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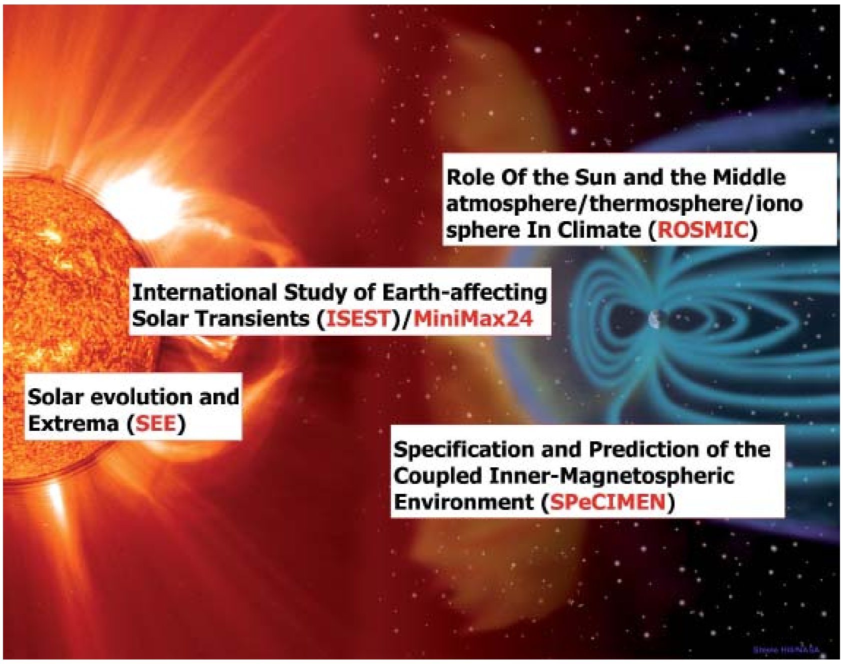

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Editorial

AT-RASC 2015

If you haven't already, you should immediately make plans to attend the first triennial URSI Atlantic Radio Science Conference, AT-RASC 2015, to be held May 18-22, 2015, in Gran Canaria, Canary Islands. This is one of the three flagship URSI conferences (the other two being AP-RASC and the URSI General Assembly and Scientific Symposium; all are triennial, so one will now occur each year), with participation from all 10 URSI Commissions. There will also be the collocated triennial ISSSE (International Symposium on Signals, Systems and Electronics) May 19-21, organized under the sponsorship of URSI Commissions C and D. Commission B is offering a School for Young Scientists. Early bird registration extends until March 31. The Web site is www.AT-RASC.com.

Our Papers

Something very unusual is going on with the sun. The previous solar minimum, in 2008-2009, and the current sunspot cycle solar maximum have had much lower levels of activity than were associated with the previous two solar cycles, and indeed than have been previously observed with modern instruments. This has led to a five-year scientific program, "Variability of the Sun and Its Terrestrial Impact (VarSITI)." The paper by C. J. Rodger describes this program, and URSI's involvement in it. The paper begins with an overview of the organization of VarSITI, and the background of other scientific studies that led to it. An introduction is given to the basic phenomena to be studied, and to the four projects that make up VarSITI. This is followed by an explanation of each of the four projects, including the goals and objectives of each project, and the fundamental science question each project is trying to answer. Particular emphasis is placed on understanding and hopefully predicting the impacts of solar variability on space and terrestrial weather. The paper concludes with a discussion of the relevance of the program to URSI, and a call for interested radio scientists to become involved. This paper provides insight into an important project that should be of interest to a very broad range of radio scientists.

The paper by David Matolak, Kate Remley, Camillo Gentile, Christopher Holloway, Qiong Wu, and Qian Zhang is the third in a three-paper series on radio-propagation studies related to public-safety communications. The first paper, "Propagation Measurements Before, During, and After the Collapse of Three Large Public Buildings," appeared in the September 2014 issue of the *Radio Science Bulletin* (pp. 31-47). The second paper, "Radiowave Propagation in Urban Environments with Application to Public-Safety Communications," appeared in the December issue (pp. 58-70). The paper in this issue deals with the characteristics of ground-based peer-to-peer wireless channels in the 700 MHz and 4.9 GHz public-safety communications bands. The results reported included models and measurements for antennas at heights associated with human-held devices, and the measurements included densely sampled power-delay profiles that can be used to quantify multipath. The paper begins with a review of previous work in characterizing peer-to-peer communications in public-safety bands. A detailed description of the measurements is then given. These were made in downtown Denver, Colorado, recording the channel transfer function as a function of frequency with a vector network analyzer. The methods used to process the data to obtain delay spread and path loss are then described. The results of these values for line-of-sight and non-line-of-sight paths are presented and discussed. The multipath characteristics of the channels were analyzed. Because the transmitter was mounted on a two-dimensional positioner, it was possible to record the channel impulse responses as functions of both the delay and angle of departure. This led to important information being obtained about the spatial characteristics of the channel. Models were derived to fit the data obtained from the experiments. The results of these studies provide valuable insight into the propagation-channel characteristics for point-to-point handheld communications in an urban environment. They also provide quite useful data for anyone trying to plan public-safety communications in such an environment.

Our Other Contributions

In this issue, we have the results from the business meetings of URSI Commissions C, D, E, F, G, and K, held at the General Assembly and Scientific Symposium in Beijing last August. These reports include the status and plans for the various Working Groups in the Commissions, as well as the scientific meeting the Commissions plan to organize for the coming triennium. The topics of sessions the Commissions plan for future meetings, and who was elected Chair, Vice Chair, and Early Career Representative for the Commission are also reported.

I started this column with by urging you to attend AT-RASC. I'll close the same way: this is going to be a an important meeting, in a great location. I hope to see you there.

Ross

In Memoriam

Balogovest Shishkov
1937 - 2015

Blagovest Shishkov was an internationally recognized and distinguished scientist in the area of statistical signal processing and data transmission. He was the Chair of the Bulgarian URSI Committee. He passed away on January 18, 2015.

Prof. Shishkov graduated from the Department of Communications at the Technical University of Sofia. He was awarded the PhD in Physics and the Doctor of Sciences in 1974 and 1991, respectively. He was a Professor in the Department of Probability and Statistics at the Institute of Mathematics and Informatics at the Bulgarian Academy of Sciences.

The research interests of Prof. Shishkov were in the areas of asymptotic methods in parameter estimation, signal detection and identification, pattern recognition and data quantization, cyclostationary signal processing and detection, and nonlinear wave interactions defined by higher-order statistics. This last investigation was devoted to mathematical modeling and optimization of the sidelobe level of large antenna arrays toward solar-power satellite and microwave power transmission applications. He created a variety of asymptotic algorithms for the detection and estimation of weak signals in a background of noise applicable to telecommunications, radar, remote-sensing systems, space research, and biomedical systems, and new algorithms in adaptive antennas and space data analysis.

Prof. Shishkov was an official member of URSI Commission C: Signals and Systems, and a member of the IEEE; IEICE; EURASIP (European Association for Signal Processing); Bulgarian Statistical Society; Bulgarian Society of Astronautics; Telecommunications Research Fellowship of Telecommunications Advancement Organization of Japan, CRL, Tokyo; CNRS Research Fellowship, CNRS-LPCE, Orleans, France.

Prof. Shishkov was an enthusiastic and talented scientist, thoroughly dedicated to his work. He had a gift for sharing his ideas with younger colleagues, whom he was always ready to help and engage in fruitful scientific work. He was active in international scientific cooperation as a visiting professor at E.N.S.E.E.I.H.T., Toulouse, France; Radio Science Center for Space and Atmosphere, Research Institute of Sustainable Humanosphere, Kyoto University, Japan; Tokai University Educational System, Japan; University Carlos III, Madrid, Spain; and as an invited researcher at ATR Adaptive Communications Research Laboratories, Radio Science Center for Space and Atmosphere, Kyoto University, Japan.

Prof. Shishkov was a keen proponent of international working-level scientific collaboration. He was a motivated organizer and a chair of the annually organized international URSI symposiums ISRSSP and ICTRS, held in different countries of Europe. It was a great privilege to collaborate and have discussions with Prof. Blagovest Shishkov. He will be sorely missed.

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SCOSTEP's New Research Program: "Variability of the Sun and Its Terrestrial Impact (VarSITI)"

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Abstract

The Scientific Committee on Solar Terrestrial Physics (SCOSTEP) has recently launched its latest five-year scientific program, "Variability of the Sun and Its Terrestrial Impact (VarSITI)." This program is intended to last from 2014 through 2018. URSI is one of SCOSTEP's formal participating bodies, and provides a representative to the Bureau that governs SCOSTEP. Through this route, URSI was involved in the selection of the projects that formed the VarSITI program. The scientific goals of VarSITI are relevant to a wide range of URSI members, and in particular to those from Commissions E, F, G, H, and J. In this brief article, we wish to alert the URSI community to VarSITI and the component projects.

1. Background Information

The Scientific Committee on Solar Terrestrial Physics (SCOSTEP) is an interdisciplinary body of the International Council for Science (ICSU). SCOSTEP promotes ICSU's mission to strengthen international science for the benefit of society. SCOSTEP runs international interdisciplinary scientific programs and promotes solar-terrestrial physics research by providing the necessary scientific framework for international collaboration and dissemination of the derived scientific knowledge in collaboration with other ICSU bodies. The Scientific Committee on Solar-Terrestrial Physics (SCOSTEP) was originally established as an Inter-Union Commission following a resolution adopted at the 11th General Assembly of ICSU in Bombay in January 1966. It was modified by the 14th General Assembly of ICSU in Helsinki in 1972 to become a Special Committee, and by the 17th General Assembly in 1978 to become a Scientific Committee.

The governing body of SCOSTEP is the SCOSTEP Bureau. The Bureau is comprised of SCOSTEP's President, the Vice President, the Representatives of the ICSU Participating Bodies, and the Scientific Secretary (ex officio). The Bureau directs scientific, administrative, and financial activities. URSI is one of the Participating Bodies inside SCOSTEP, and thus contributes a representative to the Bureau. The current URSI representative to SCOSTEP is Craig J. Rodger (New Zealand), who took up the role after the URSI General Assembly and Scientific Symposium in Beijing (China (CIE), August 16-23, 2014). Previous to this, the SCOSTEP URSI representative was Lee-Anne McKinnell (South Africa). The other Participating Bodies are IAU, IUGG, IUPAP, and COSPAR.

SCOSTEP organizes and conducts international solar-terrestrial physics (STP) programs of finite duration in cooperation with other ICSU bodies. They share results of these programs by joining in conducting meetings, conferences, and workshops, and by publishing newsletters, handbooks, and special journal issues about these solar-terrestrial physics programs. SCOSTEP is an outgrowth of earlier bodies in ICSU involved in planning and implementing the International Geophysical Year (IGY: 1957-58) and the International Quiet Sun Year (IQSY: 1964-65). SCOSTEP programs completed to date include:

- 1976-1979 IMS: International Magnetospheric Study
- 1979-1981 SMY: Solar Maximum Year
- 1982-1985 MAP: Middle Atmosphere Program
- 1990-1997 STEP: Solar-Terrestrial Energy Program
- 1998-2002 SRAMP: STEP-Results, Applications, and Modeling Phase
- 1998-2002 PSMOS: Planetary Scale Mesopause Observing System
- 1998-2002 EPIC: Equatorial Processes Including Coupling

- 1998-2002 ISCS: International Solar Cycle Study
- 2004-2008 CAWSES: Climate and Weather of the Sun-Earth System
- 2009-2013 CAWSES-II: Climate and Weather of the Sun-Earth System-II

2. Introducing the VarSITI Program

The previous solar minimum, in 2008-2009, as well as the current solar maximum of sunspot cycle 24, have been very unusual. Both these recent periods had much lower activities compared with the previous two solar cycles, 22 and 23. The solar-terrestrial physics community is now observing these very-low-solar-activity levels, and examining the consequences on and around Earth. These conditions are unprecedented in the era of modern scientific measurements. Current solar-dynamo theories are unable to predict the long-term solar-activity variations we are now seeing. It is not clear whether the last deep solar minimum and the current low solar maximum may signal the end of the recent period of relatively high solar activity, and what long-term solar activity variations we can expect in the future.

Our present understanding of how the sun influences geospace has been based on instrumental observations taken during only the recent period of possibly unusually high solar activity in the second half of the 20th century. It is uncertain how well our understanding will hold during periods of more moderate to low solar activity, which may be "the new normal" in the near future. Furthermore, it is still more unclear how all this may affect global climate change.

The new SCOSTEP program, "Variability of the Sun and Its Terrestrial Impact (VarSITI)" (2014-2018), will focus on this current period of low solar activity and its consequences on Earth. The program will span various times scales, from the order of thousands of years to milliseconds, and for various connected locations, ranging from the solar interior to the Earth's atmosphere. In order to elucidate various sun-Earth connections, we encourage communication between solar scientists (solar interior, sun, and the heliosphere) and geospace scientists (magnetosphere, ionosphere, and atmosphere). Campaign observations and data analysis are being selected for specific time intervals to focus collaboration between relevant satellite and ground-based missions as well as modeling efforts. Four scientific projects will be carried out in VarSITI. These are: (1) Solar Evolution and Extrema (SEE), (2) International Study of Earth-Affecting Solar Transients (ISEST/Minimax24), (3) Specification and Prediction of the Coupled Inner-Magnetospheric Environment (SPeCIMEN), and (4) Role Of the Sun and the Middle atmosphere/thermosphere/ionosphere In Climate (ROSMIC). They are graphically summarized in Figure 1.

The four projects were selected through a community-led "bottom up" consultation effort. In September 2012, SCOSTEP's President sent out a wide call for people to submit white papers to define the science that led to the VarSITI effort. These white papers were required to define the scientific program, including the scientific question to be addressed, an objective that could be achieved over a period of four years, data sets to be used, modeling collaborations, and a team of scientists (international steering committee) to coordinate the project. Nine white papers were submitted, covering a number of issues of solar physics, the effect of space weather on climate, and atmospheric coupling. Following this, white-paper authors were invited to a SCOSTEP meeting hosted by the International Space Science Institute in Bern, Switzerland, in May 2013. This process led to the four-project structure of VarSITI. The VarSITI program was officially launched on January 13, 2014. The Web site of the program is http://varsiti.org/. The logo for the program is shown in Figure 2.

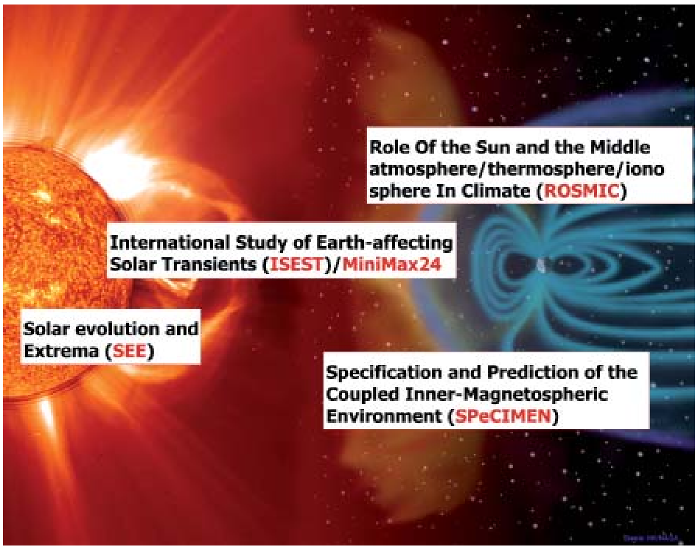

Figure 1. The four projects of VarSITI, which cover the variability of the sun, its terrestrial impact, and span the interlinked system (adapted from an image credited to Steele Hill, NASA).

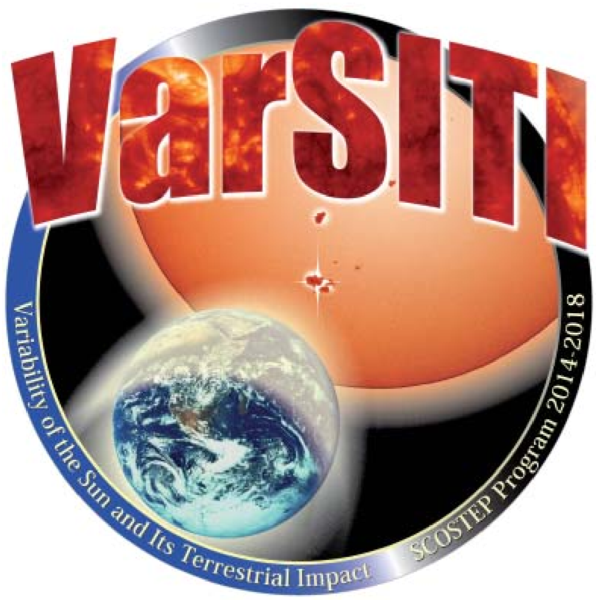

Figure 2. The logo of the Variability of the Sun and Its Terrestrial Impact (VarSITI) program.

3. The VarSITI Projects

As noted above, the VarSITI program is made up of four distinct but coupled projects, connecting from the inner workings of the Sun to the surface climate of the Earth. This wide span is one of the main reasons that the VarSITI program is likely to overlap with research efforts of many URSI scientists across multiple URSI Commissions. The four projects are the following:

3.1 SEE (Solar evolution and Extrema)

The project co-leaders are Petrus C. Martens (USA), Dibyendu Nandi (India), and Vladimir N. Obridko (Russia).

