Radio Science Bulletin

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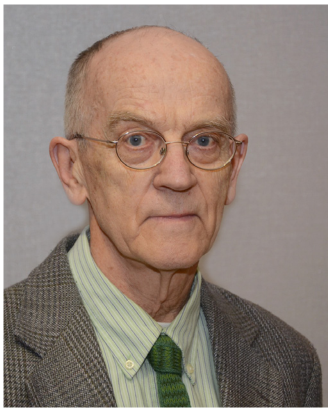
INTERNATIONAL UNION OF RADIO SCIENCE

UNION RADIO-SCIENTIFIQUE INTERNATIONALE

Prof. N. Engheta

Prof. J-P Bérenger



Dr. R.F. Benson

Prof. H.V. Poor

Prof. F.P. Andriulli

Prof. M.B. Cohen

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URSI, c/o Ghent University (INTEC)
St.-Pietersnieuwstraat 41, B-9000 Gent (Belgium)

Contents

Front cover. At the XXXIth URSI GASS in Beijing (China), the scientists whose pictures feature on the front cover will be presented with the URSI Awards. For more information, please turn to page 13 of this Bulletin.

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

Editorial

In this issue, we have a special section on "The Role of Radio Science in Disaster Management." This is the second part of a two-part series that was begun in the June 2013 issue of the *Radio Science Bulletin* (No. 345). The Guest Editors for this special section are Tullio Joseph Tanzi, François Lefeuvre, and Phil Wilkinson. They have provided a separate introduction to the special section.

Papers from the Special Section on "The Role of Radio Science in DisasterManagement"

In their invited paper, Liangpei Zhang and Bin Luo look at recent technologies for disaster management in China (CIE). They begin with a review of the phases of disaster management, noting the importance of data from remote sensing to these phases. They then describe the capabilities of the four Chinese satellites that have been launched for providing remote sensing dedicated to disaster management. Descriptions are provided for how such remote-sensing data are used in typical natural disasters in China, including earthquakes, landslides, and floods. This includes a description of some of the algorithms for processing such data for these natural disasters. This paper provides a current look at how radio science is being used in disaster management in China.

Smart phones have become ubiquitous. In their invited paper, Tullio Joseph Tanzi, Olivier Sebastien, and Fanilo Harivelo present a proposal for integrating smart phones into various aspects of risk management. The authors begin with an overview of the various aspects of risk management, and the roles played by radio communications in a crisis. They point out the potential advantages to be gained from exploiting direct links with the population. They examine the various types of smart phones currently available and likely to be available in the near future, and arrive at a set of minimum specifications that characterize the most widely available smart phones. They look at the programming aspects of smart phones. They examine how smart phones would connect in a disaster, and the human-interaction aspects of their use. They then survey and describe a number of existing smart-phone applications dedicated to various aspects of risk. They look at the various types of networks involved, and the use of smart phones before, during, and after a crisis. They consider the potential networking aspects of communications involving smart phones in a crisis in some detail. This paper provides an excellent overview of the possible advantages to be gained from using smart phones in the general population as sensors, data-reporting, and communications devices in a disaster. It also considers many of the practical issues associated with such potential use.

The topic of the invited paper by François Lefeuvre and Tullio Joseph Tanzi is the role of radio science in the first two weeks after a disaster: the "response phase" of a crisis. The role of radio science in three main areas is considered: communication, data acquisition, and emergency management. The various types of radio communication, observation, and navigation services are reviewed. The factors that can affect these due to variations in the space environment are summarized. The importance and roles of mobile ad-hoc networks in a crisis are explained. The various types of data-acquisition techniques that can be valuable in a disaster are cataloged, including techniques for space-based, aerial, and ground-based data. The methods of making use of such data for emergency management are discussed.

The efforts of the Guest Editors in bringing us this special section are gratefully acknowledged.

Our Other Contributions

Excellent radio science, a good detective story, and fascinating history: when all three are combined in a single paper, it makes for really interesting reading. That is the case with the paper by Jacob W. M. Baars. He has provided us with an account of the developments in flux-density calibration for radio-astronomy sources, spanning more than 50 years. He begins with a simple optical illustration that explains the need for an absolute measurement of the flux density from a radio source. The use of a calibration source is introduced, and the importance of knowing the gain of the antenna with which the measurement is made is explained. Methods of determining antenna gain for two important types of antennas are discussed: the dipole (and dipole array), and the pyramidal horn. The "artificial moon" method of calibrating antennas is explained, and the calibration of receivers is discussed. The paper then turns to an extensive review of absolute measurements. The nature and importance of the variation with time and frequency of the flux-density output of the major astronomical calibration sources is explained in detail. This is followed by the fascinating story of the history of how an absolute flux-density scale was developed, step-by-step, through the work of many groups around the world. This involved improvements in source spectra, gain calibration, extensions in frequency range, extensions to sources of different strengths, and the development of secondary calibration sources. As new frequency ranges of observation (e.g., millimeter and sub-millimeter wavelength ranges) and new observing instruments became available, new advances had to be made in the development of the flux-density scale. I think you will find this paper to be fascinating reading.

In his Radio-Frequency Radiation Safety and Health column, Jim Lin analyses the possible effects of a recently discovered issue related to the way studies have been done on the exposure of cell cultures to static and low-frequency electromagnetic fields. Apparently, the background static and ELF magnetic fields in biological incubators can vary by orders of magnitude, both at different positions within a single incubator and between different incubators. Furthermore, the magnitudes of these background fields can be substantially larger than the fields to which the cell cultures are being exposed. Because these background fields and their variability were not accounted for in almost all studies to date, significant questions arise regarding what should be done with the data and conclusions from such studies. These issues are considered in this column.

Kristian Schlegel has brought us reviews of two interesting books. One deals with the Earth's upper atmosphere. The other, by the same Jacob Baars who authored one of the papers in this issue, reviews his experiences with more than four decades of large radio-telescope projects.

We have reports on several conferences of interest to radio scientists: the 2013 Asia-Pacific Radio Science Conference (AP-RASC 2013), the Indian Regional Conference in Radio Science (RCRS2014), and the sixth workshop of the URSI/IAGA Joint Working Group on VLF/ELF Remote Sensing of the Ionosphere and Magnetosphere (VERSIM). We also sadly have "in memoriam" pieces on three radio scientists who have been lost to our field.

Finally, the winners of the URSI awards are announced in this issue. The awards will be presented at the Opening Ceremony of the URSI General Assembly and Scientific Symposium (GASS) in Beijing, China (CIE), August 17, 2014.

Registration and hotel reservations for the GASS (August 16-23, 2014) are available now on the Web site: http://www.chinaursigass.com/. I urge you to make your plans to attend now. One of the options for hotels is the Beijing Conference Center Hotel. This is actually spread over several buildings, but all are in close proximity to the Beijing Conference Center where the GASS sessions and Opening Ceremony will be held. I have visited one of these hotels, and it is very nice indeed, certainly on a par with (and some would say, better than) most European four-star hotels. Don't be confused by the low room rate: the rates are apparently kept low because the facilities are used for government functions. I look forward to seeing you in Beijing!

