large, e.g. by participating in a national platform on the biological effects of e.m. radiation. Nonetheless, it was noticed that the number of (technical) scientists involved in national radio science is declining partly as a result of decreasing industrial R&D most notably in telecom related activities, as well as in combination with grand societal and educational changes. As a result, some national committees are hard to populate although most notably ie. B (Fields and Waves) and J (Radio astronomy) are faring well vis a vis the national committee.

On the financial and funding side, the need arose to actively promote sponsorship to allow to maintain and expand on the Radio Science related activities e.g. through workshops. For example, the Dutch National Committee together with the Belgian National committee took it on them to continue its yearly bilateral meetings now genuinely called yearly URSI Benelux. The aim is to primarily involve (doctoral) students and postdocs.

At the same time, an involvement of other societies is sought for example the IEEE Benelux, the Dutch NERG and others. Whilst the National URSI Committee operates under the umbrella of the Royal Academy of Science, all actions involving financial and legal consequences e.g. sponsorship are channeled through the National Committees Foundation for Dutch URSI activities, an approach that so far seems to work satisfactorily potentially opening a framework for cross boundary larger radio science workshops .

## 7.6 Triennial summary from Norway (Per B. Lilje )

All Norwegian radio astronomy concerns the Cosmic Microwave Background, with ESA's Planck mission providing the main theme, but also with a participation in the ground based QUIET CMB polarization experiment in the Atacama Desert.

After the launch of Planck in May 2009, real science data have been recorded since August of that year. There was a very large effort in 2010 on applying data analysis methods previously developed in Norway to real data, and on modifying them after they had been tested on the real data. Emphasis is put on estimation of CMB power spectra and likelihoods and cosmological parameters with data that are contaminated by radiation from our own galaxy. The methods developed in Norway in recent years, based on the Gibbs sampling and internal template fitting, were successfully applied to the real Planck data. The resulting codes are now routinely used by many groups within the Planck collaboration.

The University of Oslo has the main responsibility for developing one of two independent data reduction pipelines in the QUIET experiment. In 2010, the first QUIET results were made public, and these put very strong constraints on the amplitude of primordial gravity waves.

## 7.7 Triennial summary from Russia (Igor Zinchenko)

### 1. Facilities and methods

- 1.1. The equipment complex of the Radioastron mission including the 10-m space antenna is prepared for launching. The ground station for this mission on the base of the RT-22 radio telescope is prepared.
- 1.2. The space observatory Millimetron is under development.
- 1.3. The e-VLBI technology was implemented at the "Quasar-KVO" system. A 6 station correlator ARK-6 was created for this system.
- 1.4. A calibration system for the large meter-wave radio telescope BSA was created.
- 1.5. A multi-wavelength radio heliograph consisting of 10 antennas was built on the base of the Siberian Solar Telescope. A 100 antenna system is under development.

### 2. Extragalactic studies

- 2.1. It is found that radio bursts from AGN are delayed by a few months with respect to gamma-ray bursts from these objects. This implies that gamma-rays arise in the region of particle acceleration.
- 2.2. Studies of extragalactic sources with flat spectra at the RATAN-600 radio telescope show in some cases irregular flux variations on the time scale from one to a few weeks.
- 2.3. An analysis of pulsar timing measurements from Arecibo observatory and RXTE X-ray observatory gives new constraints on the cosmological density of light cosmic strings, less than 0.1% of the critical density of the universe.

### 3. Galactic studies

- 3.1. From an analysis of VLBI maser observations in star forming regions the galactic rotation curve and parameters of the galactic spiral structure are determined. A new estimate of the Sun peculiar velocity relative LSR is obtained.
- 3.2. Variations of H<sub>2</sub>O maser spectra on the time scale of a few minutes are found.
- 3.3. Ionization of interstellar hydrogen by soft cosmic rays was found due to detection of radio recombination lines from cold clouds near SNR Cas A. The ionization rate is  $(1 \pm 0.25) \cdot 10^{-16} \text{ s}^{-1}$ .
- 3.4. From observations of the PSR 2111+47 pulsar at 112 MHz the spectrum of interstellar turbulence at small scales (100-300 km) was found. It is shown that the inner turbulence scale corresponds to the ion inertial scale.

### 4. Solar research

- 4.1. Variations of solar microwave emission with periods of ~ 10 min are found which are related to large scale kink-oscillations of the coronal magnetic loops.
- 4.2. In the solar observations at the Nobeyama radio heliograph the effect of monotonic decrease of the loop height and length in the initial phase of a burst was found. It may indicate a relationship between the pulse phase of a burst and a strong dissipation of the

electric current in the coronal magnetic loop.

- 4.3. Quasi-periodic (3-4 min) components are found in the dynamic spectra of the radio signals from space missions used to probe the solar wind at the heliocentric distances from 4 to 40 solar radii. They can be explained by magneto hydrodynamic waves from the Sun.

#### 5. Astrometry

- 5.1. In cooperation with IERS and IVS a new reference coordinate system ICRF2 is developed. According to the IAU decision it will replace the previous ICRF (International Celestial Reference Frame) system.
- 5.2. Parameters of Earth rotation are determined from two-week VLBI observations at 11 observatories including "Quasar-KVO" in the framework of the CONT08 international program.

### 7.8 Triennial Report from Sweden (Michael Lindqvist)

- The Swedish national URSI committee operates under the KVA, the national academy of science.
- Onsala Space Observatory (OSO), the Swedish National Facility for Radio Astronomy, continues to provide scientists with equipment to study the Earth and the rest of the Universe. It operate two radio telescopes in Onsala, 45 km south of Göteborg, and take part in several international projects, such as the EVN, GMVA, IVS, Herschel, LOFAR, SKA and APEX.
- OSO hosts the Nordic ALMA Regional Centre. The main mission of the Nordic ARC node, is to provide ALMA support services to astronomers in the Nordic (Denmark/Finland/Iceland/Norway/Sweden) and Baltic (Lithuania, Latvia, Estonia) countries, and in general to help and encourage the community to make the best use of ALMA.
- Chalmers/GARD/Onsala Space Observatory has developed the ALMA band 5 receivers.
- OSO has participated in the continuation of the RadioNet collaboration in the seventh EC Framework Program.
- For VLBI, OSO participated also in the EU-program EXPReS, and its follow-up NEXPReS.
- A LOFAR station will be built at OSO during 2011.