The project goals and objectives are to:

1. Reproduce magnetic activity as observed in the sunspot record, including grand minima and extended minima in dynamo simulations;

2. Amalgamate the best current models and observations for solar spectral and wind output over the Earth's history; and

3. Determine the size and expected frequency of extreme solar events.

Science questions:

1. Are we at the verge of a new grand minimum? If not, what is the expectation for cycle 25?
2. Does our current best understanding of the evolution of solar irradiance and mass loss resolve the "Faint Young Sun" problem? What are the alternative solutions?
3. What is the largest solar eruption/flare possible? What is the expectation for periods with absence of activity?

"*Are we at the verge of a new grand minimum?*"

3.2 ISEST (International Study of Earth-affecting Solar Transients/MiniMax24)

The project co-leaders are Jie Zhang (USA), Manuela Temmer (Austria), and Nat Gopalswamy (USA).

The project goals and objectives are to understand the origin, propagation and evolution of solar transients through the space between the sun and the Earth, and to develop the prediction capability of space weather.

1. Carry out campaign study to integrate theory, simulations, and observations in order to get a complete view and understanding of the chain of cause-effect activities from the sun to the Earth.

2. Use observations to identify all Earth-affecting flares, CMEs, SEPs, and CIRs during the STEREO era and their solar sources.

3. Use theoretical studies and numerical simulations to understand the structure, evolution, and dynamics of CMEs and the global context of transient events.

4. Carry out campaign study to integrate theory, simulations, and observations in order to get a complete view of the chain of cause-effect activities from the sun to the Earth.

Science questions:

1. How do coronal mass ejections (CMEs) and co-rotating interaction regions (CIRs) propagate and evolve, drive shocks, and accelerate energetic particles in the heliosphere?

"*Can we predict the impact of solar transients on space weather?*"

3.3 SPeCIMEN (Specification and Prediction of the Coupled Inner-Magnetospheric Environment)

The project co-leaders are Jacob Bortnik (USA) and Craig J. Rodger (New Zealand).

The project goals and objectives are the quantitative prediction and specification of the Earth's inner magnetospheric environment based on sun/solar-wind driving inputs.

Science questions:

1. Can the state of the Earth's inner magnetosphere be specified and predicted to high accuracy, based on inputs from the Sun and solar wind?

"*What is the physics behind radiation-belt electron-flux dynamics?*"

3.4 ROSMIC (Role Of the Sun and the Middle atmosphere/ thermosphere/ionosphere In Climate)

The project co-leaders are Franz-Josef Lübken (Germany), Annika Seppälä (Finland), and William E. Ward (Canada).

The project goals and objectives are to understand the impact of the sun on the terrestrial middle atmosphere/lower thermosphere/ionosphere (MALTI) and Earth's climate, and its importance relative to anthropogenic forcing over various time scales from minutes to centuries.

Science questions:

1. What is impact of solar forcing of the entire atmosphere? What is the relative importance of solar irradiance versus energetic particles?
2. How is the solar signal transferred from the thermosphere to the troposphere?
3. How does coupling within the terrestrial atmosphere function (e.g., gravity waves and turbulence)?
4. What is the impact of anthropogenic activities on the middle atmosphere, lower thermosphere, ionosphere (MALTI)?
5. What are the characteristics of reconstructions and predictions of TSI and SSI?
6. What are the implications of trends in the ionosphere/ thermosphere for technical systems such as satellites?

"*What influence does solar forcing have on climate and weather?*"

4. Relevance to URSI

The breadth of the scientific questions posed in the VarSITI program will be relevant to many URSI members. As SCOSTEP's role is to provide the framework for international collaboration and dissemination, these projects should stimulate more opportunities for URSI researchers to work together. Conferences, workshops, and sessions will be organized and supported around the VarSITI program and the four associated projects. In particular, it is worth noting that VarSITI has funding to provide support for organizing scientific meetings, for international and interdisciplinary campaign activities, and for database construction. As URSI refocuses itself onto its three "core" meetings (URSI GASS, URSI AT-RASC, URSI AP-RASC), the VarSITI funding may assist communities to support focused workshops during the next four years.

SCOSTEP's role is also to support capacity building for international solar-terrestrial physics research. This has included funding to support schools. Examples of this in 2014 were:

- International school on space weather, GNSS, GIS Internet and database, November 10-21, 2014, University of Koudougou, Burkina Faso
- Space Science and Applications School, June 30 - July 11, 2014, University of Rwanda, Rwanda
- Training School on New Challenges in the Study of the Impact of Solar Variability and on Climate, October 13-17, 2014, Trieste, Italy

In addition, SCOSTEP has recently launched a new capacity-building activity, the SCOSTEP Visiting Scholar (SVS) program. The objective of the SCOSTEP Visiting Scholar program is to provide training to young scientists and graduate students from developing countries in well-established solar terrestrial physics laboratories for periods of between one and three months. The aim is to fund four scholars each year, one related to each of the four SCOSTEP VarSITI themes (http://www.varsiti.org/). The training will help the young scientists to advance their careers in solar terrestrial physics, using the techniques and skills they learned during the training. We suggest that interested parties should examine the SCOSTEP and VarSITI Web sites for more information.

Peer-to-Peer Urban Channel Characteristics for Two-Public-Safety Frequency Bands

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[This is the third article in a three-article series dealing with radio-propagation studies related to public-safety communications. The first article, "Propagation Measurements Before, During, and After the Collapse of Three Large Public Buildings," appeared in the September 2014 issue of the *Radio Science Bulletin* (pp. 31-47). The second article, "Radiowave Propagation in Urban Environments with Application to Public-Safety Communications," appeared in the December issue (pp. 58-70).]

Abstract

We report on peer-to-peer (ground-based) wireless channel characteristics for an urban environment in two public-safety bands. Results were based upon measurements taken in Denver in June 2009. The public-safety bands we investigated were the 700 MHz and 4.9 GHz bands, both planned for public-safety and "emergency-responder" applications. Heretofore, characterization of an urban environment in these bands has *not* been done. Specifically, an estimation of the distributions of both the number of multipath components and their delays has not been made for these bands, this environment, and our low antenna heights. Our measurements employed a vector network analyzer, from which both path loss and delay dispersion characteristics were obtained for link distances up to approximately 100 m. Log-distance models for path loss are presented, and dispersive channel models are also described. Our dispersive channel models employed a statistical algorithm for the number of multipath components, previously used only in indoor settings. By employing a transmitter-antenna positioner, we introduced spatial diversity into the measurement system, which enabled analysis of the dispersion characteristics of the angle of departure, also new for this ground-ground channel. The channel models should be useful for public-safety communication system designers.

1. Introduction

Communications for public-safety authorities are seeing increased attention [1, 2]. This is due in part to increased awareness of the need for effective communications for so-called "emergency responders" during emergency events. In addition, new spectral allocations have been granted for public safety, so public-safety communities are working on how to best use these new bands. Several bands in the 700 MHz spectrum, formerly allocated to television broadcasting, have been reallocated nationwide to public safety. A band in the 4900 MHz spectrum has also been recently allocated. In the 700 MHz band, two 12 MHz blocks are available, from 764 MHz to 776 MHz and 794 MHz to 806 MHz, whereas in the 4900 MHz band, 50 MHz is available from 4940 MHz to 4990 MHz.

Public-safety communications have traditionally been "narrowband," with voice the primary service. Channel allocations of 6.25 kHz, 12 kHz, and 25 kHz have been used for many years. The use of new, wider-band services has been gaining popularity for applications such as video, geolocation, etc. This has initiated development of wider-band air interface standards, such as the so-called P34 standard originally developed by the Association of Public Safety Communications Officials (APCO), now part of the Telecommunications Industries Association (TIA) [3]. With the tremendous growth of wireless local and metropolitan area networks that use the IEEE 802.11 and 802.16 (WiMAX [4]) standard technologies, as well as cellular technologies including the 3GPP's Long Term Evolution (LTE) standard, the public-safety community is likely enroute to employ one or more of these technologies for reasons of reliability and economy. Typical signal bandwidths for these technologies are 1.25 MHz, 5 MHz, 10 MHz, and 20 MHz.

Deployments for public-safety communications have traditionally been of the "single-cell" or "dispatch" variety,

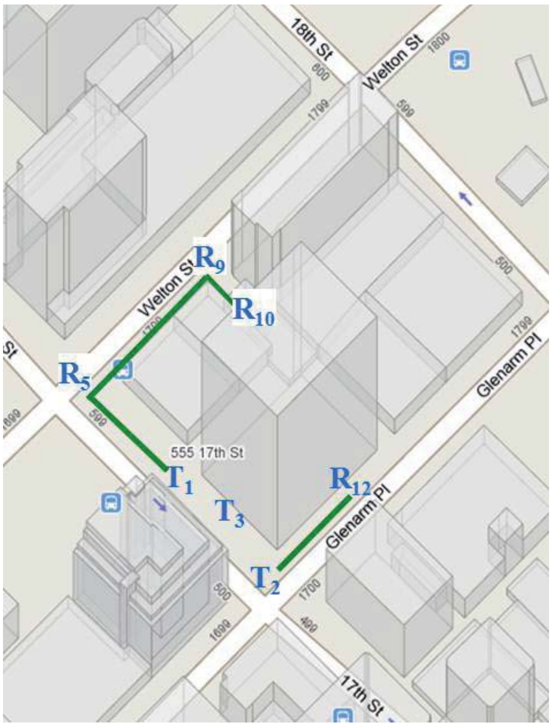

Figure 1a. An illustration of the test area.

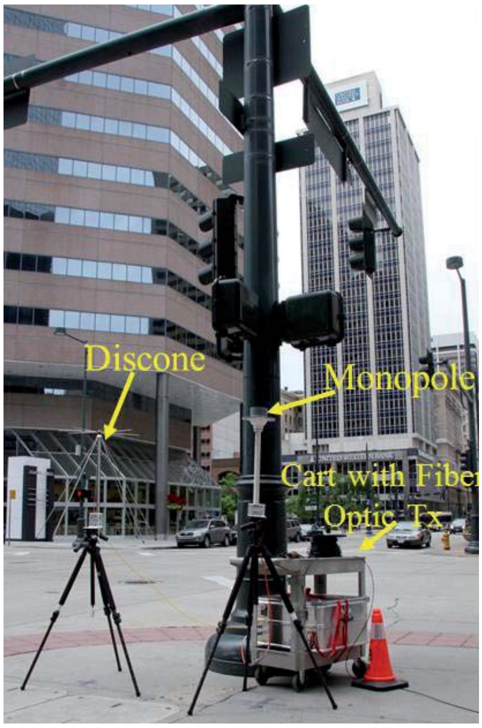

Figure 1b. A photograph of the two receiver antennas located at position R5, on the corner of Welton and 17th Streets.

where mobile users connect to a single base station that covers a wide area. For first-responder events, new types of deployments, called the jurisdictional area network (JAN) and incident area network (IAN), are in the process of being deployed [1]. The jurisdictional area network may operate as a single- or multi-cell system over a wide area (e.g., citywide), whereas the incident area network can operate as an ad hoc network, temporarily set up to provide communication services for emergency responders during an emergency event. Typical incident area network environments will include urban settings, outdoor-outdoor, outdoor-indoor, and possibly indoor-indoor. In some scenarios, these systems will be ad hoc, so that large, elevated base stations are not deployable. Communication will hence be ground-based, or "peer-to-peer" (P2P), with low-elevation antennas communicating with mobile units, and mobile units communicating with each other. Our definition here of ground-based (and peer-to-peer) is this: low-elevation (approximately pedestrian height) antennas, with typically low (pedestrian) mobile velocities.

For any wireless communication system to operate reliably, knowledge of the channel characteristics is vital [5]. Key channel characteristics that influence the selection of signaling parameters include delay dispersion, frequency coherence, Doppler spread, and temporal correlation. Knowledge of these characteristics enables optimal selection of transmission parameters (e.g., subcarrier bandwidth, symbol rate), as well as design parameters for remedial measures to counteract channel effects (e.g., equalization, diversity) [6]. Public-safety communication systems in the 700 MHz and 4900 MHz bands are yet to be widely deployed, so that characterization of the wireless channels in these bands for first responder environments is presently needed. The Department of Justice Community-Oriented Policing Services (COPS) program has funded NIST's Public Safety Communications Research Laboratory for several efforts in this area, including work described in [7-11]. The focus of NIST's work is dissemination in the open literature of measured wireless-channel characteristics in representative public-safety environments using methods that can be reproduced by other researchers. The urban-channel characterization that is the subject of this paper represents a continuation of this work.

Wireless channels have been characterized for many environments, for numerous systems, and in multiple frequency bands, with perhaps cellular channels seeing the most attention: for example, [12, 13]. Indoor channels have also been characterized [14], as have other settings such as vehicle-to-vehicle [15]. Ground-based or peer-to-peer channels have seen far less attention. Path loss in ultra-high-frequency (UHF) bands for ground-based urban channels was reported in [16]. Reports on microcell channels, studied extensively by standards bodies, typically focus on antenna heights of 3 m to 4 m, rather than the person-height conditions reported here. Most of these reports are not available in the open, peer-reviewed body of literature.

Although much work has appeared on performance of ad hoc and cooperative communications in peer-to-peer settings, this has typically addressed aspects of network algorithm design, and almost universally employed conventional nondispersive channel models. For example, [17] assumed Nakagami fading, [18] assumed Rayleigh

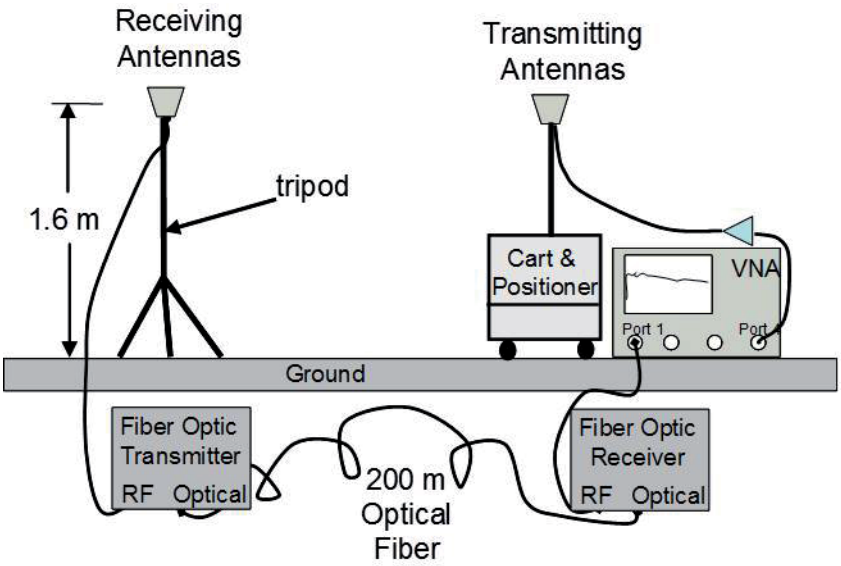

Figure 2. The vector network analyzer setup.

fading. Both of these (and most other) references on peer-to-peer communications assumed frequency *non*-selective fading, and hence did not address channel-delay dispersion. Additionally, few references focused on bands near the 700 MHz to 800 MHz band, and for those that did, most results pertained to a cellular-like deployment with one elevated antenna, e.g., [19, 20]. Similarly, although a large amount of work has been conducted for measuring and modeling channels in the 5 GHz band, e.g., [21, 22], very little has appeared for the ground-based peer-to-peer environment. Reference [23] reported on measurements in the 4900 MHz band, but did not provide much detail on channel impulse response characteristics: only the cumulative distribution function of root-mean square delay spread. This paper also provided a cumulative distribution function for penetration loss and Ricean K factors. The authors used a directional horn at 4.2 m height aimed into the building, and looked explicitly only at outdoor-indoor conditions. No explicit channel models were provided. For brevity, we have provided only representative citations to the literature in the area of urban wireless channel measurements and models.

The work described here fills a gap by presenting channel measurement and modeling results – including spatial channel characteristics and the distribution of the number and delays of multipath components – for ground-based peer-to-peer urban channels in the 700 MHz and 4900 MHz public-safety frequency bands. These data are not currently available for human-height antennas. The measurement techniques we used [11] provide complex, densely sampled power delay profiles that can be used to quantify multipath clustering [24], develop new channel models [25], and to verify more realistic, laboratory-based measurement methods, such as those based on the reverberation chamber [26].

The remainder of this paper is organized as follows. Section 2 describes the urban environment and measurement parameters. Section 3 presents delay dispersion characteristics for both line-of-sight (LOS) and non-line-of-sight (NLOS) conditions. We also describe a path-loss model based on our data. In Section 4, we provide a summary of some of the channel's spatial characteristics, and Section 5 provides conclusions.

2. Measurement Summary

The measurements were taken outdoors in the financial district of downtown Denver on Saturday, June 20, 2009. This area contains many large (over 20 story) buildings. Figure 1a shows an illustration of the test area constructed from a Google map view (© 2009 Google, Map Data © 2009 Tele Atlas). The test area was in the block between 17th Street and 18th Street, and between Welton Street and Glenarm Place. Street widths were on the order of 20 m. Three transmitter (Tx) locations and eleven receiver (Rx) locations were used, for a total of 33 transmitter-receiver location pairs. Figure 1b shows a photograph of the two receiver antennas located at position R5 on the corner of Welton and 17th Streets. Line-of-sight link distances ranged from 10 m to 80 m. Non-line-of-sight link distances were described in one of two ways:

1. by an "L-shape," with the first distance, d_1, corresponding to the line-of-sight distance from the transmitter to a corner (e.g., T_1 to R_5 in Figure 1), and the second distance, d_2, corresponding to the distance from the corner to the receiver (e.g., R_5 to R_9 in Figure 1); or

2. by a "U-shape," with d_1 as previously defined, d_2 being the corner-to-corner distance, and d_3 defined as the final distance from the second corner to the receiver (e.g., R_9 to R_{10} in Figure 1).