Ross

In Memoriam

Robert D. Hunsucker
1930 - 2014

Robert D. Hunsucker (silent key) passed away peacefully on January 9, 2014, with family in Minnesota. He was 83, and was preceded in death by his first wife, Judith. An authority on radio propagation, radio sensing of the ionosphere, and the effects of atmospheric gravity waves (AGWs) on the ionosphere, he authored over 150 research papers, the text *Radio Techniques for Probing the Terrestrial Ionosphere*, and the text *The High-Latitude Ionosphere and its Effects on Radio Propagation*, with J. K. Hargreaves. He served as Associate Editor for the journal *Radio Science* from 1992-1994, and was Editor-in-Chief from 1995-2002.

Dr. Hunsucker became fascinated with radio at an early age, becoming a licensed radio amateur (W7LOU) in high school; he later held the calls WA0LCO, KL7CYS, and AB7VP. He credited his youthful shortwave experiences with motivating his life-long interest in radio propagation, and worked at local radio stations in high school and college. He obtained degrees in Electrical Engineering and Physics from Oregon State in 1954, and joined the US Naval Reserve. He graduated from the USNR Officer Candidate School in 1954, and served on ships stationed in the Philippines, Korea, and Japan as Chief Engineer, and later as Boat Group Commander. After leaving the Navy, he returned to Corvallis, where he earned an MS in Physics in 1958, studying weather radar.

Dr. Hunsucker joined the Geophysical Institute in Fairbanks, Alaska, in 1958 as a Research Associate, studying high-latitude propagation, and worked with luminaries in the field such as Sydney Chapman. While working with groups pioneering new observational techniques in Alaska, Hunsucker became particularly interested in high-latitude space-weather effects on radio propagation. He later wrote about his interest in auroral absorption, sporadic E, and non-great-circle propagation effects on HF in an article subtitled "Look North, Young Ham" (*QST*, February 1967).

In 1964, he joined the Central Radio Propagation Laboratory in Boulder, CO, and worked as Physicist and Project Leader in radio propagation studies. He earned his PhD at the University of Colorado in 1969, working on HF backscatter research and early investigations of over-the-horizon (OTH) radar.

Dr. Hunsucker returned to the University of Alaska and the Geophysical Institute in 1971, where he pursued a variety of radio propagation and ionospheric research projects, often flying his own small plane (Figure 1) to remote arctic field sites to operate ionosondes, riometers, and radio propagation beacons. He was instrumental in the establishment and success of the Chatanika incoherent scatter radar, which provided important comparative measurements with sounding rocket flights from the nearby Poker Flat Research Range. His MF propagation studies were used by the FCC to revise rules for AM broadcasters. He taught both undergraduate engineering and graduate physics courses at UAF. He organized six international conferences through the Geophysical Institute and the Naval Postgraduate School, including NATO AGARD conferences on radio propagation.

After retiring from the University of Alaska in 1988, Hunsucker remained active in atmospheric gravity wave and radio propagation research, and was elected a Fellow of the IEEE and of the AAAS. He received the IEEE Alaska Engineer of the Year Award in 1988, and the IEEE 6th Region Citation for "Outstanding Research in Ionospheric Radio Propagation" in 2005. He relocated to Klamath Falls, OR, in 1995, where he continued HF radio propagation studies. At the time of his death, he was assisting with a detailed analysis of archived ionograms from the 1950s.

In addition to his devotion to ionospheric research, his many students and colleagues will remember Hunsucker as a man of faith and humor, often inserting quips from Walt Kelly's Pogo into his informal talks. His imaginative project acronyms and participation in "Fagoo" holiday skits were legendary at the Geophysical Institute. His love for radio and the far north never diminished. He wrote numerous articles on these subjects for popular magazines and newsletters, remarking that even after decades of work in the field, "radio is still magic." He is survived by his wife Phyllis, daughters Edith, Jeanne, and Cynthia, fourteen grandchildren, and six great-grandchildren.

Figure 1. Bob Hunsucker refueling his aircraft in McGrath, Alaska, during a scientific expedition.

In lieu of flowers, memorial contributions may be made in memory of Robert Hunsucker to the University of Alaska Fairbanks. Contributions may be made online at www.uaf.edu/giving/gift: please note "In Memory of Robert Hunsucker." For more information on memorial arrangements, please see http://www.spacenv.com/ ~rice/ rdhunsucker.html.

[This contribution was prepared by Donald Rice, Space Environment Corporation, 221 N Gateway Drive, Suite A, Providence UT 84332; Tel: +1 (435) 752-6567; E-mail: Don.Rice@spacenv.com. Most of the text was taken from a lengthy document Dr. Hunsucker left with his family, with some additions from his Geophysical Institute friends.] [A similar version of this appeared in the *IEEE Antennas and Propagation Magazine*, **55**, 6, December 2013; copyright IEEE 2013.]

Alexander Lamb Cullen 1920 - 2013

Professor Alexander Lamb Cullen, who died on December 27, 2013, combined the sharpest of scientific minds with a gentle personality and a great sense of humor. He was born in London in 1920, and was educated at Lincoln School and Imperial College. During WW2, he worked on early radar at the Royal Aircraft Establishment, Farnborough. In 1946, he took up a lectureship at University College London (UCL), where he worked with Harold Barlow in building up microwave research. In 1955, he was appointed to the Chair of Electrical Engineering at the University of Sheffield, but returned to UCL to succeed Barlow as Pender Professor and Head of Department in 1967. He was appointed OBE in 1960, and was elected Fellow of the Royal Society in 1977. Among other distinctions, he received the Faraday Medal of the Institution of Electrical Engineers (now IET).

He recounted his early time at UCL, and his relationship with Harold Barlow:

Soon after my arrival at UCL, Barlow gave a series of public lectures on microwaves, and also wrote a book on the subject which was published by Constables. Later Constables asked him to write a book on microwave measurements. He asked me to collaborate with him in writing it. He was now very busy with University as well as College matters, so I did most of the writing. When each chapter was finished, I would discuss it with Harold. He never made major changes in my text, but often suggested better ways of explaining things. We got on very well, in spite of our age and seniority difference. When Barlow delivered the book to Constables, he suggested that my name should come first in naming the authors. Constables did not like this idea; they obviously thought that the book would sell better with a distinguished Professor as the first author. But Barlow asked me to let him know which parts of the book had my own ways of treating the various topics, and he then wrote a foreword in which he gave me due credit. A typical act on his part. The book eventually became well known, and was published in Chinese and Russian.

Alongside many other achievements Cullen developed a method of measuring the radiation pattern of an antenna using a modulated near-field scatterer: originally a mechanically-rotating dipole, but nowadays an electronically-modulated scatterer. The technique is now employed in an antenna-measurement range marketed by the French company, SATIMO.

I was lucky enough to work with him in the late 1990s on a technique to measure the electrical properties of materials at mm-wave frequencies. It was an unusual collaboration – including an Iranian PhD student and another distinguished retired scientist, Dr. Arnold Lynch. Alec brought a wealth of insight and practical experience in microwave measurements ("If you want to understand an error, make it as big as possible"). The paper that we published on the work was awarded the Maxwell Premium of the IEE.