### 7.9 Triennial summary from UK ( Richard Davis )

This last year has seen the continued commissioning of e-MERLIN at Jodrell Bank Observatory (JBO). The first publication of the first science showing the double quasar gravitational lens has appeared. It shows the well known components but most interestingly there is evidence for another lens component: the straight through image seen for the first time. All colours giving 30GHz from each telescope are now in full operation. Work continues to commission the full bandwidth of 4 GHz from each telescope.

The competition for the SPO ( SKA Project Office ) has been completed for the SKA project. JBO will now be the new centre for the combined group of Manchester, Cambridge and Oxford. This will enable the e-MERLIN scientists to be brought into the SPO and the test beds of JBO to be used as precursors to the SKA.

### 8. Other

An electronic distribution list has been in use for the whole triennium as a means of communicating with the more than 400 Commission J members. The Commission J webpage on the URSI website has not been actively used, but contains a useful compendium of information on the Commission.

Commission J members under the leadership of Prof. Masatoshi Ohishi, as Chair of IUCAF, have tirelessly worked for protecting the radio astronomy frequency bands and deserve the appreciation and thanks of the entire URSI J community.

I would like to thank Prof. Steven Tingay for his work in leading the GVVWG and also for bringing it to a decisive closure.

I thank my Interim-Vice-Chair, Prof. Justin Jonas for all his help and support.

## COMMISSION K

*This report was prepared by Professor Guglielmo D'Inzeo,  
Commission K Chair 2008-2011*

### 1. Overview

In the last three years, Commission K and its members have been active in:

- a) Publishing articles in the Radio Science Bulletin,
- b) Sponsoring and funding scientific meetings,
- c) Organizing and funding a major international symposium (Bordeaux, April 2010),

- d) Preparing a white paper on Wireless Communication and Health, pending the recent evaluation of the IARC (WHO - International Agency Research on Cancer) of RF and MW fields carcinogenicity,
- e) Running two business meetings in June 2009 at BioEM2009 in Davos (CH) and June 2010 at the annual Bioelectromagnetics Society Meeting in Seul (South Korea),
- f) Developing a draft of commission strategic directions
- g) Preparing for the General Assembly and Scientific Symposium of Istanbul, Turkey, with 8 oral sessions and two poster sessions, 2 joint sessions lead by

Commission K with Commissions A and E and B and E respectively, 1 joint session lead by Commission K with commission B, for a total of 81 oral presentations and 23 poster presentations.

## 2. Contributions to the Radio Science Bulletin

### 2.1 Published Invited Contribution

- a) J. C. Lin, P. Bernardi, J.B. Andersen. 2009. "The Formation and Early Years of URSI Commission K on Electromagnetics in Biology and Medicine" *Radio Science Bulletin*. 330: 51-58
- b) G.A. Lovisolo, F. Apollonio, L. Ardoino, M. Liberti, V. Lopresto, C. Marino, A. Paffi, R. Pinto. 2009. "Specifications of in vitro Exposure Setups in the Radio-Frequency Range" *Radio Science Bulletin*. 331, 21-30

### 2.2 Radio – Frequency Radiation Safety and Health

- a) James C. Lin 2009. Radio-Frequency Radiation Safety and Health: "International Studies of Brain Tumors in Mobile-Phone Users Heads" *Radio Science Bulletin*. 328: 49-51.
- b) James C. Lin 2009. Radio-Frequency Radiation Safety and Health: "Development of Cancer in Normal Mice Exposed to Mobile-Phone Radiation" *Radio Science Bulletin*. 329: 44-46.
- c) James C. Lin 2010. Radio-Frequency Radiation Safety and Health: "Frequent Exposure to Mobile Phones Changes Cognitive Behavior in Children" *Radio Science Bulletin*. 332: 103-104.
- d) James C. Lin 2010. Radio-Frequency Radiation Safety and Health: "Mobile-Phone Popularity, Addiction, and Funding for Biological Effects Research" *Radio Science Bulletin*. 333: 51-52.
- e) James C. Lin 2010. Radio-Frequency Radiation Safety and Health: "Mobile-Phone Use and Brain-Tumor Research" *Radio Science Bulletin*. 334: 64-65.
- f) James C. Lin, 2011, Radio-Frequency Radiation Safety and Health: "ICNIRP and its Role in Setting Guidelines for Radio-Frequency Exposure - The Most Successful Application of Electromagnetics in Biology and Medicine: Magnetic Resonance Imaging" *Radio Science Bulletin*. 336: 95-100.

## 3. Sponsoring Scientific Meetings

The following scientific meetings received from Commission K. (see table 1 on page 60)

### 4. International EMF Bordeaux Event May 25-29, 2007 in Bordeaux, France

URSI International Commission K, EBEA and COST BM0704 ran a four days meeting (see [http://www.ebea.org/joint\\_meeting\\_2010.htm](http://www.ebea.org/joint_meeting_2010.htm)).

The EMF Bordeaux Event covered the following areas of EMF research:

**EBEA seasonal seminar: 26 May 2010** - "Bases for exposure limits

**COST BM0704 workshop: 27-28 May 2010** "Research strategies related to RF emerging technologies":

- Dosimetry and exposure assessment
- Risk perception and management
- Human and epidemiological research
- Experimental research: biology and mechanisms
- "Children and EMF"

**URSI Commission K mid-term meeting: 27- 29 May 2010**- "EMF Medical applications":

- New Emerging medical applications
- Interaction of THz radiation with biological systems
- Electric and magnetic stimulation of the central nervous system
- EMF cancer treatment by hyperthermia and ablation

**Joint session COST BM0704 – URSI commission K: 28 May 2010** - "MRI and occupational exposure"

More than one hundred people attended the Event. During the event several meetings were dedicated to the preparation of the Program of GASS 2011, further discussed during the Meeting of National Representatives held in Seoul, South Korea, in the following June.

## 5. White Paper on Wireless Communication and Health

Bernard Veyret is involved in managing this white paper, requested by URSI. He has the contributions by most of the authors for the different sections and a draft of the document. In order to finalize the document version, Commission K was awaiting the results of the evaluation from IARC on the carcinogenicity of RF fields which was released on 31 May. The IARC summary paper to be published in July in The Lancet. The procedure used for classification and the results will be explained and discussed in the Commission K tutorial at the GASS2011 in Istanbul.