Table 1 lists all of these distances (note that there is no Rx1 data: this receiver location was indoors, and those measured results were not included in this paper). This approach for

	Rx2	Rx3	Rx4	Rx5	Rx6	Rx7	Rx8	Rx9	Rx10	Rx11	Rx12
Tx1	$d=10$	$d=20$	$d=30$	$d=40$	$d_1=40$ $d_2=10$	$d_1=40$ $d_2=20$	$d_1=40$ $d_2=30$	$d_1=40$ $d_2=40$	$d_1=40$ $d_2=43$ $d_3=13$	$d_1=40$ $d_2=5.5$	$d_1=40$ $d_2=35.5$
Tx2	$d=50$	$d=60$	$d=70$	$d=80$	$d_1=80$ $d_2=10$	$d_1=80$ $d_2=20$	$d_1=80$ $d_2=30$	$d_1=80$ $d_2=40$	$d_1=80$ $d_2=43$ $d_3=13$	$d=5.5$	$d=35.5$
Tx3	$d=36$	$d=46$	$d=56$	$d=66$	$d_1=66$ $d_2=10$	$d_1=66$ $d_2=20$	$d_1=66$ $d_2=30$	$d_1=66$ $d_2=40$	$d_1=66$ $d_2=43$ $d_3=13$	$d_1=14$ $d_2-5.5$	$d_1=14$ $d_2=35.5$

Table 1. The transmitter (Tx) to receiver (Rx) distances (m). Line-of-sight (LOS) links contained only one distance (*d*), and non-line-of-sight (NLOS) links contained either two distances (d_1, d_2) for L-shaped paths, or three distances(d_1, d_2, d_3) for U-shaped paths.

specifying distances in the urban environment was used by others, for example [16].

The measurements employed a vector network analyzer (VNA), which measured the channel transfer function, $H(f)$, as the scattering parameter S_{ij}, with transmission from port *j* to port *i*. The transfer function was measured relative to a 4 m reference measurement made in a controlled environment, free from reflections, in order to calibrate out antenna and system effects. We thus reported path loss relative to our 4 m reference. Our four-port vector network analyzer enabled us to simultaneously connect to separate antennas for the 700 MHz and 4900 MHz bands. Omnidirectional antennas were used for both bands, with a discone for 700 MHz, and a monopole for 4900 MHz, both vertically polarized. Identical antennas were used at transmitter and receiver sites. A synchronized fiber-optic link between receiver antennas and the vector network analyzer receiver port enabled us to attain link distances up to 200 m. Figure 2 illustrates the vector network analyzer setup. The transmitter antennas were set on a cart, and mounted to a "positioner." The positioner was a motor-controlled, two-arm device that enabled us to precisely move the transmitter antennas in a Cartesian coordinate plane parallel to the ground. The positioner range was 0.5 m by 0.5 m. The receiver antennas were mounted on tripods, and were manually moved from location to location. All antenna heights were approximately 1.6 m above the ground (to the top of the antenna).

For each band, we measured $H(f)$ twice at each of the nine transmitter antenna positions (for each physical transmitter-receiver location pair), yielding 18 transfer functions per transmitter-receiver location pair. The nine transmitter antenna positions corresponded to nine points on the Cartesian grid of the positioner, with the separation between each point equal to 25 cm in both dimensions. The relative separation of the grid positions was different in the two bands, but our results and analysis for each band individually were unaffected by this. The spatial channel information for both bands should be of interest even if the array characteristics were not identical in the two bands.

Figure 3 shows a plan-view diagram of the positioner, with the nine individual antenna positions labeled P1-P9. With 33 transmitter-receiver pair combinations, a total of $18 \times 33 = 594$ transfer functions were collected. The bandwidths of $H(f)$ for both bands were set to 100 MHz, with a frequency resolution of 1 MHz (enabling a 1 μs maximum delay). However, strong interference in the lower part of the 700 MHz band reduced that usable bandwidth to 75 MHz. Our transfer functions thus covered the 725 MHz to 800 MHz and 4.9 GHz to 5 GHz frequency bands.

For much of the time during measurements, only pedestrian motion was present, although automobile traffic increased as the day progressed. Traffic around the block was "stop and go," since stoplights were present at all intersections. Auto speeds were as large as approximately 10 m/s, which for single-scattering yielded a maximum Doppler frequency at 5 GHz of [5]

$$f_d = vf/c = 10\left(5\times10^9\right)/3\times10^8 \cong 167 \text{ Hz}.$$

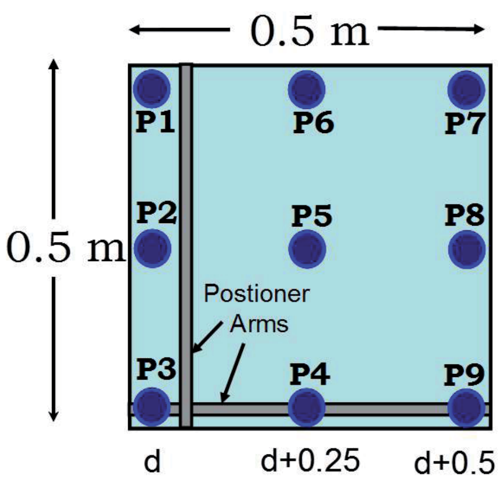

Figure 3. A plan-view diagram of the positioner, with the nine individual antenna positions labeled P1-P9.

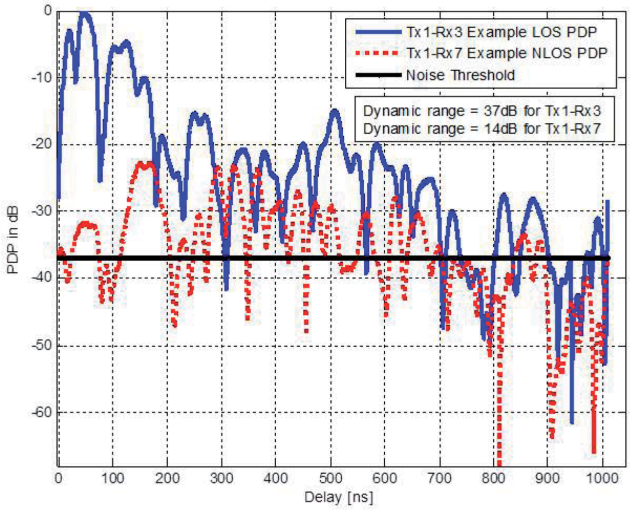

Figure 4. Example power delay profiles (PDPs) for line-of-sight (LOS) (Tx1-Rx3) and non-line-of-sight (NLOS) (Tx1-Rx7) locations, 700 MHz band.

This yielded a minimum channel coherence time of approximately $t_{c,min} \cong 1/f_d = 6$ ms for the 4900 MHz band. The same maximum velocity yielded a minimum coherence time of approximately 37 ms for the upper end of the 700 MHz band. With each vector network analyzer sweep across the band taking approximately 2 ms, we assumed the channel could be considered statistically wide-sense stationary for each measured $H(f)$, especially since most vehicle velocities were less than our cited maximum. With our measurement procedure, we were unable to measure fading dynamics. Studies of the fading statistics of this propagation environment, including the Ricean K-factor, are currently a subject of research at NIST.

3. Delay Spread and Path Loss

3.1 Mathematical Description and Processing

Baseband (complex envelope) channel impulse responses (CIRs) were computed in post processing from the transfer functions by first windowing by a Hamming window to reduce delay-domain sidelobes. This technique is often employed with vector network analyzer measurements, for example, [27]. The windowed transfer functions were then inverse Fourier transformed to obtain channel impulse responses. For a channel impulse response denoted $h(\tau, t_i)$, the corresponding ith ("instantaneous") power delay profile (PDP) was computed as $P_i(\tau) = |h(\tau, t_i)|^2$. The channel impulse response, $h(\tau, t_i)$, represents the channel output at time t_i due to an impulse input at time $t_i - \tau$, and is given by [5]

$$h(\tau, t_i) = \sum_{k=1}^{L_{pi}} \alpha_{ki} e^{j\varphi_{ki}} \delta(\tau - \tau_{ki}), \qquad (1)$$

where i indexes the ith power delay profile, L_{pi} is the number of multipath components in the ith power delay profile, and the amplitude and phase of the kth multipath component (MPC) in the ith power delay profile are α_{ki} and φ_{ki}, respectively. The d is a Dirac delta function, and τ_{ki} represents the delay of the kth multipath component of the ith power delay profile. Generally, α_{ki} and φ_{ki} are functions of time, but for each power delay profile in our case they can be considered constants. The power delay profile, $P_i(\tau)$ can be expressed as

$$P_i(\tau) = \sum_{k=1}^{L_i} |\alpha_{ki}|^2 \delta(\tau - \tau_{ki}). \qquad (2)$$

In order to separate actual multipath components from noise, we also gathered pure noise transfer functions, denoted by $N(f)$. These were obtained with the vector network analyzer's transmitting ports terminated in matched loads, so the receiver antennas received only "ambient" noise. From the $N(f)$ transfer functions, we computed complex baseband time-delay-domain noise samples. The noise samples were judged Gaussian by computing the Kullback-Leibler divergence, D_{KL} [28], a goodness-of-fit measure for probability density functions. If D_{KL} equals zero, the fit to the Gaussian density is perfect, and as D_{KL} increases, the goodness of the fit decreases. Values of D_{KL} were always less than 0.06, and typically $D_{KL} < 0.02$ indicating that the noise could be considered Gaussian.

We then set a noise threshold by means of the algorithm in [12], based upon the measured noise variance, such that the probability of false alarm was 1 in 100 power delay profiles. All power delay profile samples below the noise threshold were discarded, so that the false-alarm probability meant that for each sample in $P_i(\tau)$, the probability of mistaking a noise component for a multipath component was 0.01, or 1 noise sample mistaken for a multipath component per 100 power delay profiles. Figure 4 shows typical power delay profiles for line-of-sight and non-line-of-sight conditions for the 700 MHz band, and Figure 5 is an analogous figure for the 4900 MHz band. Note that all power delay profiles were normalized and delay-aligned by time-shifting back by the estimated direct-path delay, which was based upon the distances in Table 1. In addition, we truncated all power delay profiles after collecting the first 99% of the power delay profile energy. In Figures 4 and 5, a dynamic range is also indicated. We defined the dynamic range as the difference in dB between the power delay profile peak and the noise threshold. Mean dynamic ranges were above 18 dB for non-line-of-sight cases, and above 39 dB for line-of-sight cases. Several power delay profiles had dynamic ranges less than 10 dB, and these were judged as having too low a signal-to-noise ratio, and were therefore discarded.

Condition (Band)	RMS-DS	RMS-AS	$W_{\tau,90}$	$W_{\theta,90}$	$I_{\tau,25}$	$I_{\theta,25}$
LOS (700)	66	98	166	124	386	242
LOS (4900)	87	103	235	205	519	279
NLOS (700)	147	107	501	209	798	288
NLOS (4900)	156	97	528	260	875	292

Table 2. The summary delay spread statistics (ns) and angle spread statistics (degrees).

3.2 Delay Spread

The average power delay profiles, computed over all power delay profiles for the given case (line-of-sight or non-line-of-sight) and band, are shown in Figures 6 and 7, where we see that the average power delay profiles look similar for the two bands. Table 2 provides delay spread statistics for both cases and bands. The root-mean-square delay spread (RMS-DS) is widely used as the definitive measure of delay dispersion, and is defined as the square-root of the second central moment of the power delay profile [5]. Another delay spread measure that is sometimes used is the delay window [29]. The delay window is the duration that contains x% of the channel impulse response energy, and this is denoted $W_{\tau,x}$; Table 2 lists average power delay profile delay windows for $x = 90\%$ energy. To determine $W_{\tau,x}$, we used a symmetric window that found the "middle" x% energy. That is, for our example with $x = 90\%$, the delay window neglected the earliest 5% and the latest 5% of the channel impulse response energy. The last delay domain dispersion measure that we listed was the delay interval [29]. The delay interval, $I_{\tau,X}$, is defined as the duration of the channel impulse response containing all impulses above X dB down from the largest impulse.

As expected, non-line-of-sight delay spreads were substantially larger than those for line-of-sight cases. As also expected, delay spreads generally increased with link distance [30]. The 4900 MHz band delay spread values were also slightly larger than those for the 700 MHz band. This relationship did not always hold: delay spreads generally (but not always) decreased with increasing frequency in [31, 32], but it was not clear whether signal-to-noise ratios and dynamic ranges were equal in all bands in the results of [31] and [32]. This means that comparison of delay spread trends may not be completely fair. This held true in our case as well: because we used an external amplifier at the transmitting end of the vector network analyzer for the 4900 MHz band, the 4900 MHz dynamic ranges were generally larger than those for the 700 MHz band. Mean values of dynamic range were 38 dB for the 4900 MHz band, and 28 dB for the 700 MHz band. This can account for some of the larger delay spreads we observed at 4900 MHz. In addition, results in [31] and [32] were not for ground-based settings.

Because our measurements spanned several hours, the propagation conditions did not remain constant: conditions also of course changed with transmitter-receiver locations. This can be quantified in the delay domain by use of "instantaneous" delay-spread measures [33]. Essentially, we computed the delay-spread measures individually for *each* power delay profile. We could then collect statistics on these values over the sets of power-delay profiles to quantify the range of variation of the delay-spread measures. Figures 8 and 9 show histograms of instantaneous root-mean-square delay spread for the two bands, over all transmitter/receiver locations. These plots demonstrated the expected result that the majority of the non-line-of-sight delay spreads were larger than the majority of the line-of-sight delay spreads,

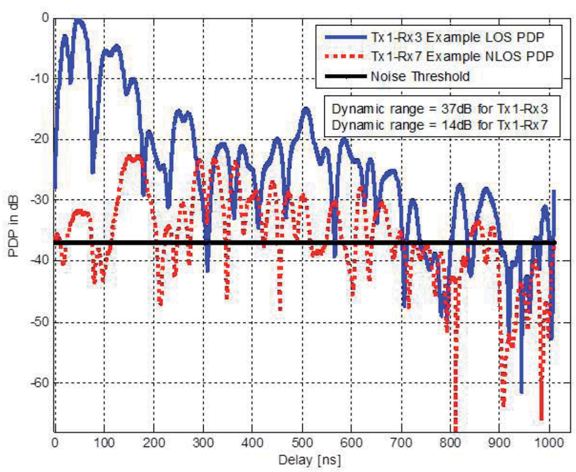

Figure 5. Example power delay profiles for line-of-sight (Tx1-Rx3) and non-line-of-sight (Tx1-Rx7) locations, 4900 MHz band.

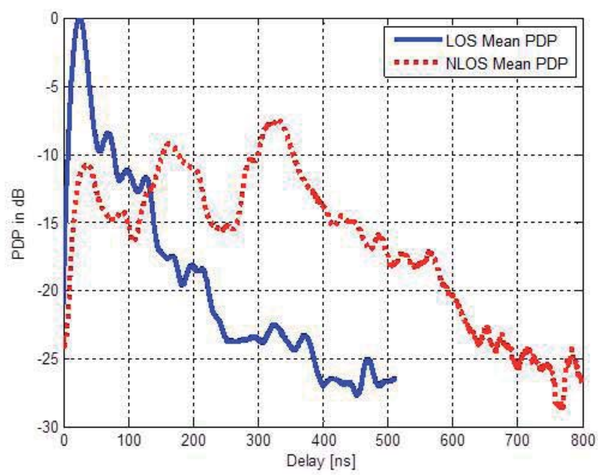

Figure 6. The average power delay profiles for all line-of-sight and non-line-of-sight locations, 700 MHz band.

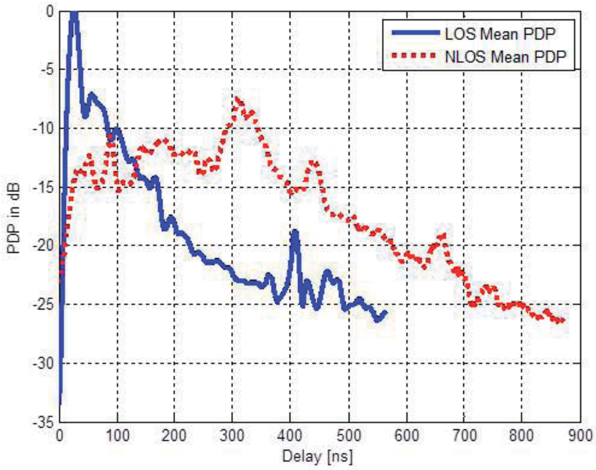

Figure 7. The average power delay profiles for all line-of-sight and non-line-of-sight locations, 4900 MHz band.

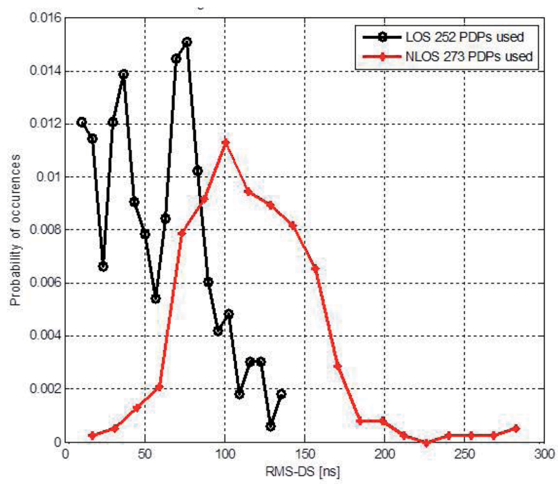

Figure 8. Histograms for root-mean-square delay spread (RMS-DS) for power delay profiles in both line-of-sight and non-line-of-sight locations, 700 MHz band.