He married Margaret in 1940, and they had a long and happy marriage, with three children: Michael, Isobel, and David.

He was an accomplished jazz musician, playing drums and clarinet. At his home, next to shelves full of books on electromagnetism, was his drum kit and (more recently) a vibraphone. In his school days, he had played music with the broadcaster, Steve Race, and they kept closely in touch throughout their lives.

He was a signatory of a letter to *The Times* in January 1986, calling on Prime Minister Margaret Thatcher to "Save British Science." This led to the foundation of the Save British Science pressure group (now the Campaign for Science and Engineering, CaSE), which has built up an enviable reputation with politicians and the media in representing the concerns of scientists and engineers.

When Eric Ash left UCL in 1985 to become Rector of Imperial College, he remarked that Alec was "the last gentleman in the business." There is no one who would disagree with that.

[Alex Cullen was Chair of URSI Commission VII from 1972 to 1974. He was Vice President of URSI from 1981 to 1987. He was President of URSI from 1987 to 1990, and Past President from 1990 to 1993.]

Hugh Griffiths
University College London
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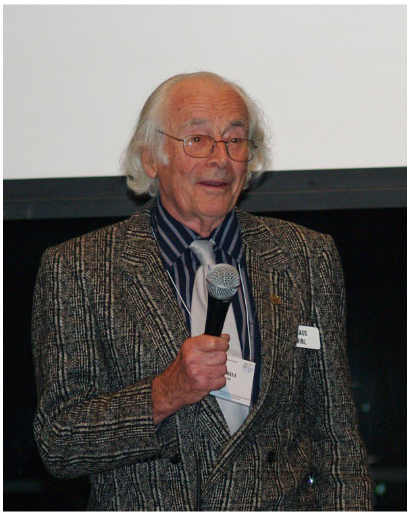
Klaus Bibl
1920 - 2013

Klaus Bibl, an internationally recognized ionospheric physicist who had started the development of the digital ionosonde, passed away on September 20, 2013. His health began failing after he returned from the URSI General Assembly in Istanbul in 2011, likely as a result of an initially untreated heart attack.



Klaus Bibl graduated in Physics at the University of Leipzig in 1943. At the end of WW II, he worked as a specialist in the ionospheric radiowave prediction division of the German military. After the war, he joined Karl Rawer's team to set up an ionospheric observatory, initially near Freiburg, Germany, as part of the French Service de Prévision Ionosphérique de la Marine (SPIM), and then the Ionospheric Institute in Breisach in 1954. Klaus Bibl used this time to also complete his academic education, which had been interrupted by the war years, and did his doctorate with the mathematician Gustav Doetsch, at the University of Freiburg.

During these pioneering years for the exploration of the ionosphere, Dr. Bibl had recognized early on the large variability and dynamics of Earth's ionospheric plasma. Following his inclination and making use of his extraordinary engineering skills, he began to conceive and develop new instrumentation for the exploration and monitoring of the ionosphere. He designed and built new HF radio sounders for vertical, oblique, and backscatter sounding. "Bibl ionosondes" were deployed in several European countries, West Germany, Belgium, Italy, Greece, and Norway, and in Africa. Measurements with these new instruments provided new insights into the dynamics and structures of the ionosphere. Solar-eclipse observations in Norway with his new ionosonde in 1954 proved that the sun's EUV diameter is larger than the visible sun. His new method of "pulse detection" won him his first patent.

After years of research at the Ionospheric Institute in Breisach and at the Telecommunications Office of the German Postal Service in Darmstadt, Dr. Bibl immigrated with his family to the USA in 1963 to join the Lowell Technological Institute in Massachusetts, today the University of Massachusetts Lowell. There, he led a group of some 30 researchers, and in 1976 became the director of the university's newly formed Center for Atmospheric Research. This was at the time when digital technologies became available, and Klaus Bibl was one of the first to recognize their importance for scientific applications. He used his knowledge and experience to develop the digital "Kinesonde" for ESSA/ITSA in Boulder, CO, an amplitude and phase measuring HF sounder. This was followed by the first fully "digital ionosonde," the Digisonde 128. This pioneering work formed the basis for the development of the global network of nearly one hundred "Lowell Digisondes," operating today at ionospheric observatories from Greenland to Antarctica. He also developed the first digital sounder that made pulse amplitude and HF phase measurements for the calculation of radio sky maps and ionospheric drift. The last of his many patents was for an HF interference-mitigation technique, which has become one of the success factors in the Lowell Digisonde® network. In 1985, Dr. Bibl stepped down as the center director, but continued his work as chief scientist at the UML Center for Atmospheric Research, and, during the last three years of his life, at Lowell Digisonde International, LLC. Dr. Bibl's enthusiasm and vision inspired generations of students and coworkers who now carry on with what he had started. In his last years, he worked frantically on the design of an efficient low-frequency transmitting/receiving antenna for spaceborne applications in magnetoionic plasma environments, work he reported on at the Istanbul URSI meeting.

Klaus was an inspiration for all of us who had the privilege of working with him. He was also known as a great debater, who was always willing to defend and explain his theories and designs. We will celebrate the life and legacy of Dr. Klaus Bibl during the International GIRO Forum in Lowell on May 21, 2014.

He is survived by his two daughters, Ulrike Campbell and Cornelia Dobrovolsky, and his son, Andreas Bibl.

Bodo Reinisch
E-mail: bodo.reinisch@digisonde.com

URSI Accounts 2013

Thanks to the careful financial management by the URSI Board and control on the administrative expenses at the URSI Secretariat, the financial situation of URSI is still in good shape. Prudent and conservative management has resulted in safeguarding of the URSI reserves in the current difficult financial circumstances. However in view of declining revenues from the Member committee dues URSI needs to broaden its budget base and optimize the use of its resources.

The Board, after in-depth discussions, has come to the conclusion that URSI and its Commissions should focus on annual cycle of the GASS and URSI "Flagship meetings". The newly established AT-RASC meeting in the Atlantic Region and possibly the established AP-RASC meeting in the Asia Pacific Region could fulfil this role. The URSI Flagship meetings should maintain the momentum created at the GASS and will continue to stress the interdisciplinary nature of the multi-commission meetings which are the distinguishing feature of URSI.

Besides this initiative to strengthen the URSI community through these Flagship meetings, the URSI Board will continue its efforts to stimulate the participation of Young Scientists in our URSI community and to increase the visibility and the services of URSI in the scientific community. Thanks to the continued effort and commitment of our URSI Member Committees, URSI Commissions and all of you as individual scientists, we are confident that URSI still faces a long and bright future.