Event Name	Site and Event Date
<b>EMC Europe 2008</b> , International Symposium on Electromagnetic Compatibility and Technical Exhibition	Hamburg, Germany, 8-12 September 2008
<b>Microwave 2008</b> , International Conference on Recent Advances in Microwave Theory and Applications	Jaipur, India, 21-24 November 2008
<b>EMC Zurich 2009</b> , 20 <sup>th</sup> International Zurich Symposium on Electromagnetic Compatibility	Zurich, Switzerland, 12-16 January 2009
<b>EMC-2009</b> , VIII International Symposium and Exhibition on Electromagnetic Compatibility and Electromagnetic Ecology	St. Petersburg, Russia, 16-19 June 2009
<b>ISTET-09</b> , International Symposium on Theoretical Electrical Engineering	Luebeck, Germany, 22-24 June 2009
<b>ICEAA 09</b> International Conference on Electromagnetics in Advanced Applications	Turin, Italy, 14-18 September 2009
<b>EMC 09</b> International Symposium on Electromagnetic Compatibility	Kyoto, Japan, 20-24 July 2009
<b>META 10</b> Second International Conference on Metamaterials, Photonic Crystals and Plasmonics	Cairo, Egypt, 22-25, February 2010
<b>AP-EMC 2010</b> Asia-Pacific EMC Symposium	Beijing, China, 12-16 April 2010
<b>EMF Bordeaux Event</b> , Common event of EBEA, URSI Commission K and COST BM0704	Bordeaux, France, 26-29 May 2010
<b>OCOSS 2010</b> , Ocean and Coastal Observation: sensors and observing systems, numerical models and information systems	Brest, France, 21-23 June 2010
<b>MSMW 2010</b> , Symposium on Physics and Engineering of Microwaves, Millimeter and Submillimeter Waves	Kharkov, Ukraine, 21-26 June 2010
<b>ICEAA 2010</b> , International Conference on Electromagnetics in Advanced Applications	Sydney, Australia, 20-24 September 2010
<b>AP-RASC – 2010</b> , Asia-Pacific Radio Science Conference	Toyama, Japan, 22-25 September 2010
<b>2010 Asia-Pacific Microwave Conference</b>	Yokohama, Japan, 7-10 December 2010
<b>EBEA2011</b> , 10th International Congress of the European Bioelectromagnetic Association	Rome, Italy, 21-24 February 2011
<b>EMC-2011</b> , 9th International Symposium on EMC and EME	Saint Petersburg, Russia, 13-16 September 2011
<b>ISAP 2011</b> , International Symposium on Antennas and Propagation	Jeju, Japan, 25-28 October 2011
<b>META'12</b> , 3rd International Conference on Metamaterials, Photonic Crystals and Plasmonics	Paris, France, 16-19 April, 2012
<b>EMC Europe 2012</b> , International Symposium on Electromagnetic Compatibility,	Rome, Italy, September 17-21, 2012
<b>ICEAA-APWC 2012</b>	Cape Town, South Africa, September 2012
<b>ISAP 2012</b> , International Symposium on Antennas and Propagation	Nagoya, Japan, October 29 - November 2, 2012

Table 1 : Scientific Meetings sponsored by Commission K

## 6. Two Meetings of National Representatives of Commission K

- June 14, 2009: A business meeting was held in Davos, Switzerland at BioEM09.
- June 26, 2010: A business meeting was held in Seoul, South Korea at the 2010 Bioelectromagnetics Meeting.

## 7. URSI Commission K Emerging Topic Areas

updated by Guglielmo d'Inzeo and Masao Taki on the basis of 2008 proposal by Frank Prato

The driving issue behind the creation of Commission K was health risk assessment mainly related to mobile

telephony. Since then, several emerging issues of heavy societal impact have been encompassed by the terms of reference for Commission K, especially in view of the still rapid development of wireless communication technologies and the emergence of the areas of “bioengineering” as a new area of emphasis at so many institutions, with new Departments of Bioengineering, Medical Imaging, Molecular Imaging and Molecular Biology being created.

Among these new applications, Commission K has identified the following as emergent:

## 7.1 Topic 1

*Emerging subject:* Biological effects of Wi-Fi  
*Why:* New wireless technology expose billions  
*Commission actions:* White paper  
*Potential interest from other Commissions:* A, B, C, E, F  
*Linkages to other Organisations:* WHO/ICNIRP/EBEA/BEMS  
*Linkages to National and International Programmes:* European cell phone studies, (Interphone, COSMOS), IEEE Society: Antennas and Propagation, Broadcast, Communications, Microwave Theory and Techniques, Product Safety, Social Implications

## 7.2 Topic 2

*Emerging subject:* Microwaves breast imaging  
*Why:* Non-ionizing method to improve much needed diagnostics  
*Commission actions:* Increase links to other commissions  
*Potential interest from other Commissions:* B, E  
*Linkages to other Organisations:* EBEA / BEMS / RSNA  
*Linkages to National and International Programmes:* Breast screening programs, National Breast Cancer Programs’, IEEE Society: Engineering in Medicine and Biology, Microwave Theory and Techniques

## 7.3 Topic 3

*Emerging subject:* Magnetic Resonance Imaging Safety  
*Why:* Sixty million patients exposed each year and 50,000 workers to static magnetic fields and Extremely Low Frequency Magnetic Fields that exceed WHO and ICNIRP limits  
*Commission actions:* Encourage research on biological effects from acute exposure in patients and chronic exposure for workers  
*Potential interest from other Commissions:* B, E  
*Linkages to other Organisations:* International Society for Magnetic Resonance in Medicine, Radiological Society of North America  
*Linkages to National and International Programmes:* National Regulatory Policies on MRI, IEEE Society: Engineering in Medicine and Biology, Magnetics

## 7.4 Topic 4

*Emerging subject:* Optical medical imaging technologies  
*Why:* Emerging technologies allow optical signal processing not possible in the past  
*Commission actions:* Identify as an important area of research  
*Potential interest from other Commissions:* B, D, E  
*Linkages to other Organisations:* Society of Molecular Imaging  
*Linkages to National and International Programmes:* IEEE Society: Engineering in Medicine and Biology, Photonics

## 7.5 Topic 5

*Emerging subject:* Photo-acoustic medical imaging technologies  
*Why:* Allows advantages of optical and ultrasound to be synergistically exploited  
*Commission actions:* Encourage research  
*Potential interest from other Commissions:* B, D, E  
*Linkages to other Organisations:* Cancer detection organizations  
*Linkages to National and International Programmes:* IEEE Society: Engineering in Medicine and Biology, Photonics