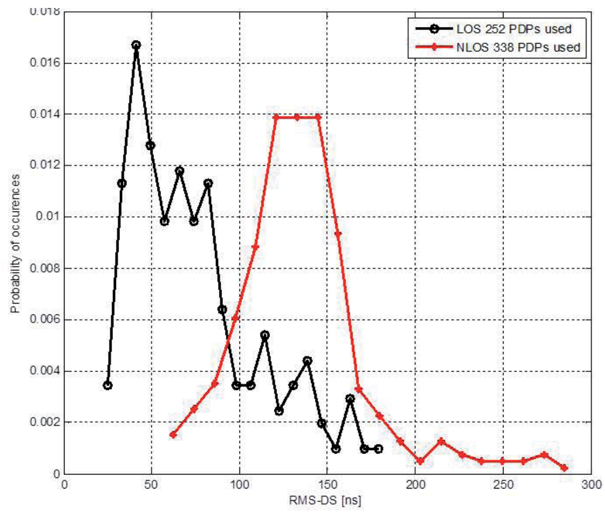

Figure 9. Histograms for root-mean-square delay spread for power delay profiles in both line-of-sight and non-line-of-sight locations, 4900 MHz band.

and that the range of delay spreads was a significant fraction of the mean. We can quantify this range via the coefficient of variation $CV = \sigma_{RMS-DS} / \mu_{RMS-DS}$, the ratio of delay spread standard deviation to delay spread mean. Values of CV here were 0.27 to 0.34 for non-line-of-sight, and 0.49 to 0.56 for the line-of-sight cases. Table 3 provides additional statistics on the instantaneous root-mean-square delay spread, and Table 4 shows analogous statistics for the 90% energy delay window $W_{\tau,90}$ and the 25 dB delay interval $I_{\tau,25}$. As expected for this peer-to-peer, short-range setting, the root-mean-square delay spread values were much smaller than those for cellular. For example, the COST207 typical urban cellular channel has RMS-DS ~ 1 μs [34]. Our delay spread values were also substantially smaller than those in [31, 32], in which median delay spreads for their (elevated-antenna) measurements ranged from 300 ns to 700 ns in frequency bands from 430 MHz to 6 GHz.

3.3 Multipath Component Distributions

When creating channel models, one would like to know the number of multipath components present. We used the algorithm in [35] to estimate the number of multipath components, denoted L_p , in each transfer function. This algorithm, which is a modified *MUSIC* algorithm for frequency estimation, uses the minimum description length criterion [36] to determine the number of multipath components, based upon modeling the time-invariant transfer function as a harmonic function of delay: that is, the Fourier transform of the *i*th channel impulse response is viewed as a function of delay, τ , at our given set of measured frequency points, $\{ f_{ki} \}$. Hence, from Equation (1) and [36, Equations (2), (3)], we have

Condition (Band)	Min	Mean	Median	90th Percentile	Max	Standard Deviation
LOS (700)	7	57	56	98	139	32
LOS (4900)	21	75	66	134	183	37
NLOS (700)	11	116	114	163	290	40
NLOS (4900)	57	135	131	172	291	37

Table 3. The summary instantaneous root-mean-square delay spread (RMS-DS) statistics (ns).

Condition (Band)	Min	Mean	Median	Max
LOS W_{90} (700)	24	152	133	427
LOS W_{90} (4900)	33	205	157	538
LOS I_{25} (700)	42	384	435	746
LOS I_{25} (4900)	112	466	**469**	**970**
NLOS W_{90} (700)	36	377	370	976
NLOS W_{90} (4900)	157	442	437	984
NLOS I_{25} (700)	51	645	671	1000
NLOS I_{25} (4900)	355	791	**825**	**1000**

Table 4. The 90% delay window, W_{90}, and the 25 dB delay interval, I_{25}, statistics (ns).

Parameter	700 MHz	4900 MHz
c_0	1.09	0.98
c_1	0.07	0.076
b_{10}	0.39	0.27
b_{11}	0.017	0.003
b_{20}	6.56	0.56
b_{21}	0.018	0.003
τ_2 (ns)	73	70
b_{30}	129	26.7
b_{31}	0.017	0.013
τ_3 (ns)	215	218

Table 6. The power delay profile exponential fit parameters of Equations (5), (6).

$$H(f,t_i) = \sum_{k=1}^{L_{pi}} \alpha_{ki} e^{j\varphi_{ki}} \exp(-j2\pi f \tau_{ki})$$

$$\to H(\tau,t_i) = \sum_{k=1}^{L_{pi}} \alpha_{ki} e^{j\varphi_{ki}} \exp(-j2\pi f_{ki} \tau), \qquad (3)$$

and this representation enables the use of *MUSIC* on this dual function for estimating the discrete delays. Note that to our knowledge, this algorithm has previously been used only for indoor channels. Summary statistics for the number of multipath components are presented in Table 5. These statistics count the number of components within a 25 dB threshold of the peak component in each power delay profile, where we truncated each power delay profile before applying the *MUSIC* algorithm. We employed this threshold because most communication systems typically do not operate at signal-to-noise ratios much larger than this value, and hence models that retain only the largest components are common, e.g., those within a 20 dB threshold in [37]. Typically, one would expect the non-line-of-sight cases to have a substantially larger number of multipath components than the line-of-sight cases, but the non-line-of-sight numbers were only slightly larger, here. We attributed this to the lower dynamic range of the non-line-of-sight power delay profiles.

The distribution of the number of multipath components, L_p, was found to be best fit by a modified uniform distribution. Specifically, let L_{pmin} equal the minimum value of L_p and L_{pmax}, its maximum value (see Table 4). We denote the probability mass function for L_p by $\Pr(L_p = m)$, with integer $m \in \{L_{pmin}$ üü $L_{pmin} +$ $L_{pmax}\}$. The mass function has weight p_0 at L_{pmax} and is uniform with weight equal to $(1-p_0)/(L_{pmax}-L_{pmin})$ from L_{pmin} to $L_{pmax}-1$, or

$$\Pr(L_p = m)$$

$$= \begin{cases} \dfrac{1-p_0}{L_{pmax}-L_{pmin}}, & m = L_{pmin}, L_{pmin}+1, \ldots, L_{pmax}-1 \\ p_0 & , m = L_{pmax} \end{cases} \qquad (4)$$

Values of p_0 are also listed in Table 5. As seen from Table 5, 18-21 multipath components sufficed for the 100 MHz channel at 4900 MHz, and 11-14 multipath components sufficed for the 75 MHz channel at 700 MHz. For construction of channel models for smaller values of bandwidths, multipath components can be combined, as in [22, 38].

The distribution of the powers in these multipath components was obtained by fitting to the average power delay profiles of Figures 6 and 7. For these cases, we employed the following models:

L_P Statistic	700 MHz		4900 MHz	
	LOS	NLOS	LOS	NLOS
Minimum	4	3	3	3
Median	11.50	13	17	20.50
Mean	10.49	11.47	16	17.91
90th Percentile	14	14	21	21
Maximum	14	14	21	21
Standard Deviation	3.34	3.10	4.70	4.74
P_0	0.3294	0.4428	0.2619	0.5

Table 5. The statistics for a number of multipath components L_P, with a 25 dB threshold from the power delay profile peak, plus the modified uniform probability mass function fit parameter, P_0.

Band	LOS Parameter v	NLOS Parameter (a,b)
700 MHz	318.2	(452.7, 1.57)
4900 MHz	340.6	(472.8, 1.6)

Table 7. The multipath component delay distribution probability density function parameters for Equations (7), (8).

$$P_{\tau,LOS}(\tau)=c_0\exp(-c_1\tau), \quad (5)$$

$$P_{\tau,üüüü}(\tau)=\sum_{k=1}^{N_c} b_{\ 0}\exp\left[-b_{\ 1}(\tau-\tau\ )\right], \quad (6)$$

where $N_c=3$ in Equation (6) is the number of clusters (or sometimes, “multipath groups”) of multipath components for the non-line-of-sight case. The use of clusters is common in channel models for other settings as well: for example, the indoor setting in [14] and the outdoor macrocell setting in [37]. Our clusters were based upon visual observation of the average power delay profiles. They were better defined for the 700 MHz band data, and we saw that the 4900 MHz band clusters tended to overlap more substantially (see Figures 6, 7). The model coefficients are given in Table 6, where the first cluster delay $\tau_1=0$.

For the delays of the multipath components within clusters, other researchers have employed randomly distributed delays: for example, Poisson in [14], or for ultra-wideband channels, uniformly distributed delays [39], or Weibull distributed delays [40, 41]. If we based the delay distribution upon the average power delay profiles, uniform distributions of delays fitted the line-of-sight cases in intervals [0, 500 ns) for the 700 MHz band, and [0, 550 ns) for the 4900 MHz band. The average power delay profiles for the non-line-of-sight cases could also be fit with uniformly distributed delays. Even better models for the delay distributions were derived by collecting statistics on delays over *all* the measured power delay profiles. The results of this were that the line-of-sight cases were best fit by an exponential distribution of delays, and the non-line-of-sight cases were best fit by a Weibull distribution [42] of delays. Specifically, the multipath component delay probability density functions were as follows:

$$p_{\tau,LOS}(\tau)=\exp(-\tau/v)/v, \quad (7)$$

$$p_{\tau,NLOS}(\tau)=\frac{\beta}{a^{\beta}}\tau^{\beta-1}\exp\left[-\left(\frac{\tau}{a}\right)^{\beta}\right], \quad (8)$$

where in the Weibull density of Equation (8), β is the shape factor, and $a=\sqrt{\Omega/\Gamma\left[(2/\beta)+1\right]}$ is a scale parameter with $\Omega=E\left(\tau^2\right)$ being the second moment, and Γ is the gamma function. Parameter values for these multipath component delay probability density functions are given in Table 7.

Finally, note that in other models [14, 37], for simplicity, the decay constants b_{k1} of Equation (6) for the decays within each cluster are assumed identical. However, as with our results here, this is not always true: some ultra-wideband models described in [39] employed different values of decay constants per cluster. If desired for simplicity, one could of course select a single value of decay constant from our models, as well.

3.4 Path Loss

With a known reference path loss and accurate calibration, we also used our vector network analyzer measurements to estimate propagation path loss. For each transmitter-receiver location pair, we had 18 path-loss measurements. These corresponded to three groups of

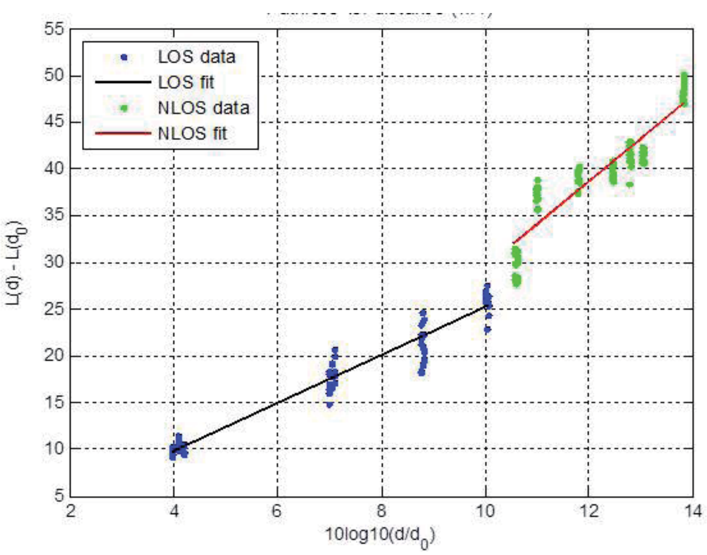

Figure 10. Excess propagation path loss (dB) as a function of $\log(\mathrm{distance}/d_0)$, 700 MHz band.

		n	σ_X (dB)	L_c (dB)
700 MHz				
Tx1	**LOS**	2.57	1.46	4.23
	NLOS	4.57	2.13	
Tx2	**LOS**	2.34	2.94	8.27
	NLOS	5.76	2.23	
Tx3	**LOS**	4.37	2.63	11.69
	NLOS	3.42	3.44	
All Tx	**LOS**	2.27	3.06	
	NLOS	3.58	2.92	
4900 MHz				
Tx1	**LOS**	1.34	1.25	7.73
	NLOS	4.04	2.47	
Tx2	**LOS**	1.59	2.54	7.08
	NLOS	5.18	3.23	
Tx3	**LOS**	1.53	2.74	12.87
	NLOS	3.47	3.02	
All Tx	**LOS**	1.64	2.65	
	NLOS	3.35	3.16	

Table 8. The path loss model parameters: $n =$ path loss exponent, $\sigma_X =$ standard deviation of Gaussian random variable, $L_c =$ corner loss.

six measurements on our Cartesian positioner: group one represented the six measurements (two measurements at each of the three positioner points) at distance *d*, group two represented the six measurements at distance $d + 0.25$ m, and group three represented the six measurements at $d + 0.5$ m. (Recall that we had nine points on our Cartesian grid for each transmitter antenna location, and at each point we collected two transfer functions: see Figure 3.)

To attempt to average out the effects of small-scale (multipath) fading, we estimated the path loss as the difference between the known transmitted power at the band's center (equal to the power at any frequency in the band) and the average of the magnitude-squared of the received transfer function, with the average taken across all frequency points in the band (75 MHz for the 700 MHz band, and 100 MHz for the 4900 MHz band). As discussed, measurements were made with respect to a 4 m reference: that is, antenna gains were also removed.

Figure 10 shows a plot of path loss in dB as a function of $10\log\left(\text{distance}/d_0\right)$ for the 700 MHz band, transmitter location T1, where $d_0 = 4$ m was the reference distance. This reference distance was also used for the 4900 MHz band. Reference measurements were made at the NIST open area test site in Boulder, CO, which closely simulated free-space conditions, with the nearest reflecting objects well outside the time window of the measurement. Ground reflections were avoided by sufficiently elevating the antennas during the reference measurement. Linear fits on the log-log scale are also shown in the figure. These were least-squares fits, and for the line-of-sight case, these fits corresponded to the following path-loss model:

$$L_{LOS}(d) = L(d_0) + 10 n_{LOS} \log(d/d_0) + X_{LOS}, \quad (9)$$

where n_{LOS} is the propagation-path-loss exponent, and X_{LOS} is a zero-mean Gaussian random variable with standard deviation σ_X dB. For non-line-of-sight L-shaped paths, we used

$$L_{NLOS}(d_1, d_2)$$

$$= \tilde{L}_{LOS}(d_1) + 10 n_{NLOS} \log(d_2/d_1) + L_c + X_{NLOS} \quad (10)$$

where n_{NLOS} and X_{NLOS} are analogous to the line-of-sight parameter definitions, distances d_1 and d_2 correspond to L-shaped path distances (see Section 2), and $\tilde{L}_{LOS}(d_1) = L_{LOS}(d_1) - X_{LOS}$, so that we did not apply the Gaussian random variable twice for the non-line-of-sight path loss. The parameter L_c is the "corner loss" added to the line-of-sight path loss at distance d_1 this loss term was also used in [16]. The corner loss represents the "step" discontinuity amount between the line-of-sight and non-line-of-sight fits: see Figure 10. The intercept value, $L(d_0)$, is equal to the free-space value at the band's center for both bands, i.e., $L_{üüü}(d\ ) = 42$ dB, and $L_{4900\text{MHz}}(d_0) = 58$ dB.

Table 8 shows values for the path-loss model parameters. Path-loss exponents for the line-of-sight case were less than those for non-line-of-sight regions, as expected. Based upon our transmitter locations, the non-line-of-sight exponents also increased with the distance from the transmitter to the corner (d_1 in Table 1). This same dependence on "corner distance" was also observed in [16]. Our measurements were in the smaller range of corner distances covered in [16], but the range of path-loss exponents found generally agreed with values given in [16]. For the line-of-sight case, exponents less than two may indicate waveguiding by the urban canyon walls: this was most noticeable for the 4900 MHz band. For the 700 MHz band line-of-sight results, fitted path-loss exponents were generally slightly larger than that for free space ($n = 2$), except for transmitter location 3; as per the model, path-loss variation is quantified by the Gaussian random variables (*X*) in Equations (9) and (10). Transmitter location 3 was very close to the building wall on 17th Street, and was partly shadowed by several pillars that extended out from the wall. The non-line-of-sight exponents ranged from 3.6 to nearly 6.

4. Spatial Characteristics

By mounting the transmitter on the two-dimensional positioner described in Section 2, we introduced spatial diversity into the measurement system. This enabled us to generate channel impulse responses both as functions of delay, τ, and angle of departure, θ. To this end, the measured frequency responses, $H_{xy}(f, t_i)$, at grid point (x, y) on the Cartesian plane of the positioner were synthesized through the conventional beamformer for a rectangular grid [43]:

$$H(f, \theta, t_i) \tag{11}$$

$$= \sum_{x=0,0.25,0.5\text{m}} \sum_{y=0,0.25,0.5\text{m}} H_{xy}(f, t_i) e^{-j\frac{2\pi f}{c}(x\cos\theta + y\sin\theta)}$$

where c is the speed of light. Taking the inverse Fourier transform of $H(f, \theta, t_i)$ then yielded the ith two-dimensional channel impulse response, $h(\tau, \theta, t_i)$. The multipath components identified and indexed according to delay, τ_{ki}, through the procedure in Section 3.3 were also indexed according to angle θ_{ki}. The latter was accomplished by segmenting the delay axis of the ith two-dimensional channel impulse response into bins

$$\left[\left(\tau_{ki} + \tau_{k-1,i}\right)/2, \left(\tau_{ki} + \tau_{k+1,i}\right)/2\right],$$

and then searching the power angle profile (PAP) of each bin along the angle axis for the angle θ_{ki} at which the peak occurred.