Prof. Paul Lagasse
Secretary General of URSI

BALANCE SHEET: 31 DECEMBER 2013

	EURO	EURO
ASSETS		
Dollars		
PNB Paribas Fortis	4,850.17	
Smith Barney Shearson	0.00	
		4,850.17
Euros		
Banque Degroof	86.10	
BNP Paribas Fortis zichtrekening	53,469.81	
BNP Paribas Fortis spaarrekening	155,180.02	
BNP Paribas Fortis portefeuillerekening	241,549.88	
		451,060.62
Investments		
Degroof Bonds EMU (formerly Demeter Sicav Shares)	22,681.79	
Rorento Units	111,614.53	
Degroof Monetary Eur Cap (formerly Aqua Sicav)	63,785.56	
Bonds	230,000.00	
Massachusetts Investor Fund	0.00	
Provision for (not realised) less value	0.00	
Provision for (not realised) currency differences	0.00	
	428,081.88	
673 Rorento units on behalf of van der Pol Fund	12,214.69	
		440,296.57
Petty Cash		71.22
Total Assets		896,278.58
Less Creditors		
IUCAF	28,037.74	
ISES	5,053.53	
		(33,091.27)
Balthasar van der Pol Medal Fund		(12,214.69)
NET TOTAL OF URSI ASSETS		**850,972.62**

The net URSI Assets are represented by:	EURO	EURO
Closure of Secretariat		
Provision for Closure of Secretariat		100,000.00
Scientific Activities Fund		
Scientific Activities in 2014	55,000.00	
Routine Meetings in 2014	15,000.00	
Publications/Website in 2014	15,000.00	
Young Scientists in 2014	0.00	
Administration Fund in 2014	105,000.00	
I.C.S.U. Dues in 2014	10,000.00	
		200,000.00
XXXI GASS 2012/2014 Fund:		
During 2009-2010-2011 (GASS 2011)		0.00
During 2012-2013-2014 (GASS 2014)		275,000.00
Total allocated URSI Assets		575,000.00
Unallocated Reserve Fund		275,972.62
		850,972.62

Statement of Income and expenditure for the year ended 31 December 2013

I. INCOME		
Grant from ICSU Fund and US National Academy of Sciences	0.00	
Allocation from UNESCO to ISCU Grants Programme	0.00	
UNESCO Contracts	0.00	
Contributions from National Members (year -1)	21,313.00	
Contributions from National Members (year)	146,148.00	
Contributions from National Members (year +1)	2,030.00	
Contributions from Other Members	0.00	
Special Contributions	0.00	
Contracts	0.00	
Sales of Publications, Royalties	230.00	
Sales of scientfic materials	0.00	
Bank Interest	2,979.59	
Other Income	6,691.39	
Total Income		**179,391.98**
II. EXPENDITURE		
A1) Scientific Activities		68,389.17
General Assembly 2008/2011/2014	119.40	
Mid Term Meetings 2015	13,919.65	
Scientific meetings: symposia/colloqiua	48,181.61	
Working groups/Training courses	0.00	
Representation at scientific meetings	6,168.51	
Data Gather/Processing	0.00	
Research Projects	0.00	
Grants to Individuals/Organisations	0.00	
Other	0.00	
Loss covered by UNESCO Contracts	0.00	
A2) Routine Meetings		28,540.81
Bureau/Executive committee	28,540.81	
Other	0.00	

A3) Publications		0.00
B) Other Activities		11,991.00
Contribution to ICSU	9,991.00	
Contribution to other ICSU bodies	2,000.00	
Activities covered by UNESCO Contracts	0.00	
C) Administrative Expenses		103,755.65
Salaries, Related Charges	89,524.95	
General Office Expenses	3,936.13	
Travel and representation	1,842.70	
Office Equipment	0.00	
Accountancy/Audit Fees	4,689.56	
Bank Charges/Taxes	4,121.72	
Loss on Investments (realised/unrealised)	(359.41)	
Total Expenditure:		**212,676.63**

Excess of Expenditure over Income	(33,284.65)
Currency translation diff. (USD => EURO) - Bank Accounts	0.00
Currency translation diff. (USD => EURO) - Investments	0.00
Currency translation diff. (USD => EURO) - Others	0.00
Accumulated Balance at 1 January 2013	884,257.27
	850,972.62

Rates of exchange

January 1, 2013	1 $ = 0.7540 EUR
December 31, 2013	1 $ = 0.7250 EUR

Balthasar van der Pol Fund	
673 Rorento Shares : market value on December 31	
(Aquisition Value: USD 12.476,17/EUR 12.414,34)	36,335.27
Book Value on December 31, 2013/2012/2011/2010	12,214.69
Market Value of investments on December 31, 2013-2010	
Degroof Bonds (formerly Demeter Sicav Shares)	80,553.00
Rorento Units (1)	701,870.00
Degroof Monetary Eur Cap (formerly Aqua Sicav)	90,032.29
Massachusetts Investor Fund	0.00
Bonds	235,584.68
	1,108,039.97
Book Value on December 31, 2013/2012/2011/2010	440,296.57

(1) Including the 673 Rorento Shares of v d Pol Fund

APPENDIX : Detail of Income and Expenditure

I. INCOME		
Other Income		
Income General Assembly 2011	0.00	
Income General Assembly 2014	0.00	
Young scientist support (Japan)	3,815.00	
Support Koga Medal	0.00	
Closure Radio Science Press	0.00	
Commission B+C	0.00	
Income bonds	2,876.39	
Other	0.00	
		6,691.39
II . EXPENDITURE		
General Assembly 2011		
Organisation	0.00	
Vanderpol Medal	0.00	
Young scientists	0.00	
Expenses officials	0.00	
Support Commissions	0.00	
General Assembly 2014		
Organisation	119.40	
		119.40
Symposia/Colloquia/Working Groups		
Commission A	1,000.00	
Commission B	9,000.00	
Commission C	2,000.00	
Commission D	1,000.00	
Commission E	3,250.00	
Commission F	7,400.00	
Commission G	3,100.00	
Commission H	3,581.61	
Commission J	2,600.00	
Commission K	9,000.00	
Central Fund	4,750.00	
Central Fund (Student Award MC)	1,500.00	
		48,181.61
Contribution to other ICSU bodies		
FAGS	0.00	
IUCAF	2,000.00	
		2,000.00
Publications		
Printing 'The Radio Science Bulletin'	0.00	
Mailing 'The Radio Science Bulletin'	0.00	
		0.00

URSI Awards 2014

At their April 2014 meeting in Ghent, based on the recommendations of the Awards Panel, the URSI Board of Officers decided to give the 2014 URSI awards to the following distinguished scientists:

Balthasar van der Pol Gold Medal

The Balthasar van der Pol Gold Medal was awarded to **Prof. Nader Engheta** with the citation,

"For groundbreaking contributions and innovations in electromagnetic theory and applications ofcomposite materials, metamaterials, and nanoscale optics, bio-inspired imaging and sensing, andmaterial-based optical nanocircuitry."

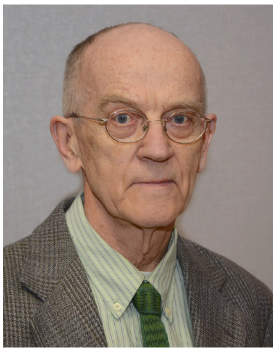
John Howard Dellinger Gold Medal

The John Howard Dellinger Gold Medal was awarded to **Dr. Jean-Pierre Bérenger** with the citation,

"For seminal work on the development of breakthrough absorbing boundary conditions for computational electromagnetics in radiosciences."