## 7.6 Topic 6

*Emerging subject:* Terahertz imaging and spectroscopy  
*Why:* New technologies allow generation of well-characterized terahertz signals  
*Commission actions:* Encourage research  
*Potential interest from other Commissions:* B, C, E  
*Linkages to other Organisations:* National Security  
*Linkages to National and International Programmes:* IEEE Society: Antennas and Propagation, Communications, Engineering in Medicine and Biology, Microwave Theory and Techniques

## 7.7 Topic 7

*Emerging subject:* Biological Effects of Extremely Low Frequency Magnetic Fields  
*Why:* Exposures increasing in intensity from diagnostic medicine (MRI), electric power generation and use, electric transport and therapeutic medical devices  
*Commission actions:* Researchers to set patient, worker and public limits of exposure  
*Potential interest from other Commissions:* B  
*Linkages to other Organisations:* National Power Utilities, Electric vehicle companies  
*Linkages to National and International Programmes:* IEEE: Engineering in Medicine and Biology, Power and Energy engineering, Product Safety Engineering, Social

Implications of Technology, Vehicular Technology

Further items will be discussed during the business meetings at GASS2011.

It is important even to stress a niche area where URSI could lead rather than follows: the proposed item is “EM field applications benefiting from a wide range of technologies and scientific understanding”.

## **8. Preparations for GASS2011, August 13-20, 2011 Istanbul, Turkey**

The preparation for the General Assembly of Istanbul (8 oral sessions and two poster sessions, 2 joint sessions lead by Commission K with Commissions A and E and B and E respectively, 1 joint session lead by Commission K with commission B, for a total of 81 oral presentations and 23 poster presentations. Apart the tutorial session

dedicated to the recent (end of May 2011) evaluation by IARC (WHO - International Agency Research on Cancer) of RF and MW fields carcinogenicity, particular attention has been dedicated to emerging biomedical applications:

- a) Interaction between EMF and Biosystems: Molecular Modelling and Ultra Short Pulses Biological Effects,
- b) Non-ionizing Electromagnetic Breast Imaging,
- c) Diagnostic Sensing
- d) Imaging and Brain Mapping
- e) Healing and Therapy
- f) To stress even the joint session with Commission B on “Uncertainty Management in Numerical Calculation and EM Field Dosimetry”

## **9. Student Support at URSI**

Commission K had \$ 5,000 € for student support and decided to use it to offset student travel costs by giving 300 € to each student.

# URSI Awards 2011

The URSI Board of Officers decided at their March 2011 meeting in Ghent to follow the recommendations of the Awards Panel and to give the 2011 Awards to the following distinguished scientists:

## The Balthasar Van der Pol Gold Medal

The Balthasar Van der Pol Gold Medal was awarded to Prof. Ehud Heyman with the citation:

*“For developing mathematical tools to analyze the generation, propagation and scattering of beam-shaped electromagnetic fields, and their engineering applications”*



## John Howard Dellinger Gold Medal

The John Howard Dellinger Gold Medal was awarded to Prof. David H. Staelin with the citation:

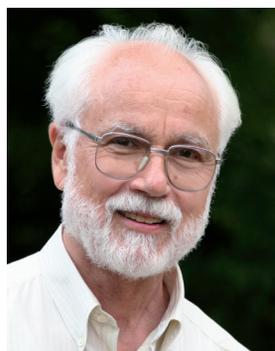
*“For seminal contributions to the passive microwave remote sensing of planetary atmospheres and the development of remote sensing of the atmosphere and environment of the Earth from space”*



## Appleton Prize

The UK Member Committee has informed the URSI Secretariat that they no longer support the Appleton Prize. It is however felt by the URSI Board of Officers that the Appleton Prize should be continued.

The URSI Board decided to award the 2011 Appleton Prize to Prof. Bodo W. Reinisch with the citation:



*For revolutionizing radio sounding from ground and space with development of the Digisonde and the IMAGE/RPI satellite instrument, both essential data providers for space weather monitoring and ionospheric modelling*

***The Awards will be presented to the Awardees during the Opening Ceremony of the XXXth General Assembly and Scientific Symposium in the Anadolu Auditorium at ICEC, Istanbul, Turkey, on 14 August 2011***

## Booker Gold Medal

The Booker Gold Medal was awarded to Prof. Ingrid C. Daubechies with the citation:



*“For her outstanding contributions to mathematics, and in particular to wavelet theory, and for the remarkable impact of her work in a wide range of applied science disciplines”*

## Koga Gold Medal

The Koga Gold Medal was awarded to Prof. Andrea Alu, with the citation:

*“For contributions to the theory and application of electromagnetic metamaterials, in particular the conception of plasmonic-based cloaking, optical nanocircuits, and anomalous propagation and radiation in metamaterials”*



### 2010 ICEAA OFFSHORE : INTERNATIONAL CONFERENCE ON ELECTROMAGNETICS IN ADVANCED APPLICATIONS

Torino, Italy, September 20 - 24, 2010

The 12th International Conference on Electromagnetics in Advanced Applications (ICEAA), co-organized by the Politecnico di Torino, Italy, and Macquarie University, Sydney, Australia, was held at the Sydney Masonic Centre on September 20-24, 2010. This conference has been held in Torino, Italy, in odd years since 1989. In 2009, the organizers decided to continue with the conference at Torino in odd years, while making it a yearly event by having it offshore at different venues around the globe in even years. Sydney was selected as the first offshore venue.

ICEAA has the IEEE Antennas and Propagation Society, the Istituto Superiore Mario Boella, and the Torino Wireless Foundation as principal co-sponsors. Other technical co-sponsors at Sydney were the IEEE Electron Devices and Microwave Theory and Techniques Societies, the IEEE Australia Section, the International Union of Radio Science (URSI), and the Australian National Committee of URSI. Roberto Graglia of the Politecnico di Torino was the Chair of the Organizing Committee, George Uslenghi of the University of Illinois at Chicago was the Chair of the Scientific Committee, and Paul Smith of Macquarie University chaired the Local Organizing Committee. Trevor Bird of CSIRO was the IEEE-APS representative, and Andrew Parfitt of the University of South Australia was the URSI representative.



Figure 2. Paul Smith at the opening ceremony.



Figure 1. A snake at the welcome reception.