Most researchers conducting joint spatial-temporal analysis [44-52] assumed independence between the delay and angle domains. In this study, we also found that assumption to be valid in line-of-sight conditions, and partially valid in non-line-of-sight to within multipath component clusters. Together with Equations (5)-(8), this allowed the power-delay-angle profile, $P(\tau, \theta)$, and the multipath component delay-angle distribution probability density functions, $p(\tau, \theta)$, to be respectively separated into their marginal components as

$$P_{LOS}(\tau, \theta) = P_{\tau,LOS}(\tau) P_{\theta,LOS}(\theta), \tag{12}$$

$$P_{NLOS}(\tau, \theta) = P_{\tau,NLOS}(\tau) P_{\theta,NLOS}(\theta), \tag{13}$$

and

$$p_{LOS}(\tau, \theta) = p_{\tau,LOS}(\tau) p_{\theta,LOS}(\theta), \tag{14}$$

$$p_{NLOS,k}(\tau, \theta) = p_{\tau,NLOS}(\tau) p_{\theta,NLOS}(\theta), \tag{15}$$

where k denotes the cluster index in Equation (6). Note that P is power as a function of both delay and angle, and p is the density (discrete) of the presence/absence of multipath component as a function of both delay and angle.

In order to characterize the power-angle profile, the non-line-of-sight multipath components were grouped into three clusters based solely on their delay index according to the same clustering rule described in Section 3.1. Once clustered, the powers of the multipath components of each cluster were first normalized to a unity sum, while their angles were shifted by setting their mean cluster angle to zero. The normalized powers as functions of the shifted angles from each cluster were then superimposed to extract the angle decay constants, $c_{1,\theta}$ and $b_{k1,\theta}$, for the following models, through a robust fit to the data points (robust fitting henceforth denotes the Trust Region Method, explained in [53]):

$$P_{\theta,LOS}(\theta) = \exp\left(-c_{1,\theta}|\theta|\right), \tag{16}$$

$$P_{\theta,NLOS,k}(\theta) = \exp\left(-b_{k1,\theta}|\theta - \mu_\theta|\right), \tag{17}$$

where $\mu_\theta \sim \mathrm{U}[0, 2\pi)$ is a uniformly distributed random variable that represents the mean cluster angle in non-line-of-sight conditions. Table 9 contains the parameter values. The values showed that in general, the fitted power decreased with a smaller decay constant in both line-of-sight and non-line-of-sight conditions at 4900 MHz compared to 700 MHz, which was likely due to the increased scattering at higher frequencies. In non-line-of-sight, the decay

Parameter	700 MHz (1/°)	4900 MHz (1/°)
$c_{1,\theta}$	0.00103	0.00040
$b_{11,\theta}$	0.00494	0.00257
$b_{21,\theta}$	0.00221	0.00012
$b_{31,\theta}$	0.00124	0.00040

Table 9. The power angle profile (PAP) exponential fit parameters of Equations (16), (17).

Parameter	700 MHz (°)	4900 MHz (°)
v_{LOS}	73.8	86.3
$v_{NLOS,1}$	52.7	56.6
$v_{NLOS,2}$	40.3	81.9
$v_{NLOS,3}$	77.3	86.0

Table 10. The multipath component angle distribution probability densityfunction parameters, Equations (18), (19).

constant of the first cluster was the largest, and tended to decrease with cluster index, meaning that the power spread in angle progressively from the first to the third cluster. The decay constant of the third cluster was close to zero, and comparable to those values in line-of-sight conditions for which the power was spread more uniformly around the azimuth angle-of-departure.

The powers of the first and second non-line-of-sight clusters were the most concentrated in angle, because the clusters arrived from (likely, singly) reflected paths that yielded arrivals at the receiver from distinct directions. Conversely, the sole cluster in line-of-sight combined paths that were much shorter and concentrated in delay (see RMS-DS in Table 2), and with arrivals that had strong and comparable powers. The variance in the line-of-sight component angles was attributable to local scattering. This difference between line-of-sight and non-line-of-sight was first observed in [46]. Last, the third cluster in non-line-of-sight combined reflected paths (possibly multiple reflections) from distant scatterers with weaker and comparable powers, and so resembled the line-of-sight angle distribution, yet on a larger spatial scale.

As in [44-46], we found the probability density functions of the shifted angles to be Laplacian distributed in both line-of-sight and non-line-of-sight conditions:

$$p_{\theta,LOS}(\theta) = \frac{1}{2v_{\theta,LOS}} \exp\left(-\frac{|\theta|}{v_{\theta,LOS}}\right), \qquad (18)$$

$$p_{\theta,NLOS,k}(\theta) = \frac{1}{2v_{\theta,NLOS,k}} \exp\left(-\frac{|\theta-\mu_\theta|}{v_{\theta,NLOS,k}}\right). \qquad (19)$$

The scale parameters, $v_{\theta,LOS}$ and $v_{\theta,LOS,k}$, were also found by robust fitting of a curve to the histograms of the centered angles given from the clusters in line-of-sight and non-line-of-sight conditions, respectively, with a distinct fit for each cluster *k*. The values appear in Table 10, and confirmed the observations noted above for the power-angle profile: in non-line-of-sight conditions, the angle distribution of the first cluster was narrower and tended to spread out with cluster index, whereas the scale parameter of the distribution of the third cluster was comparable to line-of-sight conditions. The distributions at 4900 MHz are also wider than at 700 MHz, due to increased scattering.

Note that considering the *i*th two-dimensional channel impulse response alone yielded only two responses per location pair for $i = 1, 2$. In order to generate more responses to greater populate the data points in Equations (16)-(19), we generated 16 channel impulse responses per antenna-position pair by grouping the grid points of the positioner by rows with index $i = 1, 2$, and then taking the $8 = 2^3$ group permutations to generate $H(f, \theta, t_i)$ in Equation (11). The other eight permutations were given by grouping the grid points by column, instead. Although a total of $512 = 2^9$ permutations would have been possible by taking the points individually rather than by row or column, there would have been less variation between the two-dimensional channel impulse responses. We found that groups of three struck a fair balance between variation and number of responses. As explained in Section 2, while each vector network analyzer sweep was completed within the coherence time of the channel, the channel did change during the spatial sweep over the positioner grid points, mainly due to the passing cars on the street. As our intention was to capture the salient properties of the fixed environment, which included primary scatterers consisting of surrounding buildings and streets, we hoped to average out the mobile scatterers by means of the permutation method explained above.

Finally, we completed our spatial analysis by providing the angle spread statistics complementary to those described in Section 2 for delay, namely the root-mean-square angle spread (RMS-AS); the angle window, $W_{\theta,90}$, which is defined as the space along the angle axis that contains 90% of the two-dimensional channel impulse response energy of each cluster; and the angle interval, $I_{\theta,25}$, which is defined as the space of the two-dimensional channel impulse response energy of each cluster containing all impulses above 25 dB down from the largest impulse. These quantities are reported in Table 2, together with the analogous quantities in delay. The angle dispersion statistics (RMS-AS, $W_{\theta,90}$, $I_{\theta,25}$) again were consistent with our previous observations in that all three estimated quantities were generally larger at 4900 MHz than at 700 MHz, resulting in a wider angle spread in the former due to increased scattering.

5. Conclusion

In this paper, we reported on channel measurements and models for urban peer-to-peer ground-based channels in the 700 MHz and 4900 MHz public-safety bands. This application and band has *not* been previously studied. Non-mobile outdoor measurements for link distances up to approximately 100 m were made with a vector network analyzer and omnidirectional antennas at a height of 1.6 m.

For propagation path loss, we found path-loss exponents to range from 1.3 to 4.4 for line-of-sight cases, and from 3.6 to 5.8 for non-line-of-sight cases around corners. In agreement with results found by other researchers, delay dispersion statistics appeared similar for the two bands. The 90th percentile values for the root-mean-square delay spread ranged from approximately 100 ns for line-of-sight cases at 700 MHz, to 170 ns for non-line-of-sight cases at 4900 MHz, with maximum values of delay spread near 300 ns. We employed a "dual *MUSIC*" algorithm to determine the number of multipath components. We found that for our measurement bandwidths of 75 MHz at 700 MHz and 100 MHz at 4900 MHz, the mean values of the number of multipath components were 11 and 17, respectively. Least-square fits for the powers and delays of the multipath components were also computed, yielding complete statistical delay domain channel models. The angle dispersion statistics were also found to be similar for the two bands. However, in general we observed a wider multipath component angle distribution at 4900 MHz than at 700 MHz, due to the increased scattering at higher frequencies. In non-line-of-sight, the earlier-arriving clusters corresponding to the dominant reflected paths were also more concentrated in angle compared to the later arrivals. The 90th-percentile window containing the angle-of-departure spread for the 700 MHz line-of-sight data was 124°, and increased to 205°, 209°, and 260° for the 700 MHz non-line-of-sight, 4900 MHz line-of-sight, and 4900 MHz non-line-of-sight cases, respectively, even though the rms angular spread was within 10° for all four conditions.

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Report on GASS Commission Business Meetings

COMMISSION C (RADIOCOMMUNICATION SYSTEMS AND SIGNAL PROCESSING

1. Results of Election of Vice Chair

Two distinguished candidates were nominated for the position of Vice Chair: Prof. Amir Zaghloul from Virginia Tech in the US, and Prof. Said El-Khamy from Alexandria University in Egypt. Both candidates were present at the meeting, and gave a statement about their vision of URSI in general, and Commission C in particular. Collecting the votes received by e-mail as well as those expressed at the meeting, the count was in favor of Prof. Amir I. Zaghloul to act as the new Commission C Vice Chair.

2. Results of Election of Early Career Representative

Three candidates were nominated for the Early Career Representative (ECR): Ms. Noha Ossama El-Ganainy, from the Arab Academy of Science and Technology, Egypt; Mr. Ruisi He, from the Universite Catholique de Louvain, Belgium; and Dr. Hongjian Sun, from Durham University, UK. Ruisi He was present at the meeting, and presented himself and his view of his role as ECR. Collecting the votes received by e-mail as well as those expressed at the meeting, the count was in favor of Ruisi He, who will act as Commission C's ECR.

3. Appointment of Associate Editor for *Radio Science Bulletin*

Both Prof. Amir Zaghloul and Prof. Said El-Khamy were appointed as Associate Editors to cover the diverse topics of Commission C.

4. Updates/Status of Working Groups

Commission C currently has no working groups.

5. Updates to Terms of Reference of Commission

The terms of reference were reviewed, and it was agreed that they continue to be appropriate and representative of Commission C. No changes were therefore made.

6. Meetings Proposed to be Supported in the Coming Triennium

For a number of years, Commission C has organized the International Symposium on Signals Systems and Electronics (ISSSE). It is proposed to continue supporting this main conference of Commission C.

7. Report and Comments on the Scientific Program of the Commission for the Current GASS

In the GASS 2014, Commission C received an exceptionally large number of papers: in excess of 200 papers, covering all of the various areas of the Commission. This reflects the expansion in wireless communication systems, information theory, radar technology, and signal processing. The Commission is pleased to announce that its nominee, Prof. Dr. H. V. Poor, USA, was awarded the Issac Koga Gold Medal.

8. Proposed Sessions for the Next GASS

A number of sessions are planned for the next GASS. Topics include information theory and coding; distributed radar; energy harvesting and green communications; massive multiple antenna technology for future wireless communications; mm-wave communications for small cells and backhaul and indoor access; multi-tier multi-frequency networks; radio localization techniques: satellite, indoor, in tunnels, autonomous; circuit technologies for mobile communications; signal processing for cognitive radio; challenges and advances of carrier aggregation below 6 GHz; resource allocation; and remote sensing.

9. Proposed Sessions for the AT-RASC

The Commission's ISSSE conference is collocated with the AT-RASC, where open and invited special sessions are organized. Topics include 5G, information theory and coding, multiple antenna technology, cognitive radio, green communication, and energy harvesting. In addition, a number of joint sessions were organized with Commissions D and F. The ISSSE will run for three days, May 19-21. The symposium is sponsored by URSI, with technical sponsorship form the IET.

10. Other Business

None.

Chair: Prof. Sana Salous
School of Engineering and Computing Sciences, Durham University, UK DH1 3LE

Vice Chair: Prof. Amir Zaghloul
US Army Research Laboratory and
Virginia Tech, Bradley Department of Electrical and Computer Engineering

Early Career Representative: Dr. Ruisi He
Associate Professor, State Key Laboratory of Rail Traffic Control and Safety, Beijing Jiaotong University, Beijing, 100044, China

COMMISSION D (ELECTRONICS AND PHOTONICS)

1. Results of Election of Vice Chair

There were two candidates for the position of Vice Chair. Hong Guo (China (CIE) and Apostolos Georgiadis (Spain). The result of the election was that Apostolos Georgiadis was elected Vice Chair.

2. Results of Election of Early Career Representative

There were three candidates for the position of the Early Career Representative: Ergun Simsek (USA), Radek Smid (Czech Republic), and Arnaud Vena (France). As a result of the election, Arnaud Vena was elected Early Career Representative.

3. Appointment of Associate Editor for *Radio Science Bulletin*

Arnaud Vena accepted acting as Associate Editor for the *Radio Science Bulletin*.

4. Updates/Status of Working Groups

4.1 D.1 RFID Technologies and Privacy of Data

The Chair is Smail Tedjini (France), and the Vice Chair is Gaetano Marrocco (Italy). We wish to continue, and expect to produce a document/report for the next triennium. There is no change in the representative of this WG, but we plan to invite new participants from the other Commissions, and also some external contributors.

5. Updates to Terms of Reference of Commission

New terms of reference were proposed for Commission D during the business meeting at GASS 2014, Beijing:

The Commission promotes research and reviews new developments in:

- Electronic devices, circuits, systems and applications;
- Photonic devices, circuits, systems and applications;
- Physics, materials, modeling, design, technology and reliability of devices down to nanoscale devices including quantum devices, with particular reference to radio science applications.

The Commission deals with devices for generation, detection, storage, and processing of electromagnetic signals together with their applications from the low frequencies to the optical domain.

La Commission tend à promouvoir les recherches et la revue des nouveaux développements dans:

- dispositifs électroniques, circuits, systèmes et applications;

- dispositifs photoniques, circuits, systèmes et applications;
- physique, matériaux, Modélisation, conception, technologie et fiabilité des dispositifs jusqu'au dispositifs nanométrique y compris les dispositifs quantique présentant un intérêt particulier pour les applications des radiosciences.

La Commission étudie les dispositifs pour la génération, la détection, le stockage, et le traitement des signaux électromagnétiques, ainsi que leurs applications des basses fréquences au domaine optique.

6. Meetings Proposed to be Supported in the Coming Triennium

Not applicable.

7. Report and Comments on the Scientific Program of the Commission for the Current GASS

Not applicable.

8. Proposed Sessions for the Next GASS

Topic (Commissions)
Contact: E-mail

Radio Signal Processing (D, DBC)
C. Caloz: christophe.caloz@polymtl.ca

Energy Harvesting (DB, DBC)
S. Tedjini: Smail.tedjini@grenoble-inp.fr

Wireless Sensing (D, DB)
Ching Eng Jason: pngce@ihpc.a-star.edu.sg

THz (D)
J-L Coutaz: Jean-Louis.Coutaz@univ-savoie.fr

Quantum Optics Information and Metrology (D, DA)
Hong Guo: hongguo@pku.edu.cn

Frontiers in Optical Fibers (D)
S. Selleri: stefano.selleri@unipr.it

Micro and Nano Photonic Devices (D)
F. Kaertner: franz.kaertner@cfel.de (C. Wong)

9. Proposed Sessions for the AT-RASC

D1 Trends in RFID for Identification and Sensing
D2 Energy Harvesting in Wireless Systems
D3 RF MEMs and NEMS
D4 Trends in THz Communications
D5 60 GHz Electronics
D6 Multi-Physics Modeling in Radio Frequency Nanoelectronics
D7 Graphene Nanoelectronics Applications
D8 Plasmonics
D9 Fiber Lasers and Solid State Lasers
D10 Optical Sensors and Biosensors
D11 Signal Processing Antennas
D12 Broadband Ubiquitous Network
D13 Special Sessions

Special Sessions:

S-D: Photonics in the International Year of Light

S-AD: Wireless Power Transmission and Energy Harvesting

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COMMISSION E (ELECTROMAGNETIC ENVIRONMENT AND INTERFERENCE)

1. Results of Election of Vice Chair

There were two candidates for the position of Vice Chair. They were Prof. F. Gronwald and Prof. Y. Hobara. 15 votes received from Canada, China (CIE), Germany, India, Ireland, Israel, Italy, Japan, Korea, Netherlands, Norway, Portugal, Switzerland, UK, and USA.

Dr. Frank Gronwald was declared elected as the Vice Chair of Commission E for the current triennium.

2. Results of Election of Early Career Representative

There were three candidates for the position of Early Career Representative. They were G. Gradoni, Ch. Kasmi, and N. Mora Parra. 17 votes were received from Brazil, China (CIE), Egypt, France, Germany, India, Japan, Korea, Netherlands, Norway, Portugal, Russia, S. Africa, Sweden, Switzerland, UK, and USA.