Appleton Prize

The Appleton Prize was awarded to **Dr. Robert F. Benson** with the citation,



"For fundamental contributions to knowledge of the interactions of spaceborne radio sounders with the Earth's plasma environment and to the use of sounders as diagnostic probes of that environment."

Booker Gold Medal

The Booker Gold Medal was awarded to **Prof. H. Vincent Poor** with the citation,

"For outstanding contributions to the science and technology of communications and signal processing."

Issac Koga Gold Medal

The Issac Koga Gold Medal was awarded to **Prof. Francesco P. Andriulli** with the citation,

"For contributions to computational electromagnetics, specifically the development of preconditioned and stable integral equation solvers."

The URSI awards will be presented to the awardees during the Opening Ceremony of the XXXIth General Assembly and Scientific Symposium at the Beijing Convention Center in Beijing, China (CIE), on August 17, 2014.

Santimay Basu Prize

The Santimay Basu Prize is a new URSI award, established to honor the memory of Dr. Santimay Basu, a scientist who was closely associated with URSI for many years. The Prize is awarded to a young scientist, not more than 35 years old on September 30 of the year preceding the General Assembly and Scientific Symposium of URSI, who has made an outstanding contribution to research that furthers the understanding of radiowave propagation in random media and its application for the benefit of society. The Santimay Basu Prize was awarded to **Prof. Morris B. Cohen** with the citation,

"For contributions to ELF/VLF radiowave instrumentation, propagation, and generation in the ionosphere and magnetosphere, and for initiating and fostering an international network of young scientists in developing countries."

IUCAF Annual Report for 2013

1. Introduction

The Scientific Committee on Frequency Allocations for Radio Astronomy and Space Science, IUCAF, was formed in 1960 by its sponsoring Scientific Unions, the IAU, URSI, and COSPAR. Its brief is to study and coordinate the requirements of radio frequency allocations for passive (i.e., non-emitting or receive-only) radio sciences, such as radio astronomy, space research and remote sensing, in order to make these requirements known to the national administrations and international l bodies that allocate frequencies. IUCAF operates as a standing inter-disciplinary committee under the auspices of ICSU, the International Council for Science. IUCAF is a Sector Member of the International Telecommunication Union (ITU).

2. Membership

At the end of 2013 the membership for IUCAF elected by the three parent organizations was:

URSI	S. Ananthakrishnan (Com J)	India
	S. Reising (Com F)	USA
	I. Häggström (Com G)	Sweden
	A. Tzioumis (Com J)	Australia
	W. van Driel (Com J)	France
IAU	H. Chung	Korea (Republic of)
	H.S. Liszt (Vice Chair)	USA
	M. Ohishi (Chair)	Japan
	T. Gergely	USA
	A. Tiplady	South Africa
COSPAR	Y. Murata	Japan

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

3. International Meetings

During the period of January to December 2013, its Members and Correspondents represented IUCAF in the following international meetings:

3-5, April	55th CRAF (Committee on Radio Astronomy Frequency) Zurich, Switzerland
8-12, April	Working Party 7D (Radio Astronomy) Geneva, Switzerland
25 June – 3 July	Space Frequency Coordination Group meeting (SFCG-33) Toulouse, France
10-18, September	ITU-R Study Group 7 (Science Services) and Working Party 7D (Radio Astronomy) Geneva, Switzerland
19-20, September	ITU-BIPM Workshop on the Future of Leap Seconds Geneva, Switzerland

Additionally, many IUCAF members and its associates participated in numerous national or regional meetings (including CORF, CRAF, RAFCAP, the FCC etc.), dealing with spectrum management issues, such as the preparation of input documents to various ITU meetings.

4. IUCAF Business Meetings

IUCAF had face-to-face committee meetings during the WP7D meetings in April and September. IUCAF ad-hoc meetings were held to discuss further its meeting strategy.

A major issue for the IUCAF was the 4th IUCAF School on spectrum management for radio astronomy. IUCAF members discussed how to organize the School, including topics to be presented at the School. The details of the School are described in section 6 of this annual report.

Although such face-to-face meetings have been convenient and effective, throughout the year much IUCAF business is undertaken via e-mail communications between the members and correspondents.

5. Protecting the Passive Radio Science Services

The most important event in protecting the passive radio science services occurred during World Radiocommunication Conferences which are held in every 3-4 years for updating international rules (the Radio Regulations) in using the frequency resource, which will then be referred to by each government in order to update its national radio act. The next WRC is scheduled to be held in 2015 (WRC-15).

An agenda item regarding the protection of radio astronomical observations from possible (highly probable) interference caused by collision avoidance radars at around 79 GHz region (77-81 GHz) is of importance to the radio astronomy community. Relevant technical studies have been undertaken in the ITU-R. IUCAF submitted a few contribution documents on how to protect radio astronomy observations at around 79 GHz. Since the radio astronomy observations are quite susceptible to man-made radio interference, the studies concluded that a separation distance of about 40 km would be required to protect radio astronomy observations from collision avoidance radars operating at around 79 GHz region.

There is another agenda item to consider possible allocations for radar operations to monitor the Earth environment; the radar is planned to operate in the 8700-9300 MHz and 9900-10500 MHz from a satellite orbiting the Earth. Since the radar operations require wide frequency range (600 MHz), the sidelobes away from the center frequency of the transmission may interfere with not only passive remote sensing observations and radio astronomy observations in the 10.6-10.7 GHz band. IUCAF and CRAF have submitted to the ITU-R study results regarding the probable impact to the passive observations by the proposed radar, which are incorporated to a new ITU-R Report.

IUCAF member, A. Tzioumis, is the Chair of ITU-R Working Party 7D (radio astronomy). And IUCAF member, H. Chung, is the vice-chairman of ITU-R Study Group 7 (Science Services).

6. Preparation for the 4TH IUCAF Spectrum Management School

The 4th IUCAF school on spectrum management for radio astronomy is scheduled to be held between April 7th and 11th, 2014, at the Joint ALMA Observatory, Santiago, Chile. This is the first IUCAF school on spectrum management held in the southern hemisphere. At the day of writing of this report, there are about 50 people preregistered from 13 countries: Chile, Brazil, Argentina, Japan, Germany, UK, the Netherlands, USA, China, South Korea, Australia, and Malaysia. The primary targets of the School are new comers in the spectrum management, since there are a few regulators from Chile, the school will provide a good opportunity to create good relationship with the Chilean government.

The summer school program will cover introductions to radio astronomy and Earth observations, radio science and related technologies and procedures on how to use (allocate) frequency resources. This includes the structure and role of the International Telecommunication Union (ITU) and regional telecommunities (CEPT, CITEL, APT); the roles of science bodies to protect radio astronomy and Earth observations (IUCAF, CRAF, CORF, RAFCAP); interference mitigation techniques; and radio interference topics such as Software-Defined Radio (SDR), Cognitive Radio Systems (CRS), and others. There will also be a lecture on the SKA project and radio quiet zones for future radio astronomy. The school program is available from the IUCAF's web page at http://www.iucaf.org/sms2014/ .