The conference received over 450 submissions that were reviewed by the Scientific Committee, composed of scientists from 12 countries. The 231 accepted papers were scheduled in 31 sessions, of which 17 were specially organized sessions. In addition, there were two short courses attended by a total of 16 participants: one on “Antennas for Body-Centric Wireless Communications,” given by Koichi Ito of Chiba University; and the other on “Some Modern Applications of Beam Methods to Electromagnetic Antenna and Scattering Problems,” given by Prabhakar Pathak of the Ohio State University.

The technical sessions covered a wide variety of topics, such as EM in biomedicine, EM materials and measurements, nano-magnetics, inverse scattering and remote sensing,



Figure 3. Rodolfo Zich at the opening ceremony.



Figure 4. Bob Nevels at the opening ceremony.

EM sensing in the marine environment, EMC technology, intentional EMI, wideband and multiband antennas, wireless communications, metamaterials, high-precision optical and microwave signal generation, signal processing for advanced radar applications, geophysical EM, phased and adaptive arrays, computational EM, optoelectronics and photonics, modeling of devices and circuits, hybrid methods, radio telescope antennas, technologies for mm and sub-mm waves, miniaturized antennas, EM theory, and advances in mathematical methods. The conference was attended by 260 registered participants and several accompanying persons from 36 countries. The scientific and financial success of the conference was due in no small part to the tireless work of the local organizers: Paul Smith, Trevor Bird, Karu Esselle, Christine Hale, Stuart Hawkins, Ross Moore, and Elena Vinogradova.

A welcoming reception was held on Sunday evening, at which guests could handle local fauna, such as crocodiles and snakes (Figure 1). At the opening ceremony, several dignitaries addressed the participants, including Paul Smith, Chair of the LOC (Figure 2); Rodolfo Zich, President of both the Istituto Superiore Mario Boella and the Torino Wireless Foundation (Figure 3); and Bob Nevels, President of the Antennas and Propagation Society (Figure 4).

The Award Banquet was a wonderful gala event, held at the Sydney Masonic Centre. Participants were treated to excellent food and Australian wines, and entertained by singers from the Sydney Opera House (Figures 5 and 6). The prize for the best paper authored by a Young Scientist, consisting of a certificate and a check for 1,100 AUD, was awarded to Dr. Yi Huang of the Shanghai Jiaotong University



Figure 5. (l-r) Trevor and Adele Bird, Roberto Graglia, George Uslenghi, and Don Wilton at the banquet.



*Figure 6. A soprano from the Sydney Opera House entertained the banquet participants.*



*Figure 7. Andrew Parfitt welcomed the banquet attendees.*

for his paper “Study on Multi-Walled Carbon Nanotube Resonator.” The organizers expressed their gratitude to URSI Commission D and its Chair, Prof. Franz Kaertner, for funding this prize. A recognition consisting of a 50% discount on registration at the next ICEAA conference was awarded to Dr. M. W. Hyde of the US Air Force Institute of Technology.

A keynote address to banquet participants was given by Prof. Andrew J. Parfitt, President of the Australian National Committee of URSI (Figure 7).

A memorable event at the banquet was the signing of the Memorandum of Understanding coupling future

editions of ICEAA with the newly-created IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications (APWC) (Figure 8). The next two editions of the ICEAA-APWC dual conference are to be held in Torino, Italy, on September 12-17, 2011, and in Cape Town, South Africa, on September 2-8, 2012. The Local Organizing Committee for the Cape Town venue is chaired by Prof. David B. Davidson of Stellenbosch University.

Piergiorgio L. E. Uslenghi  
 Chair of the ICEAA Scientific Committee  
 University of Illinois at Chicago  
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*Figure 8. Bob Nevels, President of AP-S, giving the signed memo of understanding to Roberto Graglia, Chair of the ICEAA Organizing Committee.*

# URSI CONFERENCE CALENDAR

An up-to-date version of this Conference Calendar, with links to various conference web sites can be found at <http://www.ursi.org>

## July 2011

### **IconSpace 2011: International Conference on Space Science & Communication**

*Genting Highlands, Pahang, Malaysia, 12-13 July 2011*  
Contact: Dr. Wayan Suparta, Institute of Space Science (ANGKASA), Level 2, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia, E-mail: wayan@ukm.my, w\_suparta@yahoo.com, Website: <http://www.ukm.my/ispace>

## August 2011

### **XXXth URSI General Assembly and Scientific Symposium**

*Istanbul, Turkey, 13-20 August 2011*  
Contact: URSI Secretariat, c/o INTEC, Sint-Pietersnieuwstraat 41, B-9000 Gent, Belgium, Fax +32 9 264 4288, E-mail: info@ursi.org and ursigass2011@ursigass2011.org, <http://www.ursigass2011.org>

### **3rd International Colloquium on Scientific and Fundamental Aspects of the Galileo Programme**

*Copenhagen, Denmark, 31 August - 2 September 2011*  
Contact: ESA Conference Bureau, ESA-ESTEC, PO Box 299, NL-2200 AG Noordwijk, The Netherlands, Tel: +31-71-565 5005, Fax: +31-71-565 5658, <http://www.congrex.nl/11a12/>

## September 2011

### **ISROSES II - International Symposium on Recent Observations and Simulations of the Sun-Earth System**

*Borovets, Bulgaria, 11-16 September 2011*  
Contact: Mary Dugan, Los Alamos National Laboratory, Los Alamos, NM, USA, E-mail: isroses@lanl.gov

### **ICEAA-APWC 2011 - International Conference on Electromagnetics in Advanced Applications**

*Torino, Italy, 12-17 September 2011*  
cf. Announcement in the Radio Science Bulletin of September 2010, p. 77-78.  
Contact: Prof. P.L.E. Uslenghi, Dept. of ECE (MC 154), University of Illinois at Chicago, 851 S. Morgan Street, CHICAGO, IL 60607-7053, USA, Tel : +1 312 996-6059, Fax : +1 312 996 8664, E-mail : uslenghi@uic.edu, <http://www.iceaa.net>

### **EMC2011 - International Symposium on EMC and EME**

*Saint-Petersburg, Russia, 13-16 September 2011*  
cf. Announcement in the Radio Science Bulletin of March 2011, p. 106.