Dr. Gabriele Gradoni was declared elected as the Early Career Representative (ECR) of Commission E for the current triennium.

3. Appointment of Associate Editor for *Radio Science Bulletin*

Dr. F. Gronwald (Vice Chair elect) was appointed as the Associate Editor for the *Radio Science Bulletin*.

4. Updates/Status of Working Groups

A number of working groups have been established to provide 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 the group's activities during the three-year period.

4.1 E1. Terrestrial and Planetary Electromagnetic Noise Environment

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

This working group deals with the study of the characteristics of electromagnetic noise taking place not only in the terrestrial but also in the planetary environment. The most well-known noise is the atmospheric radio noise from lightning discharges (the so-called sferics, in a wide frequency range from ULF to VHF). Some examples of topical subjects on sferics are (1) monitoring of global lightning activity as studied by high-frequency noise and Shumann resonance phenomena in the ELF band, and (2) ELF transients related to the optical emissions in the mesosphere due to the lightning. Higher-frequency lightning emission provides us with the information on the fine structure of lightning electrical structure, while lower-frequency noise provides us with the macroscopic nature of lightning. The noise coming from the ionosphere/magnetosphere will be discussed as well: micro-pulsations in the ULF range, VLF/ELF emissions and HF emissions due to the plasma instabilities in space. Also, our recent topic is radio emission from the lithosphere, which again covers a wide frequency range, from dc to VHF (or even more). The characteristics and generation mechanisms of those effects and also the seismic effect on the ionosphere will be discussed. Finally, the radio noise environment on other planets (such as Jupiter) will also be our topic. The interactions of these natural noises with artificial noises due to human activity is another subject. Power-line harmonic radiation penetrates into the ionosphere/magnetosphere and induces particle precipitation into the lower ionosphere (this is a kind of pollution of the natural environment by human activity). We also discuss the interaction of the natural environment with human activity.

4.2 E2. Intentional Electromagnetic Interference

Co-Chairs: M. Bäckström (Sweden) and W. Radasky (USA)

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 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.

Over the 2011-2014 period, a large number of conferences dealt with IEMI, along with other aspects of HPEM:

- Joint IEEE AP-S and URSI meeting in Spokane, Washington, July 3-8, 2011. Dr. Giri and Prof. Uslenghi organized an "In Memoriam" special session to remember Dr. Carl Baum (11 papers).

- URSI General Meeting in Istanbul, Turkey, August 15-19, 2011. There was a session organized by Dr. Sabath and Dr. Radasky entitled "High Power EM and IEMI," with 11 papers presented.

- A weeklong short course, HPE 201-2011, was presented in Schloss Noer, Germany, September 18-24, 2011. Dr. Dave Giri served as lecturer and course director.

- IEC SC 77C (High Power Transient Phenomena) Project and Plenary Meetings in Seoul, South Korea, October 19-21, 2011. Work continued on IEMI and HEMP standards for protecting civil systems from these threats. Dr. Radasky chairs IEC SC 77C and the Secretary is Dr. Hoad.

- USNC-URSI conference in Boulder, Colorado, January 4-7, 2012. Several papers were presented dealing with IEMI.

- APEMC in Singapore, May 21-24, 2012. A special session on HEMP and IEMI was organized by Dr. Radasky. Another regular session on HPEM was also held. A total of eight papers were presented.

- EUROEM symposium held in Toulouse, France, from July 2-6, 2012. This symposium was dedicated entirely to HPEM topics, and had 218 papers and 312 participants. There was a significant number of papers dealing with IEMI.

- IEEE EMC symposium held in Pittsburgh, Pennsylvania, from August 4-10, 2012. A workshop was held dealing with intentional EMI (IEMI), and 15 papers were submitted dealing with HPEM and also EM information leakage.

- Joint ICEAA 2012 – IEEE APWC 2012 – EEIS 2012 (URSI Commission E) conference held in Cape Town, South Africa, September 2-7, 2012. Eleven papers were presented dealing with various aspects of HPEM, including IEMI.

- Conference on Environmental Electromagnetics (CEEM) held in Shanghai, China (CIE), from November 6-9, 2012. Several sessions were organized with IEMI papers.

- Directed Energy Professional Society (DEPS) Symposium held in Albuquerque, New Mexico, from November 26-30, 2012. While this conference was aimed mainly at source development, there was a session that included papers covering HEMP and IEMI.

- National Radio Science Meeting sponsored by the USNC-URSI held in Boulder, Colorado, from January 9-12, 2012. There were a few papers dealing with HPEM and IEMI at this meeting.

- An IET seminar entitled "Extreme Electromagnetics – The Triple Threat to Infrastructure," held in London, England, on January 14, 2013. Ten papers were presented dealing with impacts of HPEM (HEMP, IEMI, and severe geomagnetic storms) on the critical infrastructures.

- Asia-Pacific EMC (APEMC) symposium held in Melbourne, Australia, from May 18-23, 2013. There was a workshop on the protection of commercial facilities from HEMP and IEMI, and there was a special session on HPEM with eight papers presented.

- IEEE EMC symposium held in Denver, Colorado, from August 4-8, 2013. There was a workshop on EM information leakage, and a special session on IEMI with six papers presented.

- A session entitled "Intentional EMI (IEMI) and EMC" was organized at PIERS 2013, August 12-15, 2013, in Stockholm, with eight papers.

- EMC Europe Symposium held in Brugge, Belgium, from September 2-6, 2013. There was a workshop presented on the impact of IEMI on the critical infrastructures in Europe, reviewing the work of three special EU-funded projects. A special session on EM information leakage was also held.

- 8th Future Security Research Conference in Berlin, September 17-19, 2013. There were session, "Electromagnetic Threats and Countermeasures," consisting of seven papers, and a panel session with the same title.

- IEC SC 77C (High Power Transient Phenomena) project and plenary meetings held in Ottawa, Canada, from September 23-27, 2013. Work continued on IEMI and HEMP standards for protecting civil systems from these threats. Dr. Radasky chairs IEC SC 77C, and the Secretary is Dr. Richard Hoad from the UK.

4.3 E3. High-Power Electromagnetics

Co-Chairs: F. Sabath (Germany) and R. L. Gardner (USA)

The objective is to encourage research in high-power electromagnetics (HPE). The technical area of HPE consists of the physics and engineering associated with electromagnetic sources, where nonlinear effects associated with high-field regions (and air breakdown) must be 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, because of local field enhancement.

4.4 E4. Lightning Discharges and Related Phenomena

Chair: V. A. Rakov (USA) and S. Yoshida (Japan)

Lightning discharges are one of the two natural sources of electromagnetic interference (EMI), the other being electrostatic discharge. Electric and magnetic fields generated by lightning represent a serious hazard to various systems, particularly those containing sensitive electronics. This WG focuses on the characterization of lightning and its interaction with engineering systems and with the environment, as well as on lightning detection and testing. It covers all aspects of lightning research, including observations, field and laboratory experiments, theoretical studies, and modeling.

Sessions on lightning discharges and related phenomena were organized at PIERS 2011 in Marrakesh, ICAE 2011 in Rio de Janeiro, ICLP 2012 in Vienna, GROUND/LPE 2012 in Bonito, SIPDA 2013 in Belo Horizonte, GROUND/LPE 2014 in Manaus, and ICAE 2014 in Norman, Oklahoma.

4.5 E5. Interaction With and Protection of Complex Electronic Systems

Co-Chairs: F. Gronwald (Germany), J-P. Parmentier (France), and H. Reader (South Africa)

This working group studies the various electronic and electromagnetic aspects related to the interaction with and protection of complex electronic systems. The focus is the analysis of the various coupling paths and their associated transfer functions into complex electronic systems, as formalized in the framework of electromagnetic topology. Analytical, numerical, and measurement techniques are used to characterize the electromagnetic fields and currents in a complex environment. In the analysis, special attention is placed on the emergence of new technologies, and the inclusion of advanced materials and communication systems. Functional safety is an integral part of the studies

4.6 E6. Spectrum Management

Chair: T. Tjelta (Norway) and R. Struzak (Poland)

The E6 focus is on sound scientific spectrum management for improved utilization of the radio frequencies for protection of wireless communications service and radio science. The goal is to assure further development of radio science and communication services, unobstructed by potential radio interference due to unwanted energy in the form of out-of-band and in-band encroaching and deleterious in-band and out-of-band emissions. The electromagnetic spectrum is treated as a limited natural resource, with a multitude of competing demands for access to it and use of it. Spectrum management seeks innovative means and technologies for adequate coexistence of all of them, taking into account the need of protection of new and incumbent wireless and wired communication services, systems, and equipment, with special focus on science services and those that use passive technologies.

Two of the papers presented at the previous GASS were revised and submitted to the *Radio Science Bulletin*, and were published in No. 340, on the topics

- Spectrum Management Overview
- Opportunistic Secondary Spectrum Access: Opportunities and Limitations

The WG planned a session at the first Commission E Electromagnetic Environment and Interference Symposium (EEIS 2012) in Cape Town, but there was very limited response and, in the end, no session on spectrum management. This was seen as a good opportunity to deal with the spectrum issues in between the General Assemblies.

A session on spectrum-management topics has been planned together with Commission J for the GASS 2014. Some papers were received, and the session will be held.

It appears difficult to engage the community in between General Assemblies to address spectrum-management topics: either to improve spectrum utilization, or to ensure an acceptable, "interference free" environment for radio science services.

4.7 E7. Geo-Electromagnetic Disturbances and Their Effects on Technological Systems

Chair: A. Viljanen (Finland)

4.8 E8. Electromagnetic Compatibility in Wired and Wireless Systems

Co-Chairs: A. Zeddam (France), F. Rachidi (Switzerland) and F. Gronwald (Germany)

The intensive use of the electromagnetic spectrum for communications has resulted in issues of compatibility and interoperability between different users. In addition, the continual increase in the operating frequencies of products and higher frequency sources of disturbances (such as ultra-wideband systems) has resulted in an increase of potential EMC problems in communication systems, and the use of power lines for carrying data is adding to interference problems. This session will focus on theoretical and experimental EMC aspects in both wired and wireless communication systems. Potential remedies will be also addressed.

4.9 Commission E

Joint Working Groups

4.9.1 Inter-Commission Working Group on Solar Power Satellites

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

4.9.2 Inter-Commission Working Group on Natural and Human Induced Hazards and Disasters

Co-Chair for Commission E: W. A. Radasky (USA)

4.9.3 EGH. Seismo Electromagnetics (Lithosphere-Atmosphere-Ionosphere Coupling)

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

5. Updates to Terms of Reference of Commission

There were no updates to the Terms of Reference.
The current Terms of Reference are as follows:
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.

6. Meetings Proposed to be Supported in the Coming Triennium

Commission E will support the following meetings in the current triennium:

- First URSI Atlantic Radio Science Conference (URSI AT-RASC), May 18-22, 2015, to be held in the ExpoMeloneras Convention Centre, Gran Canaria, Spain.
- Asia-Pacific Radio Science Conference (AP-RASC), August 21-25, 2016, to be held in the Convention Center, Seoul, South Korea.
- URSI General Assembly and Scientific Symposium, Montreal, Canada, to be held in 2017.

7. Report and Comments on the Scientific Program of the Commission for the Current GASS

Commission E offered 16 sessions at the URSI GASS in Beijing (2014). In addition, there were five more sessions co-organized with other Commissions. They were all well attended and, generally speaking, there were several lively discussions following the presentations.

In the URSI Questionnaire for Participants of the URSI GASS in Istanbul (2011), 22 (8.4%) of the 261 respondents chose Commission E as the Commission that best met their needs. Also, 51 (9.1%) of the respondents from the 2011 GASS said they attended Commission E sessions. We wish to get similar results if such a questionnaire was available at the GASS in Beijing.

8. Proposed Sessions for the Next GASS

Referring to the sessions listed under item 9 below, the planned sessions for the URSI GASS in Montreal 2017 are expected to be very similar. There is the possibility of adding some more special sessions on current topics.

9. Proposed Sessions for the AT-RASC

At the time of writing this report (February 12, 2015), the sessions planned at AT-RASC are as follows:

- E.1 Communication in the Presence of Noise
- E.2 Crosstalk
- E.3 Electromagnetic Compatibility Education
- E.4 Electromagnetic Compatibility Measurements and Standards
- E.5 Electromagnetic Noise of Natural Origin
- E.6 Electromagnetic Radiation Hazards
- E.7 High-Power Effects of Transients on Electronic Systems
- E.8 Spectrum Management and Utilization
- E.9 Other
  - S-EB. High-Power Electromagnetics
  - S-EC. Time Reversal in Electromagnetic Environments: Theory and Applications
  - S-EF1. Understanding Microwave Processing of Materials
  - S-EF2. Statistical Methods in Electromagnetics
  - S-EAB. Chaos and Complexity in Electromagnetics
- E.10 Latest Results

We intend to combine papers into technical sessions with five or six papers or 10-12 papers in each session from the submitted papers.

10. Other Business

None.

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COMMISSION F (WAVE PROPAGATION AND REMOTE SENSING)

Three business meetings were planned at the URSI GASS 2014 (August 17-23, Beijing, China) by Roger Lang, Chair of Commission F: Monday August 18, 17:40-19:00; Wednesday August 20, 17:40-19:00; Friday August 22, 17:40-19:20. During these business meetings, several topics were discussed by the members of Commission F, as described in the following.

1. Results of Election of Vice Chair

The candidates for Vice Chair for 2014-2017 were T. Tanzi (France) and V. Chandrasker (USA). V. Chandrasker (Colorado State University, Fort Collins, CO 80523 USA; e-mail: chandra@engr.colostate.edu) was elected Vice Chair.

2. Results of Election of Early Career Representative

The candidates were S. Das (India), D. Swain (India), S. Ambroziak (Poland), and M. Kurum (Turkey). M. Kurum (TUBITAK-BILGEM, Information Technologies Institute, Gebze, Kocaeli, PK: 74, 41470 - Turkey; e-mail: mehkurum@hotmail.com) was elected ERC.

3. Appointment of Associate Editor for *Radio Science Bulletin*

The past Associate Editor was Simonetta Paloscia (Vice Chair 2011-2014), who handled the review of a couple of papers for publication in the *Radio Science Bulletin*. The new Associate Editor for the *Radio Science Bulletin* is now V. Chandra, assisted by M. Kurum.

4. Updates/Status of Working Groups

The existing working groups of Commission F are the following:

4.1 Working Group on Mitigation of Ionospheric and Tropospheric Effects on GNSS

Chair: Bertram Arbesser-Rastburg

A short report is provided on the activities of Joint Working Group FG "Atmospheric Remote Sensing Using Satellite Navigation Systems" for the 2014-2017 triennium. The Co-Chair for Commission F is B. Arbesser-Rastburg (Netherlands); the Co-Chair for Commission G is C. Mitchell (United Kingdom).

Several scientific symposia with relevant topics have been held in the last URSI triennium under the auspices of URSI:

- ICTRS 2014, 26-27 June 2014 in Luxembourg (Keynote Speaker Francois Lefreuvre)
- The URSI Commission F Triennial Open Symposium, 30 April to 3 May 2013 in Ottawa, CA (Local Chair: Dr. Cesar Amaya) This Symposium covered all scientific areas of interest to URSI Commission F - this includes remote sensing of the troposphere by GNSS signals.
- Three events were directly organized by the Co-Chairs of WG FG:
  - The 3rd International Colloquium on Scientific & Fundamental Aspects of the Galileo Programme: This colloquium was held at the Danish Design Centre in Copenhagen, Denmark, from August 31 to September 2, 2011, and had sessions on the troposphere and ionosphere, with emphasis on topographic retrieval techniques.
  - The 2013 Beacon Satellite Symposium (http://people.bath.ac.uk/ee3jarr/beaconsatellite2013/). This symposium, which has a 40-year-long tradition, was organized by URSI Commission G, WG G2: "Studies of the Ionosphere Using Beacon Satellites." The 2013 edition was held from July 8-12, 2013, in Bath, UK, and the local chair was Prof. Cathryn Mitchell. It attracted over 150 people, and included topics on measurements of ionospheric quantities such as TEC and scintillation index using GNSS signals. It featured seven oral sessions and one poster session. A selection of papers will be published in a special issue of *Radio Science*.
  - The 4th International Colloquium on Scientific & Fundamental Aspects of the Galileo Programme (http://congrexprojects.com/2013-events/13c15/). This colloquium was held at the Ministry of Transport in Prague from December 4-6, 2013. It had specific sessions on the ionosphere, the troposphere, and on remote sensing with GNSS signals. The event was attended by 97 participants from 23 countries.

Bertram Arbesser considered it a great honor to be asked to continue to lead URSI Working Group FG. However, realizing that the Matera Workshop was 11 years ago, and considering that he is now retired and no longer on the Dutch National URSI Committee, Bertram suggested giving somebody else an opportunity. In particular, he suggested a person who has the right profile for this task: Nicolas Floury, the head of the Wave Interaction and Propagation Section at ESA, who is an expert in remote sensing and has an intimate knowledge of ionospheric physics. Moreover, he is the Commission F representative on the Dutch National URSI Committee, and he has experience with organizing workshops. Nicolas was contacted by Simonetta Paloscia, and he accepted with great enthusiasm the role of working group coordinator.

Next generation remote sensing radars (M. Chandra, J. Isnard, T. Tanzi and W. Keydel)

4.2 Next-Generation Remote-Sensing Radars

Co-Chairs: M. Chandra, J. Isnard, T. Tanzi, and W. Keydel

4.3 RFI Working Group

This is a joint working group of Commissions F, G, H, and J. They will hold a two-day meeting at AT-RASC. The organizer is Willem Baan.