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

7. Contact with the Sponsoring Unions and ICSU

IUCAF maintains regular contact with its supporting Scientific Unions and with ICSU. The Unions play a strong supporting role for IUCAF and the membership is greatly encouraged by their support. IUCAF continued its activities towards strengthening its links with other passive radio science communities, in particular in space science, and defining a concerted strategy in common spectrum management issues.

IUCAF has been informed by ICSU that it plans to review activities of IUCAF towards the end of 2015, beginning 2016. The review will be conducted by the Committee on Scientific Planning and Review (CSPR) of ICSU, which decided on a workplan to review all of the ICSU Interdisciplinary bodies at regular (normally every 5 years) intervals. This is a good opportunity for IUCAF to revisit its 40-years-old Terms of Reference.

Two IUCAF members, A. Tzioumis and M. Ohishi, are appointed the Organising Committee (OC) members of IAU Commission 50. M Ohishi is also an OC member of IAU Commission 51 (Bioastronomy). M. Ohishi chairs the Working Group on Astrophysically Important Spectral Lines under Division B, IAU. He is also appointed the official liaison between the IAU and the ITU, and a member of WG Redefinition of UTC, Division A, IAU. IUCAF member, S. Ananthakrishnan, is the president of URSI Commission J (radio astronomy).

8. Publications and Reports

IUCAF has a permanent web address, http://www.iucaf.org/, where the latest updates on the organization's activities are made available. All contributions to IUCAF-sponsored meetings are made available on this website.

9. Conclusion

IUCAF interests and activities range from preserving what has been achieved through regulatory measures or mitigation techniques, to looking far into the future of high frequency use, giant radio telescope use and large-scale distributed radio telescopes. Current priorities for the coming years are: the protection of radio astronomy observations from collision avoidance radars at around 79 GHz region, and studies on the operational conditions that will allow the successful operation of future giant radio telescopes.

IUCAF plans to hold the 4th Summer School on Spectrum Management in April, 2014, in Santiago, Chile. IUCAF has saved its budget for supporting young scientists and engineers at the planned summer school, who are expected to work together in future. It would be a very good opportunity for radio scientists in the South America to learn how to protect radio quiet environment that is needed for the passive radio science services.

IUCAF is grateful for the moral and financial support that has been given for these continuing efforts by ICSU, URSI, IAU and IAU during the recent years. IUCAF also recognizes the support given by radio astronomy observatories, universities and national funding agencies to individual members in order to participate in the work of IUCAF.

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Introduction to the Special Section on the Role of Radio Science in Disaster Management, Part II : March 2014

Guest Editors: Tullio Joseph Tanzi, François Lefeuvre and P.J. Wilkinson

In this issue, we have a second section on the "Role of Radio Science in Disaster Management," with Tullio Joseph Tanzi, François Lefeuvre, and Phil Wilkinson as Guest Editors. As with the previous section, which appeared in the *Radio Science Bulletin* No. 345 (June 2013), the invited papers are expanded and reviewed versions of papers that were originally presented at a joint URSI-ISPRS session. Such collaborations are expected to be pursued in the future.

When a natural disaster occurs in a populated zone, fast and effective organization of the disaster management is necessary to assist the affected population, reduce the number of victims, and limit the economic impact. Detection and monitoring of the impact and effects are generally done via spaceborne and airborne remote-sensing surveys, through radio and optical instruments. URSI (International Union of Radio Science) and ISPRS (International Society for Photogrammetry and Remote Sensing) are complementary. URSI covers studies in the fields of radio, telecommunications, and electronic sciences. ISPRS covers photogrammetry and remote sensing. Complementary areas include risk-monitoring systems, the acquisition of heterogeneous data, data handling, and quantitative risk and damage assessments. In addition, cross fertilization of ideas may be expected.

Cooperation between URSI and ISPRS was initiated at the 2011 International Symposium on Geo-Information for Disaster Management (Gi4DM) in Antalya, Turkey. This was followed by the 2011 URSI GASS in Istanbul, Turkey, and at the 2012 XXII ISPRS Congress in Melbourne, Australia. An URSI-ISPRS session has been organized by URSI Commissions C and F for the Beijing GASS in August 2014.

In the special section in the June 2013 *Radio Science Bulletin* No. 345, three papers were published:

- Monia Hamdi, Laurent Franck, and Xavier Lagrange, "Topology Modelling and Network Partitioning: An Application to Forest-Fire Fighting"
- Xavier Chaze, Amal Bouejla, Franck Guarnieri, and Aldo Napoli, "Causal Probabilistic Modelling with Bayesian Networks to Combat the Risk of Piracy Against Offshore Oil Platforms"
- Antoine Gademer, Laurent Beaudoin, Loïca Avanthey, and Jean-Paul Rudant, "Application of the *Extended Ground Truth* Concept for Risk Anticipation Concerning Ecosystems"

In the present issue of the *Radio Science Bulletin*, three papers are presented:

- The paper by Liangpei Zhang and Bin Luo is "Recent Developments in Remote-Sensing Technologies for Disaster Management in China." After presenting the available data, the authors summarize the technical measures to be used, and illustrate results obtained for several natural-disaster events.
- The paper by Tullio Joseph Tanzi, Olivier Sebastien, and Fanilo Harivelo, "Towards a Collaborative Approach for Disaster Management Using Radio Science Technologies," proposes a collaborative approach intended for disaster management. New radio technologies are discussed, such as new communicating objects such as smart phones, digital tablets such as the iPad, and other technological objects to be used for the detection of victims of avalanches, for instance.
- The paper by François Lefeuvre and Tullio Joseph Tanzi, "Radio Science's Contribution to Disaster Emergencies," deals with radio propagation and radio navigation in a crisis period; spaceborne, airborne, and ground-based remote-sensing instruments, including synthetic-aperture radars (SAR); and data management via a geographical information system (GIS) for the decision-making processes.

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Recent Developments in Remote-Sensing Technologies for Disaster Management in China

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Abstract

China is one of the countries most affected by natural disasters. Al most all kinds of disasters can be found in China. Thanks to the capability of remote sensing for the rapid collection of information in all phases of disaster management, a lot of effort has been put into the development of remote-sensing technologies in China. In this paper, some recent developments are introduced. At first, four recently launched satellites – Beijing-1, CBERS-02B, and HJ-1A/1B – are presented, as well as applications based on their data. Afterwards, research on the processing of remote-sensing data carried out in China for disaster management is introduced.

1. Introduction

China is one of the countries that is the most affected by natural disasters. Figure 1 shows the locations of the major natural disasters in China from 1900 to 2000. It can be seen that almost all kinds of disasters can be found in the eastern part of China, which is very densely populated. Nevertheless, this doesn't indicate that natural disasters are rare in the western part of China. Since the western part of China is covered by mountains, deserts, etc., where habitants are sparse, only very few natural disasters have been reported.