Contact: EMC 2011, St.Petersburg State Electrotechnical University "LETI", 5, Prof. Popov Street, St. Petersburg, 197376, Russia, Phone/Fax:+7 812 346-46-37, Website : <http://www.eltech.ru/conference/emc/2011/>

### **EMC Europe 2011**

*York, United Kingdom, 26-30 September 2011*  
Contact: Prof. A. C. MARVIN, Department of Electronics, University of York, Heslington, YORK, YO10 5DD, UNITED KINGDOM, Phone : +44 (0)1904 432342, Fax : +44 (0)1904 433224, E-mail : conference@emceurope2011.york.ac.uk, Website : <http://www.emceurope2011.york.ac.uk/>

## October 2011

### **ISAP2011 - 2011 International Symposium on Antennas and Propagation**

*Jeju, Japan, 25-28 October 2011*  
cf. Announcement in the Radio Science Bulletin of June 2010, p. 53-54.

Contact: 5F Daehan Bldg., #1018 Dunsan-Dong, Seo-Gu, Daejeon 302-120, Korea, Tel: +82-42-472-7463, Fax: +82-42-472-7459, isap@isap2011.org, <http://www.isap2011.org>

## April 2012

### **META'12 - 3rd International Conference on Metamaterials, Photonic Crystals and Plasmonics**

*Paris, France, 19-22 April 2012*  
Contact : Said Zouhdi, META'12 General Chair, Paris-Sud University, France, Tel : + 33 1 69 85 16 60, Fax: +82 42 472 7459, E-mail: said.zouhdi@supelec.fr, Website : <http://metaconferences.org/ocs/index.php/META/META12>

## July 2012

### **EUROEM 2012**

*Toulouse, France, 2-6 July 2012*  
Contact: Dr. Jean-Philippe Parmantier, ONERA, DEMR/CEM, BP 74025, Avenue Edouard Belin, 31055 TOULOUSE Cedex 4, FRANCE, Fax : +33 5 62 25 25 77, <http://www.euroem.org/>

### **COSPAR 2012 - 39th Scientific Assembly of the Committee on Space Research (COSPAR) and Associated Events**

*Mysore, India, 14 - 22 July 2012*

cf. Announcement in the Radio Science Bulletin of September 2010, p. 78-79.

Contact: COSPAR Secretariat, c/o CNES, 2 place Maurice Quentin, 75039 Paris Cedex 01, France, Fax: +33 1 44 76 74 37, E-mail : [cospar@cosparhq.cnes.fr](mailto:cospar@cosparhq.cnes.fr), Website : <http://www.cospar-assembly.org/>

## September 2012

### ICEAA 2012

*Cape Town, 2-8 September 2012*

Contact: Roberto D. Graglia, Corso Duca degli Abruzzi 24, Dip. Elettronica, Politecnico di Torino, Torino 10129, Italy, +39 0115644056, +39 0115644056, +39 0115644099 (fax), Website : <http://www.iceaa.net/>

### EMC Europe 2012 - 2012 Interantional Symposium on Electromagnetical Compatibility

*Rome, Italy, 17-21 September 2012*

Contact : Marcelo D'Amore, Department of Electrical Engineering, Sapienza University of Rome, Via Eudossiana 18, I-00184 Rome, Italy, E-mail : [marcello.damore@uniroma1.it](mailto:marcello.damore@uniroma1.it), Website : <http://www.emceurope2012.it>

## October 2012

### ISAP 2012

*Nagoya, Japan, 29 October - 2 November 2012*

Contact: Professor Koichi Ito, General Chair of ISAP2012, Chiba University, 1-33 Yayoi-cho, Inage-ku, Chiba-shi, Chiba 263-8522, Japan, Fax: +81-43-290-3327, E-mail : <http://www.isap12.org>

# News from the URSI Community



## NEWS FROM A MEMBER COMMITTEE

### RUSSIA

### MIGULIN VLADIMIR VASILIEVICH

Vladimir Vasilievich Migulin, Academician of the Russian Academy of Sciences, professor, laureate of many state awards, is the outstanding Soviet and Russian Scientist, educator, organizer of scientific research and simply a very good and benevolent Man.

Vladimir Vasilievich Migulin was born on July 10, 1911 in the settlement of Sereda (presently Furmanov) of the Ivanovo Region. After finishing school and Physics-Mechanical Department of the Leningrad Polytechnic (1932) he started working at Leningrad Electrophysical Institute in the Nonlinear System Laboratory headed by professor N.D. Papalexey. He conducted research of parametric excitation of oscillations and parametric regeneration that made the basis of the theory and design of modern parametric amplifiers and converters.

V.V. Migulin conducted the whole cycle of pioneer research in radio interferometry. He managed to identify the phase structure and propagation velocity of radiowaves over the Earth's surface. The results of these researches were used in development of radionavigation, radiogeodesy systems and in other fields of practical application of radio interferometry methods. During the war Vladimir Vasilievich was called to the Army and served there till the end of the war. In 1945 V.V. Migulin was awarded the Order of Red Star and in 1946 – the USSR State Prize.

In 1946 Vladimir Vasilievich defended his doctoral thesis on the theme "Interference of Radiowaves". He acquired the status of professor and became the Head of the Radiolocation Chair in the Lomonosov Moscow State University. Working at this chair Vladimir Vasilievich developed and lectured some new special courses "Fundamentals of Radiolocation", "Self-Oscillation and Parametric Systems", "Interference Methods of Radiowave Propagation Study".

In 1951 V.V. Migulin was appointed Director of



the Sukhumi Physics Engineering Institute. The results of his work in this institute were praised high and in 1953 he was awarded the second State Prize. His extensive knowledge, high responsibility, adherence to principles, responsiveness and brilliant organizing abilities were well known to the Soviet and foreign scientists. More than once V.V. Migulin went to Switzerland, Austria and Germany to participate in scientific conferences. From 1957 to 1959 Vladimir Vasilievich was Deputy Director General of International Atomic Energy Agency (IAEA) (Vienna, Austria).

In the period from 1969 to the end of 1996 V.V. Migulin headed the National Committee of the Union Radio-Scientifique International (URSI). And in 1972-1978 he was Vice-President of URSI. Thanks to his energetic and skillful management this period in the work of the URSI National Committee was very fruitful. The delegations of the Russian scientists were active participants of all URSI General Assemblies, numerous conferences, symposia, meetings devoted to discussion of the most burning issues in radiophysics, radio engineering, electronics and informatics that were held in many world countries, including the USSR.