5. Updates to the Terms of Reference of the Commission

The focus of Commission F is on wave propagation and remote sensing.

The goal of the Commission is to study wave propagation and remote sensing in a non-ionized environment.
Specific focus areas include:

- Propagation of waves through Earth and planetary atmospheres and wave interaction with Earth and planetary surfaces, including oceans, land, ice and sub-surfaces.

- Wireless propagation in natural and man-made environments.
- Remote sensing of Earth and planetary environments using active and passive techniques.
- Propagation and remote sensing using Global Navigation Satellite Systems (GNSS) and satellite communication links.
- Applications of these studies, particularly to Earth and planetary sciences, climate studies, and communications.

6. Meetings Proposed to be Supported in the Coming Triennium

Past Commission F Meetings were held in Ottawa (URSI Commission F Triennial Open Symposium, April 30-May 3, 2013) and in Helsinki (Microwave Signatures in November 2013).

Coming meetings are

- AT-RASC meeting in Gran Canaria in May 2015 and AP-RASC meeting
- International Symposium on Signals & Systems (ISSS, Commission C Meeting) that was combined with AT-RASC

A proposal for a further meeting on microwave signatures was made by Simonetta Paloscia. This could be organized in France in 2016 by Monique Dechambre, who is the URSI France national representative.

7. Report and Comments on the Scientific Program of the Commission for the Current GASS

The Commission thinks that the scientific program of the current URSI GASS was well articulated and well representative of all fields of wave propagation and remote sensing.

8. Proposed Sessions for the Next GASS

Setting up a scientific program for a triennium is the prime activity of an URSI Commission in order to achieve an exchange of ideas and research results among individual scientists throughout the world. This is carried out at General Assemblies and other meetings. The main goal of URSI is to give opportunities, especially to young scientists, to present their results.

The members of Commission F will consider the list of sessions already organized for URSI GASS 2014, and will focus on a list of future sessions by taking into consideration the new developments in all fields regarding wave propagation and remote sensing in a non-ionized environment.

The Commission encourages:

a. The study of all frequencies in a non-ionized environment:

   i. wave propagation through planetary, neutral atmospheres and surfaces;

   ii. wave interaction with the planetary surfaces (including land, ocean, and ice), and sub-surfaces;

   iii. characterization of the environment as it affects wave phenomena;

b. The application of the results of these studies, particularly in the areas of remote sensing and communications;

c. The appropriate cooperation with other URSI Commissions and other relevant organizations.

To further these objectives, the Commission collaborates with other URSI Commissions and with other concerned organizations and scientific unions.

9. Proposed Sessions for the AT-RASC

The new elected Vice Chair proposed the organization of a session for the AT-RASC meeting on "Atmospheric Propagation: Advanced Concepts in Propagation and Remote Sensing of Precipitation from Earth and Space."

10. Other Business: Representatives to Other Organizations

Some members of Commission F are representatives of other international organizations:

- IEEE GRS: Steve Reising
- ISPRS: Callisto Tanzi
- SCOR: Scientific Commission on Ocean Research: Roger Lang

- IUCAF: Scientific Commission on Frequency Allocations: Steve Reising
- CoSPAR: Commission on Space Research: Bertram Arbesser-Rastburg
- ITU: Jean Isnard

Chair: Simonetta Paloscia
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COMMISSION G (IONOSPHERIC RADIO AND PROPAGATION)

The Commission G business meetings were held on Monday, August 18, 2014; Wednesday, August 20, 2014 (together with Commission H); and Friday, August 22, 2014.

1. Results of Election of Vice-Chair

At the Monday meeting, Patricia Doherty was elected as the new Commission Vice Chair.

2. Results of Election of Early Career Representative

At the Monday meeting, Seebany Datta-Barua was elected as the Early Career Representative.

3. Appointment of Associate Editor for *Radio Science Bulletin*

The Vice Chair confirmed her willingness to be an Associate Editor of the *Radio Science Bulletin*. John Mathews agreed to assist as History Editor of the *Radio Science Bulletin*. The Chair requested an *RSB* contribution from the tutorial lecturer.

4. Updates/Status of Working Groups

4.1 G1: Ionosonde Network Advisory Group

The Chair is I. A. Galkin (USA), the Vice Chair is J. B. Habarulema (RSA), the *INAG Bulletin* Editor is P. Wilkinson (Australia). (Just after the GASS, Prof. Dr. Baigi Ning from Chinese Academy of Sciences Institute of Geophysics became the Vice Chair.)

4.2 G2: Studies of the Ionosphere Using Beacon Satellites

The Vice Chairs are P. Doherty (USA) with another Vice Chair to be determined, and the Honorary Chair is R. Leitinger (Austria).

4.3 G3: Incoherent Scatter Working Group

The Chair is M. McCready (USA), and the Vice Chair is I. McCrea (UK).

4.4 URSI/COSPAR on International Reference Ionosphere (IRI)

The Chair is David Altadill (Spain), the Vice Chair for COSPAR is Shigeto Watanabe (Japan), the Vice Chair for URSI is Vladimir Truhlik (Czech Republic), and the Secretary is Dieter Bilitza (USA).

4.5 Inter-Commission Working Groups

4.5.1 GF: Middle Atmosphere

The acting Co-Chairs for Commission G are Jorge L. Chau and Erhan Kudeki. There is no Co-Chair for Commission F.

4.5.2 GH: Active Experiments in Space Plasmas

The Co-Chair for Commission G is Todd R. Pedersen, and the Co-Chair for Commission H is M. Kosch.

4.5.3 EGH: Seismo-Electromagnetics (Lithosphere-Atmosphere-Ionosphere Coupling)

The Chairs are Y. Hobara (E), S. Pulinets (G), and H. Rothkaehl (H).

Different kinds of electromagnetic precursors have been accumulated during the last few decades. In particular, geoelectric signals, ULF (ultra-low-frequency) and ELF (extremely low-frequency) electromagnetic emissions are the direct signatures of seismic activity. There have also been observed perturbations in the atmosphere and ionosphere in possible association with earthquakes. The final goal is to understand different kinds of electromagnetic phenomena in the context of lithosphere-atmosphere-ionosphere coupling.

4.5.4 JHG: Inter-Commission Working Group on Characterization and Mitigation of Radio Interference

The Chairs are Terry Bullet (G), Willem Baan (J), and Hanna Rothkaehl (H).

Motivation: Increased commercial and public use of the radio spectrum increasingly affect the scientific use of the spectrum, which is of concern for all URSI Commissions using direct spectral measurements. The higher sensitivity of the scientific detection systems and the observations outside allocated bands will further increase the vulnerability of scientific observations in the rapidly changing spectrum environment.

The presence of interference in scientific data requires the implementation of active mitigation measures to reduce the effects on the measurements. Different science applications and different spectral characteristics of the interference require a variety of mitigation schemes and methodologies.

Purpose: The purpose of the Inter-Commission Working Group (ICWG) is to utilize the interdisciplinary nature of the URSI Commissions in dealing with interference issues, and to capitalize on the different experiences of each of the disciplines. An ICWG will facilitate the discussion of spectral characteristics of interference and applicable mitigation methodologies in order to find new and improved solutions for interference problems. In particular, the interference-rejection experience of commercial usage may provide lessons for the passive users of the spectrum. Exchanging experiences and learning from each other will be a primary objective of the ICWG.

ICWG activities: The ICWG will be used to identify active players in RFI issues in the various URSI Commissions, and to establish a network for exchanging ideas and experience. In addition, dedicated sessions will be facilitated at future URSI meetings, starting with AT-RASC 2015.

4.5.5 Inter-Commission Working Group on Solar Power Satellites

The Chair is Prof. H. Matsumoto (Japan), the Co-Chairs for Commission E are Z. Kawasaki (Japan) and J. Gavan (Israel), the Co-Chair for Commission H is K. Hashimoto (Japan), and the Co-Chair for Commission G is K. Schlegel (Germany).

4.5.6 URSI/IAGA VLF/ELF Remote Sensing of the Ionospheric and Magnetosphere (VERSIM)

The Co-Chair for IAGA Commissions 2 and 3 is C. J. Rodger (New Zealand), the Co-Chair for URSI Commission H is J. Lichtenberger (Hungary), the Co-Chair for URSI Commission G is to be determined.

5. Updates to the Terms of Reference of the Commission

New terms of reference were widely discussed (including discussion on the Internet). The following were agreed to and later ratified by Council.

Commission G on Ionospheric Radio and Propagation (including ionospheric communications and remote sensing of ionized media).

The goal of the Commission is to study the ionosphere and provide its broad understanding to support the use of radio by society on Earth and in space.

Specific areas of focus include:

- Observation of ionospheric structure, variability, coupling, and trends at all relevant scales.
- Modeling of the ionosphere to enable understanding and prediction of its properties.
- Development of the tools, techniques, and instruments necessary to measure ionospheric properties.
- Theory and practice of ionospheric radio propagation and scattering.
- Applications to radio systems, global navigation, communications, space weather, and situations of global concern.

To further these objectives, the Commission collaborates within URSI and with other concerned organizations and scientific unions.

6. Meetings Proposed to be Supported in the Coming Triennium

None provided.

7. Report and Comments on the Scientific Program of the Commission for the Current GASS

None provided.

8. Proposed Sessions for the Next GASS

8.1 "Modeling Geospace Environment"

Conveners: A. A. Namgaladze, e-mail: namgaladzeaa@mstu.edu.ru; M. Foerster, e-mail: mfo@gfz-potsdam.de; O. Martynenko, e-mail: Oleg.Marttinen@google.com.

Abstract

This session will be devoted to the latest achievements in the area of modeling the system consisting of the Earth's atmosphere, ionosphere, plasmasphere, and magnetosphere, including its electrodynamics. The coupling processes of interactions between various regions of the geospace environment will be considered using modern first-principle physical-numerical models. The problems of the inputs and initial and boundary conditions of the models will be discussed, as well as results of their validation via comparisons among the models and both ground-based and satellite observations. This session will foster collaboration among modelers, data providers, and research communities in order to improve mutual understanding and state-of-the-art data analyses of geospace missions.

8.2 HGE: "Atmospheric, Ionospheric, Magnetospheric and High-Energy Effects of Lightning Discharges"

Conveners: Sebastien Celestin (H), e-mail: sebastien.celestin@cnrs-orleans.fr; Ningyu Liu (G), e-mail: nliu@fit.edu; Martin Fullekrug (E), e-mail: M.Fullekrug@bath.ac.uk.

Abstract

The recent discovery that lightning discharges can cause energetic radiation, relativistic particles, and transient luminous events has marked a profound advance in our understanding of the Earth's atmospheric electrodynamic behavior. This session will explore these novel processes and their impact on the atmosphere and the near-Earth environment. The session solicits contributions that advance knowledge in the areas of the global atmospheric electric circuit, lightning physics, transient luminous events, energetic radiation, relativistic particles, and their impact on the Earth's atmosphere, ionosphere, and magnetosphere. One key focus of the session will be novel observations onboard space platforms, such as the lightning imagers on geostationary satellites, the TARANIS satellite, the ASIM payload on the International Space Station, and related ground-based observations and their modeling. Interdisciplinary studies that emphasize the connection between atmospheric layers and the relationship between atmospheric electricity and climate change are particularly welcome.

8.3 Other Proposed Sessions

"Assimilative Modeling and Global Ionosphere Observations"
Chairs: Ivan Galkin and Dieter Bilitza (G)

"Transient Ionospheric Phenomena"
Chairs: John Mathews (G) and TBD (H)

"Plasmo/iono Weather Applications"
Chairs: Matthew Angling and TBD (G)

"Beacon Satellites"
Chairs: Patricia Doherty and TBD (G)

"Plasma Instabilities and Irregularities"
Chairs: Frank Lind (G) and Robert Pfaff (H)

"Algorithms and Methods"
Chairs: Sean Elvidge and TBD (G)

"Modeling Geospace Environment"
Chair: A. A. Namgaladze, M. Foerster (G), O. Martynenko

"Active Experiments"
Chair: Natasha Jackson-Booth (G), and V. Sonwalkar and Robert Moore (H)

"Latest Results"
Chairs: IS, PD, JM (G) (presentations about 10 min)

"Inter-Commission Working Group on Characterization and Mitigation of Radio Interference"
Proposed by Commission J to E, F, G, and H

Chairs: Terry Bullet (G), Willem Baan (J),
Hanna Rothkaehl (H)

"Inter-Commission Working Group on Seismo Electromagnetics (Lithosphere-Atmosphere-Ionosphere Coupling"
Proposed by Commissions E, G, and H
Chairs: Y. Hobara (E), S. Pulinets (G), H. Rothkaehl (H)

"Ionospheric, Magnetospheric and High Energy Effects of Lightning"
Chairs: V. Pasko (G), S. Celestin (H), M. Fullekrug (E)

The final list of the sessions will be presented during AT-RASC 2015.

8.4 Commission G Tutorial for the 2017 GASS

Timothy J. Fuller-Rowell will give a tutorial at the next GASS, title to be confirmed.

9. Proposed Sessions for the AT-RASC

We invite you to submit papers (500 words) for this meeting. The deadline for submission of papers is December 15, 2014.

10. Other Business

10.1 Commission G Memberships

An update of the list of Commission G Representatives was identified.

10.2 Other issues

The number of submitted papers and author attendance at the 2014 GASS have to be encouraged, particularly poster papers.

For the next meeting, poster papers should be submitted on topics relevant to each session, and properly marked.

Initiatives to improve URSI meeting attendance and session leadership amongst young scientists were discussed.

Chair: Iwona M. Stanislawska
E-mail: stanis@cbk.waw.pl

Vice Chair: Patricia H. Doherty
E-mail: Patricia.Doherty@bc.edu

Early Career Representative: Seebany Datta-Barua
E-mail: sdattabarua@gmail.com

COMMISSION K (ELECTROMAGNETICS IN BIOLOGY AND MEDICINE)

1. Results of Election of Vice Chair

During the 2014 GASS, the candidates for Commission K Vice Chair were Samyoung Chung (South Korea) and Gianluca Lazzi (USA). Dr. Samyoung Chung was elected as Vice Chair of URSI Commission K. He works for the National Radio Research Agency in the Ministry of Science, ICT, and Future Planning in South Korea as an Acting Director. He is in charge of the EMF exposure regulation and measurement methods. Since 2008, he has been involved in the ITU-T SG5 as a Vice Chair.

2. Results of Election of Early Career Representative

During the 2014 GASS, the candidates for the Early Career Representative (ECR) were Puyan Mojabi (Canada), Heba Ahmed Shaban (Egypt), Martin O'Halloran (Ireland), and Sachiko Yamaguchi-Sekino (Japan). Dr. Puyan Mojabi was elected as ECR for URSI Commission K. He is an Assistant Professor in the Department of Electrical and Computer Engineering at the University of Manitoba, Winnipeg, Manitoba, Canada. His current research interests include microwave biomedical imaging, electromagnetic field measurements, and environmental remote sensing.

3. Appointment of Associate Editor for *Radio Science Bulletin*

During the URSI GASS 2014 Beijing, Dr. Puyan Mojabi was elected as an Associate Editor for the *Radio Science Bulletin*. Puyan also serves as an Early Career Representative of Commission K.

4. Updates/Status of Working Groups

During the URSI GASS 2014 Beijing, URSI Commission K decided to create a working group dedicated to "Stochastic Modeling for Exposure Assessment." The conveners of this working group are Joe Wiart (France) (wiart@telecom-paristech.fr), and Tongning Wu, China (CIE) (wutongning@emcite.com).

5. Updates to Terms of Reference of Commission K

The last revision of the terms reference of Commission K was in 2008, during the GASS in Chicago in 2008. During the URSI GASS 2014, it was decided to keep the terms reference of Commission K as they were.

6. Meetings Proposed to be Supported in the Coming Triennium

In the coming triennium, it was decided during the Commission K business meeting to support a meeting in Ghent (around BioEM 2016 in Belgium).

7. Report and Comments on the Scientific Program of the Commission for the Current GASS

10 regular sessions were organized during the GASS. In addition to these sessions, one common session with AE (KAE), two with B (KB), two with B and E (KBE), one with E (KE), and one with C and D (CDK) were organized. These sessions showed a relative decrease of research dedicated to the sanitary impact of RF emitted by mobile phones, even if the dosimetry dedicated to compliance tests or epidemiological studies is still an important domain. The sessions have shown the importance of potential application of radio science in medical applications. The discussions during the sessions demonstrated the importance of uncertainty management, and led to a session working group dedicated to "Stochastic Modeling for Exposure Assessment" being proposed. The seven common sessions over the 17 also showed the importance of common work with other URSI Commissions.

8. Proposed Sessions for the Next GASS

The sessions that will be organized for the next GASS will have to take into account the importance of joint sessions. However, no specific sessions have been proposed for the next GASSS, since the discussion was mainly on the proposed sessions in AT-RASC.

9. Proposed Sessions for the AT-RASC

The AT-RASC symposium was intensively discussed during the Commission K business meeting. On the one hand, it is a new symposium that is in competition with others, even if the URSI framework gives to AT-RASC a good opportunity to share interdisciplinary work. AT-RASC is "open," so no regular sessions have been proposed, since they are not relevant. Since RF exposure and uncertainty management are important topics, it was decided during the Commission K business meeting to support and propose two special sessions on these aspects.

10. Other Business

None.