Modern disaster management consists of five phases. Two of these take place before the disaster: disaster prevention and disaster preparedness. Three phases are after the occurrence of a disaster: disaster relief, rehabilitation, and reconstruction [1]. Disaster management is usually represented by a cycle, since after the occurrence of a disaster, society will prepare for the next disaster.

Only when detailed information on the characteristics of the disasters has been obtained can disaster mitigation be successful. Remote sensing, which can rapidly acquire information about different aspects, is a very efficient tool for providing knowledge on very large areas for all the phases of disaster management.

In the prevention and preparedness phases, remote sensing can provide fundamental data (mainly, the properties of the terrain) in order to construct hazard maps, which indicate the possibilities of disasters in different areas. When a disaster occurs, the efficiency of collecting information by using remote sensing is very high, which is probably the only solution to globally monitor the situation in the disaster areas. In the disaster relief phase, the damage caused can be estimated based on remote-sensing data. The information about the damage can then guide the reconstruction activities in the last phase of disaster management.

In this paper, we will introduce some recent developments in remote-sensing technologies of China for disaster management. In Section 2, the recently launched Chinese remote-sensing satellites, dedicated to disaster management, will be introduced, as well as some applications based on their data. Afterwards, research on the processing of remote-sensing data carried out in China for disaster management will be presented in Section 3. Finally, in Section 4, we conclude.

2. Chinese Remote-Sensing Satellites Dedicated to Disaster Management

Since the successful launch of the first satellite in 1970, remote sensing for disaster management has always been

Figure 1. Locations of the major natural disasters in China between 1900 to 2000 [2].

one of the most important functionalities of Chinese space missions. After the millennium, Chinese space technologies have dramatically developed. While achievements such as the manned space missions (Shenzhou-5, -7, -9), the space station (Tiangong-1), the lunar-exploration missions (Chang'e-1, 2), and the space-based positioning system (Beidou-1, 2) have drawn worldwide attention, the capabilities of Chinese remote-sensing satellites have also been considerably improved. In this section, we will introduce the satellites recently launched by China dedicated to disaster management, which are summarized in Table 1.

2.1 Beijing-1

The Beijing-1 satellite was successfully launched in 2005. Medium- and high-resolution imaging sensors were onboard. The multi-spectral sensors have 32 m spatial resolution, while the panchromatic sensor has 4 m spatial resolution. By using image-fusion technologies such as pan sharpening, the spatial resolution of the multi-spectral images can increase to 4 m [3]. The lifetime of Beijing-1 has been extended from five years to seven years. It can be seen that this satellite has capabilities similar to LandSat TM.

Since its launch, research on the use of the Beijing-1 satellite's data for disaster management has been carried out. In [4, 5], eco-environmental problems after the Wenchuan Earthquake in the southwest of China, including biotope changes, vegetation cover changes, hydro-ecology changes, and land degradation, were analyzed based, on the images taken by Beijing-1. In [6], the enteromorpha clathrata (a kind of green algae) that appeared near Qingdao was monitored, based on the multi-date images taken by Beijing-1 for preventing biological disasters. In [7], the soil-erosion risk was evaluated by using images from Beijing-1 for the area around Guanting reservoir (near Beijing).

2.2 CBERS-02B

The China-Brazil Earth Resources Satellites (CBERS) are a series of remote-sensing satellites co-designed by China and Brazil, under the bilateral cooperation agreement signed in 1988. In total, three satellites have been built: CBERS-01, launched in 1999; CBERS-02, launched in 2003; and CBERS-02B, launched in 2007. CBERS-02B, which is the most important satellite, was the first high-resolution optical remote-sensing satellite in China. It is CBERS-02B which allowed China to participate in the international charter (space and major disasters) in 2007.

Ever since the launch of CBERS-02B, thanks to its high spatial resolution, many applications have been reported based on its data for disaster management. In [40], the damage of the vegetation after the Wenchuan earthquake

Platform (Satellite)	Payloads (Resolution)	Swath (km)	Band	Wavelength (µm)
Beijing-1	Multi-spectral (32 m)	600	Blue Red NIR	0.45–0.52 0.63–0.69 0.77–0.90
	Panchromatic (4 m)	24		0.50–0.80
CBERS-02B	Multi-spectral (20 m)	113	B01	0.45–0.52
			B02	0.52–0.59
			B03	0.63–0.69
			B04	0.77–0.89
			B05	0.51–0.73
	High resolution – HR (2.36 m)	27	B06	0.50–0.80
	Wide Field Imager – WFI (258 m)	890	B07 B08	0.63–0.69 0.77–0.89
HJ-1A	Multi-spectral (30 m)	single	1	0.43–0.52
		360 double 720	2 3 4	0.52–0.60 0.63–0.69 0.76–0.90
	Hyperspectral Imager (100 m)	50	110–128 bands	0.45–0.95
HJ-1B	Multi-spectral (30 m)	the same as HJ-1A		
	Infrared (150 m)	720	5	0.75–1.10
			6	1.55–1.75
			7	3.50–3.90
	Infrared (300 m)	720	8	10.5–12.5

Table 1. Recent remote-sensing satellites launched by China for disaster management.

was assessed in Dujiangyan city of Sichuan Province, China. In [9], the methods for detecting geological hazards in the Beichuan area induced by the Wenchuan earthquake, based on CBERS-02B images, were introduced. In [10], the mechanism of landslides that occurred in the Three Gorges was studied by using the indices deduced from the CBERS-02B multi-spectral images. Maize acreage was estimated by using CBERS-02B images collaborated with EN-VISAT MERIS images in [11]. On the coastal areas, the CBERS-02B images were used for analyzing the impacts of Typhoons Tianying and Dawei in Hainan province, China [12]. The images can also be used for the detection and risk estimation of forest fires [13].

2.3 HJ-1A/1B

HJ-1A/1B are two small satellites for environmental surveillance and natural-disaster management, launched in 2008. The CCD sensors onboard the HJ-1A and HJ-1B satellites are exactly the same, which allow a revisit period as short as two days. Another particular characteristic is the imaging spectroscopy on the HJ-1A satellite, which is the first operational Chinese spaceborne hyperspectral sensor. Soon after its launch, the data provided by the HJ-1 satellites was applied for detecting the landscape change in the Wenchuan area, which was seriously affected by the earthquake that occurred in 2008 [14]. This work showed a great potential for monitoring and assessment of natural hazards by the HJ-1 satellites. The hyperspectral and the multi-spectral infrared sensors on the HJ-1A/1B satellites allow accurate monitoring [15, 16a] and risk assessment [17] of the drought. In addition, these particular sensors can provide data for fire monitoring [18] and water-quality surveillance [19]. In [20], the data provided by the HJ-1B satellites was used for damage analysis of landslides and debris caused by a typhoon in Taiwan. In addition, the hyperspectral data also provide the possibility for atmospheric studies, such as haze monitoring [21].

3. Remote-Sensing Data Processing for Disaster Management

In this section, recent Chinese research results obtained on the management of some typical natural disasters that occurred in China (earthquakes, landslides, and floods) using remote-sensing data will be presented.