In 1969 Vladimir Vasilievich Migulin became Director of the Institute of the Earth's Magnetism, Ionosphere and Radiowave Propagation of the Russian Academy of Sciences (IZMIRAN) where he worked for more than two decades. In those years IZMIRAN became the leading research organization in the country in studies of ionosphere and magnetosphere. In 1970 Vladimir Vasilievich was elected Corresponding Member of USSR Academy of Sciences. It was in IZMIRAN that the talent of V.V. Migulin as the serious Scientist and organizer of researchers combining the fundamental and experimental investigations in resolving practical tasks was shown the best. In 1971 V.V. Migulin was awarded the Order "Badge of Honor". IZMIRAN



conducted systemic research of radiowave propagation in the ionosphere and processes of natural and induced disturbances in the ionosphere. This institute is the main participant of experiment “Zarnitsa” and the Soviet-French experiment “Araks” on injection of electron beams into the ionosphere and magnetosphere of the Earth.

V.V. Migulin was the scientific leader of the program on development of the man-made Earth’s satellite “Intercosmos-19” launched in 1979. Scientific experiments conducted with the help of this satellite permitted to discover some new phenomena. Data received from this satellite were used in some pioneer works in new research areas – associating the electromagnetic processes in the near-Earth space with the solar activity. The response of the ionosphere to the processes going on in the Earth’s lithosphere was detected. These studies allowed for preparation of space experiments targeted to forecast of disastrous earthquakes with the help of IZS. The feeling of new, perspective in the science and broad scientific interests inherent in V.V. Migulin gave impetus to researches in various areas. New data were received on the global distribution of electron concentration in the ionosphere, its variations in time and some other interesting and important regularities. Vladimir Vasilievich headed the works on study of the effect

of natural and artificial disturbances in the ionosphere on the radiosystem operation using long-range ionosphere propagation of short waves. He represented the Academy of Sciences in the commission on unidentified flying objects. IZMIRAN under direct guidance and with participation of V.V. Migulin developed the new direction in physics – solar-Earth physics. Later he became the chair of the Council on the solar-Earth links. His active research activities Vladimir Vasilievich always combined with training of qualified specialists in radiophysics of broad competence, candidates and doctors of sciences who are working successfully in the institutes of the Academy of Sciences and other research institutions of our country, CIS countries and far foreign countries. Using the lectures delivered at the Moscow State University he wrote textbooks and education aids that are very popular in the world.

V.V. Migulin was the Chairman of the Soviet Commission on International Project “International Research of the Magnetosphere”. For a long time he headed the Scientific Council on radiowave propagation. In the period from 1972 to 2001 V.V. Migulin worked in the Presidium of the USSR Academy of Sciences (later RAS), was the deputy of academic secretary of the Division on General Physics and Astronomy – supervised works in radiophysics, radio engineering and geophysics and was also responsible for international relations. In 1992 he was elected the Fellow of the Russian Academy of Sciences. In 1989 V.V. Migulin left the post of IZMIRAN Director and became the Advisor at the Institute Directorate. The untiring and fruitful scientific, pedagogical, research, organizational and public activities of V.V. Migulin were marked by government awards: two Orders of Lenin, Order of October Revolution, Order of Labor Red Banner, Order of Red Star, “Badge of Honor”, “For Merits before Motherland”, many medals, including the medals of the participant of the Great Patriotic War.

V.V. Migulin died on September 22, 2002.

Leading Research Worker of IZMIRAN  
Doctor of Physics & Mathematics,  
Official Member of URSI  
V.I. Larkina

## Electromagnetic Compatibility Engineering

edited by Henry W. Ott, New York, John Wiley & Sons, August 2009, Hardcover, ISBN: 978-0-470-18930-6,  
872 pp., USD 127.00

This is an outstanding book. At 872 pages thick, it is a valuable follow-up to Ott's earlier books, *Noise Reduction Techniques in Electronic Systems* (first edition, 1975; second edition, 1987).

Part 1 of the current book, "EMC Theory" (10 chapters, 422 pages) follows to some extent the earlier books. However, there are important differences: many pages are devoted to the present EMC (electromagnetic compatibility) regulations and requirements. The chapters on cables, grounding, and shielding have been substantially expanded.

Part 2, "EMC Applications" (Chapters 11 thru 18, 308 pages) presents a lot of new material on the design of modern printed-circuit boards. Included are power distribution and problems specific to digital circuits. In modern digital systems, more functions are combined in smaller sizes. Both radiation and conducted emission are discussed, as well as the reverse aspect, the immunity of electronic systems exposed to outside disturbances.

The layout of printed-circuit boards is discussed in detail. The ground plane carries return currents in such a manner that magnetic fluxes are minimized, which reduces inductance and interference. Recommendations on the design of multilayer boards with a number of signal layers and ground planes are given (Chapter 16).

In designing the layout of mixed-signal printed-circuit boards (combining analog and digital circuits, as in A/D and D/A converters), all return currents – analog and digital – should flow in the ground plane (Chapter 17). Should that ground plane have a split? A split may, however, introduce additional problems.

Chapter 18, on "Precompliance EMC Measurements," follows. There is an interesting quote on p. 693: "Of all the various types of EMC measurements possible, the common-mode current measurement is the most useful and will provide the biggest payback in terms of dollars saved....learn to do it, and do it often."

Seven appendices (A thru F, 91 pages) follow. All are interesting and instructive. Appendix B, on p. 740, has an unexpected title: "The Ten Best Ways to Maximize the Emission from Your Product." It turns out to be a funny and also a quite informative section.

I admire Ott's open attitude about EMC, expressed in various ways. A few examples are the following:

- pp. 36-37, Section 1.15, in which network theory is compared to Maxwell's equations
- p. 106: "The search for a 'good ground' is very similar to the search for the Holy Grail."
- p. 120: Both the voltage definition and the current definition of ground are given.
- p. 144: "All ground loops are not bad, and a designer should not get paranoid about the presence of a ground loop. Most ground loops are benign."
- p. 243: "Shielding effectiveness can be analyzed in many different ways. One approach is to use circuit theory...." Comment by the reviewer: it is unfortunate that Kaden's book, *Wirbelströme und Schirmung in der Nachrichtentechnik (Eddy Currents and Shielding in Radio Engineering)* has never been translated into English.
- p. 288: "...the ideal shield, a paint can." Comment by the reviewer: In high-voltage labs, I have seen oil drums being used to shield measuring equipment.

On the subject of partial inductances, Appendix E, I would like to suggest an alternative description, based on Faraday's law. To analyze an electrical system, we use models; preferably, the simplest model useful for the problem on which we are working. Within that model, the "equivalent circuit diagram" is usually the starting point.