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Vice Chair: Samyoung Chung
National Radio Research Agency in the Ministry of Science, ICT, and Future Planning
767 Bitgaram-ro Naju-si, South Korea
Office: 82-61-338-4520; Mobile: 82-10-4764-2418
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Early Career Representative: Puyan Mojabi
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E-mail: Puyan.Mojabi@UManitoba.ca

Union Resolutions and Recommendations Adopted at the Beijing GASS

U1. Membership dues

The URSI Council,

Considering,

1) that the previous Council's decision specifies that Member dues shall be adjusted for inflation each year;
2) that if URSI does not adjust its Member dues to account for inflation each triennium a much larger adjustment may be required in the future;
3) that total inflation in many Member Committees has been in the range of 4% to 5% over the past triennium;
4) that however some Members may have problems obtaining funding for an increase in dues;
5) that it is also prudent to keep any dues increases in accord with those of other scientific unions

resolves

that the URSI Board shall investigate the impact of a dues increase in the range of 5% on the ability of Member Committees to pay the increase, and shall investigate the range of dues increases being instituted by other scientific unions;

and further resolves

that the URSI Board shall be authorized to increase the dues of URSI members by an amount for the next triennium consistent with the results of these investigations.

U1. Cotisations des membres

Le Conseil de l'URSI,

considérant,

1) que la précédente décision du Conseil précise que les cotisations des membres doivent être réévaluées chaque année en fonction de l'inflation ;
2) que si l'URSI ne réévalue pas les cotisations de ses membres chaque triennat, pour tenir compte de l'inflation, une majoration plus importante sera nécessaire dans le futur ;
3) qu'au total l'inflation, pour une majorité de pays membres, a été comprise entre 4 et 5 % pour le triennat passé ;
4) que cependant certains membres peuvent rencontrer des difficultés pour obtenir les fonts correspondant à l'augmentation de leurs cotisations ;
5) qu'il convient d'être attentif à ce que l'augmentation de cotisations soit conforme à celles des autres unions scientifiques ;

décide

que le Bureau de l'URSI doit se renseigner sur la capacité des pays membres à supporter une augmentation de leurs cotisations de l'ordre de 5% de même que sur le niveau de réévaluation de cotisation effectuée par les autres unions scientifiques ;

et décide en outre

que le Bureau de l'URSI est autorisé à augmenter les cotisations des membres de l'URSI, pour le prochain triennat, d'un montant en accord avec les résultats de ces enquêtes.

U2. Membership Status of Chile

The URSI Council,

Considering,

1) that Chile is currently an Associate Member of URSI;
2) that URSI received a letter from Chile requesting its wish to continue its current status;
3) that URSI would like to continue relations with Chile;

resolves

to maintain Chile as Associate Member of URSI.

U2. Statut du Chili au sein de l'URSI

Le Conseil de l'URSI,

Considérant,

1) que le Chili est actuellement membre associé de l'URSI ;
2) que l'URSI a reçu du Chili un courrier exprimant son souhait de maintenir son statut actuel ;
3) que l'URSI souhaite poursuivre les relations avec le Chili ;

décide

de maintenir le Chili en tant que membre associé de l'URSI.

U3. Membership Status of Argentina and Iraq

The URSI Council,

Considering,

1) that Argentina and Iraq are currently Associate Members of URSI;
2) that URSI has not received a response regarding whether Argentina and Iraq wish to continue their current status;
3) that URSI would like to continue relations with Argentina and Iraq, and hopes that they may once again become active in URSI;

resolves

to maintain Argentina and Iraq as Associate Members of URSI.

U3. Statut de l'Argentine et de l'Iraq au sein de l'URSI

Le Conseil de l'URSI,

Considérant,

1) que l'Argentine et l'Iraq sont actuellement membres associés de l'URSI ;
2) que l'URSI n'a pas reçu de réponse quant à savoir si l'Argentine et l'Iraq souhaitent maintenir leur statut actuel ;
3) que l'URSI souhaite poursuivre les relations avec l'Argentine et l'Iraq, et espère qu'ils pourront redevenir actifs dans l'URSI ;

décide

de maintenir l'Argentine et l'Iraq en tant que membres associés de l'URSI.

U4. Membership Status of Denmark

The URSI Council,

Noting

that the Danish Member Committee has reinstated the payment of its membership dues

confirms

and welcomes Denmark back as Member.

U4. Statut du Danemark au sein de l'URSI

Le Conseil de l'URSI,

notant

que le Danemark a rétabli le paiement de ses cotisations

confirme

et accueille le Danemark entant que membre.

U5. Acceptance of New Members by the Board

The URSI Council,

Considering,

1) That URSI is actively encouraging countries (and especially developing countries) to become Members of URSI;
2) That the URSI Statutes currently permit new Members to be approved into the URSI membership only by action of the Council, which typically meets only every three years, at General Assemblies and Scientific Symposia of URSI;
3) That when a country wishes to become a Member of URSI, it is most beneficial to the country and to URSI for the country to be able to be immediately accepted into membership and become active in URSI affairs;
4) That the requirements for membership in URSI are well defined in the URSI Statutes;

resolves

that the Council authorizes the Board to accept into membership between General Assemblies a country that meets the requirements for membership in the Statutes.

U5. Acceptation de nouveaux membres par le bureau

Le Conseil de l'URSI,

Considérant,

1) Que l'URSI encourage activement les différents pays (en particulier les pays en voie de développement) à devenir membres de l'URSI ;

2) Que les statuts actuels de l'URSI ne permettent l'adhésion de nouveaux membres de l'URSI que par une action du Conseil, lequel se réunit généralement tous les trois ans, lors des Assemblées générales et symposia scientifiques de l'URSI ;
3) Que lorsqu'un pays souhaite devenir membre de l'URSI, il est plus intéressant pour le pays en question et pour l'URSI d'être en mesure d'admettre immédiatement son adhésion afin qu'il puisse devenir actif au sein de l'URSI ;
4) Que les conditions d'adhésion à l'URSI sont bien définies dans les statuts URSI;

décide

que le Conseil autorise le Bureau à accepter comme membre, entre deux assemblées générales, les pays qui respectent les conditions d'adhésion des Statuts.

U6. XXXIInd General Assembly and Scientific Symposium

The URSI Council,

Having considered the invitations for the XXXIInd General Assembly and Scientific Symposium that have been submitted by the URSI Member Committees from Canada (Montreal), and Italy (Rome);

resolves

1) To accept the invitation of the Canadian URSI Committee to hold the XXXIInd General Assembly in Montreal in August 2017;
2) To record its thanks to the Member Committees of Canada and Italy for their invitations.

U6. la XXXIIe Assemblée générale et symposia scientifiques

Le Conseil de l'URSI,

Ayant examiné les invitations pour la XXXIe Assemblée générale et symposia scientifiques qui ont été soumises par les Comités membres de l'URSI du Canada (Montréal) et de l'Italie (Rome) ;

décide

1) d'accepter l'invitation du Comité URSI du Canada à tenir la XXXIIe Assemblée générale à Montréal en août 2017 ;
2) de renouveler ses remerciements aux Comités Membres du Canada et de l'Italie pour leurs invitations.

U7. Vote of thanks to the China (CIE) Member Committee

The URSI Council,

resolves unanimously to convey to the China (CIE) Member Committee its warm thanks and appreciation for the organisation of the XXXIst General Assembly and Scientific Symposium in Beijing.

U7. Remerciements au Comité Membre Chinois (CIE) de l'URSI

Le Conseil de l'URSI,

décide à l'unanimité de transmettre au Comité Membre Chinois (CIE) ses vifs remerciements et sa reconnaissance pour l'organisation de la XXXIe Assemblée générale à Pékin.

CONFERENCE REPORTS

Report on The International Conference on Foundations and Frontiers in Computer, Communications and Electrical Engineering (C2E2-2015)

West Bengal, India, 9 - 10 January 2015

1. Introduction

The Sir J. C. Bose School of Engineering, an institution of the Supreme Knowledge Foundation Group of Institutions (SKFGI), hosted the 2nd International Conference on Foundations and Frontiers in Computer, Communications and Electrical Engineering (C2E2-2015) in the French colonized and historic City of Chandannagar, Mankundu, Hooghly, West Bengal, India on January 9-10, 2015. The conference commemorated 150 years of Maxwell's Equations. It was sponsored by URSI, IEEE AP-S/MTT Kolkata Chapter, BRNS, DRDO, CSIR-CEERI, DST, State DST, and IPR.

2. Conference Objectives

The main objectives of the conference were to bring together leading academicians, scientists, emeritus professors, delegates, researchers, and students across the globe (Figure 1), and to share and exchange their experiences by combining presentations in the theory and applications of Maxwell's equations in various domains of engineering. The key objectives of the conference were:

1. To create more awareness about the emerging trends in the field of computers, communication, and electrical engineering, with applications of Maxwell's equations.

2. To provide an international forum for the exchange of information on the state-of-the-art research in the areas of antennas, propagation, electromagnetic engineering, radio science, cloud computing, image processing, software engineering, electric power, transmission, and other related areas.

3. To explore opportunities and provide a platform to stimulate discussion on key issues of Maxwell's equations, and to have conceptual understandings of the study of dipole radiation, basic understanding of the concept of light as photons, and also using Maxwell's equations for the study of electromagnetism.

Although the Sir J. C. Bose School of Engineering (SKFGI) was celebrating the 150th year of Maxwell's equations, it also paid homage to Galileo on his 450th birth anniversary, since Galileo's work marked the onset of the rise of mathematics as a language of physics. It was indeed a fusion of curiosity, conviction, and courage. Maxwell's equations for electromagnetism have been

Figure 1. Indian participants from CSIR-CEERI, DRDO, IIT, JU, the Chair of C2E2, and foreign participants from Japan, USA, and Taiwan.

called the “second great unification in physics,” after the first unification realized by Isaac Newton. This aspect was highlighted by the invited speakers and dignitaries at the conference.

The conference added a new dimension by the presence of eminent academicians at Swami Vivekananda Auditorium, along with several delegates: Prof. (Dr.) D. V. Giri, Adjunct Professor at the University of New Mexico, USA; Prof. Dr. Tadao Nagatsuma, Department of Systems Innovation, Osaka University, Japan; and Prof. Dr. Tzyh-Guang Ma, National Taiwan University of Science and Technology, Taiwan. Aside from these personalities, Prof. Dr. Rabiranjan Chattopadhyay, Minister-in-charge of Technical Education, Government of West Bengal, presided over the function. Prof. Dr. Tadao Nagatsuma delivered the keynote address. The conference was also attended by a galaxy of eminent persons, delegates, and dignitaries: Prof. N. B. Chakrabarti, Indian Institute of Technology (IIT), Kharagpur, West Bengal, India; Prof. S. C. Dutta Roy, former professor at IIT New Delhi, India; Prof. A. K. Ray, Director, Indian Institute of Engineering Science and Technology, Shibpur, Howrah, West Bengal, India; Prof. P. Banerjee, former scientist at National Physical Laboratory, New Delhi, India; Dr. S. N. Joshi, Emeritus Scientist, Central Electronics Engineering Research Institute (CEERI), Pilani, Rajasthan, India; Dr. L. N. Joshi, Chief Scientist, CEERI-Pilani, India; Prof. Bhaskar Gupta, Jadavpur University, Kolkata, India; Prof. Sourangshu Mukhopadhyay, Burdwan University, West Bengal, India; Dr. Rowdra Ghatak, National Institute of Technology, Durgapur, West Bengal, India; and several other academicians from India and abroad.

The conference received a huge response through the submission of research papers. A few of them were:

1. “James Clerk Maxwell: The Man Who Changed Everything and Was One of Einstein’s Heroes,” by Prof. N. B. Chakraborty (IIT Kharagpur, West Bengal, India)

2. “EM Revitalization Program in Taiwan,” by Prof. Tzyh Guang Ma (National Taiwan University)

3. “Radio Spectral Evolution with Photonics Technologies,” by Prof. Tadao Nagatsuma (Graduate School of Engineering Science, Osaka University)

4. “Solar Power Satellite: Technological Strategy and Global Status,” by Prof. P. Banerjee (former scientist at NPL, New Delhi, and Amity University, Noida, Uttar Pradesh, India)

5. “Materials and Technologies in Growth of Microwave Tubes,” by Dr. S. N. Joshi (CEERI-Pilani, Rajasthan, India)

6. “A Parametric Study of Microstrip Patch Antenna,” by A. Bhattacharya and Prof. B. N. Biswas (Sir J. C. Bose School of Engineering, Chandannagar, Mankundu, West Bengal, India)

7. “A New Method of Obtaining an Ultra-Short Optical Pulse by the Use of Optical Kerr Material and a Sawtooth Optical Pulse,” by Agnijitha Chatterjee and Sourangshu Mukhopadhyay (University of Burdwan, West Bengal, India)

8. “Performance Analysis of VM Scheduling Algorithm of CloudSim in Cloud Computing,” by Md. Ashifuddin Mondal et al. (Narula Institute of Technology, Kolkata, India)

9. “Design of RF Section for X-Band Sheet Beam Klystron,” by S. Indumathi, Prof. L. M. Joshi, et al. (CEERI-Pilani, Rajasthan, India)

10. “Electromagnetic Analysis of Concentric Split Ring Resonators in Conjunction with Microstrip Lines,” by Mukul Das, Dr. Rowdra Ghatak, et al. (National Institute of Technology, Durgapur, West Bengal, India)

The conference was blessed by Prof. Raj Mittra of USA and Prof. Tibor Berceli of Europe, world-renowned stalwarts in the field of electronics and communications engineering.

Along with those invited talks, several other research papers were all published in the *International Journal of Electronics and Communication Technology*, (*IJECT*), **6.1**, SPL-1, English, January-March 2015.

Prof. B. N. Biswas
Chair C2E2 2015
E-mail: baidyanathbiswas@gmail.com

URSI CONFERENCE CALENDAR

March 2015

One week Workshop on Microwave Engineering Essentials for Multiparameter Radar Remote Sensing
Jodhpur, Rajasthan, India, 23-28 March 2015
Contact : Prof. Dr. Madhukar Chandra, Technical Universiy of Chemnitz, Reichenhainerstrasse 70 D-09126 Chemnitz, Germany, Phone : +49 371 531 33 168, Fax : +49 371 531 833 168, E-mail : madhu_chandrainfotech.tu-chemnitz.de

JS2015 – Annual meeting of the French Committee - URSI-France 2015 Scientific Days
"Probing matter with Electromagnetic Waves"
Paris, France, 24-25 March 2015
Contact: Prof. Alain Sibille, Télécom ParisTech, Dept Comelec, 46 rue Barrault, F-75634 Paris Cedex 13, France Phone : +33 01 45 81 70 60, Fax : +33 01 45 80 40 36, E-mail : alain.sibille@telecom-paristech.fr, http://ursi-france.mines-telecom.fr//index.php?id=74

May 2015

URSI AT-RASC 2015 – First URSI Atlantic Radio Science Conference 2015
Gran Canaria, Spain, 18-25 May 2015
Contact: Prof. Peter Van Daele, URSI, Sint-Pietersnieuwstraat 41, B-9000 Gent, Belgium, E-mail: peter.vandaele@intec.ugent.be, http://www.at-rasc.com

July 2015

CEM'15 – Computational ElectroMagnetics International Workshop
Izmir, Turkey, 2-4 July 2015
Contact: cemworkshop@gmail.com or Prof. Levent Gürel ABAKUS Computing Technologies, Fax +90 312 265 0671 E-mail: cemworkshop@gmail.com or Prof. Levent Gürel, ABAKUS Computing Technologies, Fax +90 312 265 0671, E-mail: lgurel@gmail.com, http://cem15.computing.technology/index.html

September 2015

Metamaterials 2015
Oxford, United Kingdom, 7-10 September 2015
Contact: Prof. Richard W. Ziolkowski, Litton Industries John M. Leonis Distinguished Professor, Electrical and Computer Engineering Professor, College of Optical Sciences, University of Arizona, Tucson, AZ 85721, E-mail: ziolkowski@ece.arizona.edu, http://congress2015.metamorphose-vi.org

IEEE Radio and Antenna Days of the Indian Ocean 2015
Mauritius, 21 - 24 September 2015
Contact: RADIO 2015 Conference Secretariat, Radio Society (reg. no. 13488), Gobinsing Road, Union Park, Mauritius, Email: radio2015@radiosociety.org http://www.radiosociety.org/radio2015

November 2015

COSPAR 2015
2nd Symposium of the Committee on Space Research (COSPAR): Water and Life in the Universe
Foz do Iguacu, Brazil, 9-13 November 2015
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http://cosparbrazil2015.org/

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

Corrections and Addendum: List of URSI Officials

In the December 2014 issue of the Radio Science Bulletin, there were some typos in the list of URSI Officials (pp. 93-102) for which we apologize.

These typos have been corrected and were published in an updated version of the December 2014 RSB on **http://www.ursi.org/files/RSBissues/RSB_351_2014_12.pdf**

Commission A, India: Prof. A. Ramakrishnan should read Dr. A. Sen Gupta.

Commission D, India: Prof. A. Ramakrishna instead of a blank.

Commission B, Sweden: Prof. J. Sjöberg should read Prof. **D.** Sjöberg.

Commission B, Switzerland: Dr. J. Mosig should read **Prof.** J. Mosig.

We have also received updates from the Swedish and the Polish URSI Member Committees, which were not able to submit their changes in time due to elections that took place in January 2015.

SWEDEN:

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Commission J: Prof. M. Szymczak

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Due to health problems, Prof. R.L. Dowden is no longer the Commission E Official Member for New Zealand. It is to be decided who will replace him.

Information for Authors

Content

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

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