Sometimes we just want to know  $V$  and  $I$  at the output terminals, as a function of  $V$  and  $I$  at the input. Several equivalent circuit diagrams can be used for this purpose. However, if we want to study processes inside the real system, the equivalent circuit diagram is often inadequate. We can try to refine the equivalent circuit diagram, but sometimes we have to use field theory, rather than network or circuit theory.

The discussion of Appendix E on partial inductances is an example of this dilemma. To introduce the partial inductances, we squeeze the spread-out magnetic flux, enclosed by the full current loop, into a number of compact,

symbolic inductances, which together form a mesh, around which the sum of the voltages is zero. We have returned to network theory and Kirchhoff's Voltage Law. The advantage is that we can calculate voltages and we can use standard computer programs.

Note that in this model, the voltages across the partial inductances are potential differences. However, in reality, measured voltage differences depend on the layout of the test leads: see Figure E-13 in Appendix E, p. 782, where indeed different measured results are observed.

I prefer to use Faraday's Law: it is not too difficult, and it retains the three-dimensional geometry. The voltage *along* a wire remains small and is caused by its resistance. Voltmeters, as in Figure E-13, see this resistive voltage, but also induced voltages due to the  $d\Phi/dt$  enclosed by their test leads.

Induced voltages, equal to  $-d\Phi/dt$  in a loop, cannot be localized; the induced voltage may show up across open terminals or across a voltmeter. Such "nearby" voltages across an input or across a poorly insulated spot can be derived. An important advantage is that Faraday's Law makes it possible to optimize – in terms of EMC – the routing of sensitive cables and wiring.

The alternative suggested above does not change my admiration and positive appreciation for Henry Ott's book. EMC will remain with us in the foreseeable future, and we need books like this one.

Piet C.T. Van der Laan  
Professor Emeritus, Eindhoven University of  
Technology, the Netherlands  
E-mail: P.C.T.v.d.Laan@tue.nl

### **Fundamentals of Wave Phenomena, Second Edition**

edited by Akira Hirose and Karl E. Lonngren, Raleigh, NC, SciTech Publishing, 2010, Hardcover,  
ISBN: 978-1-891121-92-0; 384 pp., USD 67.50

This volume is announced as a textbook for use in university courses at advanced or first-year graduate levels. Indeed, the presentation and the contents of the 15 chapters are, in principle, quite adequate for that purpose. They cover oscillations; all types of waves, including their propagation and interaction with the environment; as well as aspects of geometric optics and, briefly, the wave-particle dualism. They also provide mathematical tools, such as Taylor series expansion, Fourier analysis, and Laplace transformation, before the last chapter outlines nonlinear waves, solitons, shocks, and chaos. For the expert, the book is easy to read, contains quite a few useful formulae, but does not present any new insight – in line with the target group of the book.

However, there is a problem: the necessarily inexperienced reader will be confronted with a text that despite the statement of the authors that they will adhere to the meter-kilogram-second unit system (which should be called Systeme International d'Unites, SI), contains on more than 200 pages up to ten non-conformances with SI and its guidelines. Similarly, mathematical conventions of writing the Euler number,  $e$ ; the imaginary unit,  $i$ ; and the differentiation symbol,  $d$ ; are not observed. In addition, the concept of physical quantities is not applied in many instances.

Although the coverage of wave phenomena is rather complete, there are a few noticeable omissions. Tsunamis are mentioned in the text (not in the index), but their important property, i.e., a nearly dispersionless propagation across oceans, is not presented. Chapter 15 would clearly be the right place for describing a bore as

a spectacular tidal phenomenon. The Doppler effect of electromagnetic waves requires a detailed discussion of the aberration of light, but Bradley's discovery in 1782 is only touched upon under geometric optics. Consequently, the optical Doppler effect is not adequately presented, and the generalized Equation (8.9) is even wrong. Equation (15.59), giving the amplitude of a newly created soliton, appears to be wrong, as well. The reader would also like to know the *complete* configuration of the Poynting vector field for a dc current, since the authors have chosen to include this non-oscillatory item in the book. However, in general the equations can be interpreted correctly if the reader is able to substitute the SI rules in the inappropriately written statements.

It might be helpful to consult the SI brochures issued by BIPM and NIST available at [http://www.bipm.org/en/si/si\\_brochure/](http://www.bipm.org/en/si/si_brochure/) and <http://www.nist.gov/pml/pubs/sp811/index.cfm>.

There are few typographical errors and redundancies. The statement on p. 300 that Einstein proposed the term *photon* should be qualified by the remark that he talked about *Energiequanten* having energies of  $h\nu$ , and that G. N. Lewis introduced the term *photon* in 1926.

The many enlightening examples given are a positive aspect of the book, but more than two-thirds unfortunately suffer from the shortcomings discussed above.

Klaus Wilhelm  
E-mail: wilhelm@mps.mpg.de

# Information for authors



## Content

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

Scientific papers are subjected to peer review. The content should be original and should not duplicate information or material that has been previously published (if use is made of previously published material, this must be identified to the Editor at the time of submission). Submission of a manuscript constitutes an implicit statement by the author(s) that it has not been submitted, accepted for publication, published, or copyrighted elsewhere, unless stated differently by the author(s) at time of submission. Accepted material will not be returned unless requested by the author(s) at time of submission.

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Material submitted for publication in the scientific section of the *Bulletin* should be addressed to the Editor, whereas administrative material is handled directly with the Secretariat. Submission in electronic format according to the instructions below is preferred. There are typically no page charges for contributions following the guidelines. No free reprints are provided.

## Style and Format

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All papers accepted for publication are subject to editing to provide uniformity of style and clarity of language. The publication schedule does not usually permit providing galleys to the author.

Figure captions should be on a separate page in proper style; see the above guide or any issue for examples. All lettering on figures must be of sufficient size to be at least 9 pt in size after reduction to column width. Each illustration should be identified on the back or at the bottom of the sheet with the figure number and name of author(s). If possible, the figures should also be provided in electronic format. TIF is preferred, although other formats are possible as well: please contact the Editor. Electronic versions of figures *must* be of sufficient resolution to permit good quality in print. As a rough guideline, when sized to column width, line art should have a minimum resolution of 300 dpi; color photographs should have a minimum resolution of 150 dpi with a color depth of 24 bits. 72 dpi images intended for the Web are generally *not* acceptable. Contact the Editor for further information.

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## Review Process

The review process usually requires about three months. Authors may be asked to modify the manuscript if it is not accepted in its original form. The elapsed time between receipt of a manuscript and publication is usually less than twelve months.

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