3.1 Earthquake

China deeply suffers from earthquakes. Three of the top ten world's most-fatal earthquakes happened in China. In 1976, the Tangshan earthquake killed more than 240,000 people, which is the most dangerous earthquake in the history of the People's Republic of China. In 2008, a magnitude 8.0 earthquake hit Wenchuan in the western part of China, and killed more than 60,000 people.

Soon after an earthquake, aerial remote-sensing images have rapidly covered all the influenced sites [22]. Parallel photogrammetric processing has been applied to the raw data, which provides timely and accurate images on the affected areas [23]. Emergent interpretation of the remote-sensing data has provided rough but immediate information on the location and dimensions of the destroyed houses, roads, and other structures, etc., which has served for rescuing lives, rebuilding traffic lines, and estimating the disaster situation [22, 24]. Further studies in [25] showed the capabilities of remote sensing in post-disaster damage assessment and planning during the rescue operation, soon after a devastating earthquake. An earthquake has taken place in a mountainous area, where the weather conditions are very difficult for optical remote sensing. SAR (synthetic-aperture radar), which can provide information in all weather conditions, was a very important tool for the assessment of damages in the Wenchuan earthquake. For example, in [26, 27], collapsed buildings were detected by using post-seismic high-resolution SAR images. In [28], disaster phenomena – including infrastructure damage, and earthquake-triggered geological disasters, such as landslides, debris flow, landslide lakes, etc. – were analyzed based on airborne SAR and optical images. By comparing the pre- and post-seismic remote-sensing images, surface changes caused by the earthquake can be easily detected [29-32]. Earthquakes can often induce secondary disasters, such as epidemic diseases, landslides, barrier lakes, debris flow, etc. In [33], indices derived from remote-sensing images, such as the NDVI (normalized difference vegetation index) and NDWI (normalized difference water index), were considered as factors for estimating the risk of epidemic diseases after the earthquake. Landslides caused by the earthquake were identified based on the jump of NDVI derived from MODIS images in [34]. In addition, a database of the landslides was created based on the interpretation of remote-sensing images in [35].

3.2 Landslide

Mountainous areas cover most of the territory in China. The Himalaya Mountains extend from Tibet to the southwest of China. The southeast of China is hilly, which also has densely populated regions. Landslides, which often occur in mountainous areas, are therefore major natural disasters in China. Remote-sensing data, including optical and radar images, combined with GIS (geographic information system) is a important approach for landslide monitoring and prediction. In the 1980s, Chinese researchers began to manually interpret remote-sensing data for the monitoring of landslide-prone areas for the construction of infrastructure [36, 37]. In [38, 39], remote-sensing images were registered with geographic information system systems by manually selected GCPs (ground control points) in order to obtain three-dimensional landslide models. In [40a], a more generalized framework for landslide surveying and monitoring was presented. High-resolution airborne images were used for the identification of landslides. The surrounding environment was identified by medium-resolution satellite images, such as LandSat TM, ETM+, SPOT, and ASTER images. More-precise interpretations were performed on stereo images. The results were then registered on large-scale topographic maps. However, it has to be noted that the research on landslides in China mainly focused on the construction sites of infrastructure, such as Three Gorges Dam. The surveying, monitoring, and prediction of landslides in disaster-prone areas are still limited [40b].

3.3 Flood

Flooding is one of the most dangerous and frequent natural disasters in China. It causes enormous losses each year. 10% of the territory, 500 million people, and more than 100 cities are under the threat of flood in China [41].

Remote sensing, which can provide large-scale data covering massive territories, is always a very important approach for the surveying, monitoring, and assessment of floods in China. In the 1990s, remote-sensing images had already shown their great potential in the rescue and reconstruction phases after the massive flood of the Yangtze River in 1998 [42, 43]. After the millennium, thanks to the new remote-sensing satellites with moderate and high spatial resolutions, more-sophisticated schemes for the surveying, monitoring, and assessment of flooding were proposed. In [44], the authors proposed a scheme for monitoring the flooding of the Huai River in 2003, based on real-time hydrological data and multi-temporal remote-sensing images. In [45], a dynamic, real-time flood-monitoring system based on a remote-sensing network was proposed. Moderate remote-sensing satellites, for example, LandSat TM, ETM+, SPOT, CBERS, etc., can efficiently provide information about the land coverage and flooding in a relatively large area. In [46], the images captured by the CBERS-02 satellite were used for monitoring the ice of the Yellow River between 2003 and 2004, which provided fundamental information for estimating the risk of flooding. The DEM with SPOT images were fused in [47] in order to provide realistic three-dimensional visualization for evaluating the risk of floods. Some low-resolution satellites, such as NOAA-AVHRR, MODIS, etc., can provide images with relatively high temporal resolution. In [48], the NOAA-AVHRR images were used for assessing the agricultural losses during the flood of 1998 in the western part of Jilin. In [49], a method for flooding-area estimation was proposed by using MODIS data. The method was applied for producing thematic maps of the flood of 2003 in the Wei River.

4. Conclusion

In this paper, some recent developments of remote-sensing technologies for disaster management in China have been introduced. The recently launched remote-sensing satellites for disaster management – Beijing-1, CBERS, and HJ-1A/1B – have been presented, as well as some typical research results based on the data provided by these satellites. Some developments of algorithms for processing of remote-sensing data for the purpose of disaster management have also been introduced. These were concentrated on three typical disasters in China: earthquake, landslide, and flooding.

5. Acknowledgments

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Towards a Collaborative Approach for Disaster Management Using Radio Science Technologies

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Abstract

This article proposes an approach in parallel to existing professional approaches to support risk management with information technologies. The idea is to rely on the nowadays massively spread smart phones to detect a crisis at an early stage, emit terrain recommendations for a non-skilled public, and facilitate the work of rescue teams. Indeed, current devices embed various sensors that can measure and process information, which can be sent to a control center. Specialists can thus have a better overview of the situation. Our aim is thus to browse a realistic panel of the situation by presenting many aspects brought by current research work in the fields that are related, and to then make propositions to define the features of such an alternative system. After dealing with technical considerations about terminals (type, variability, programming, and aspects of design and usability) and radio networks, we present an architecture that allows communication from the terrain to the public authorities using multiple wireless interfaces, taking into account the specific conditions of a disaster occurring.

1. Introduction

Between 1975 and 2009, more than 10,000 natural disasters killed more than 2,500,000 persons worldwide, and produced an evaluated damage cost of US$1.7 trillion. Earthquakes, landslides, tropical typhoons, severe tempests, floods, and infectious diseases were major causes [1, 2].

During such an event, maintaining a communication link between victims, on the one hand, and the various actors of the response, on the other hand, is important. This link remains a constraint even in non-catastrophic circumstances, for instance, a major blackout in a network (electricity, water, etc.), or communication issues due to damaged roads or other means of transportation. When a natural disaster occurs in a populated area, fast and efficient management of the crisis is of paramount importance to support the population, reduce the number of victims, and limit the economic impact [3, 4]. A non-optimal organization causes delays and reduces the efficiency of the support operations. Such operations are thus more difficult to lead: casualties and losses rise, and the return to normal conditions can be prevented or delayed. In a crisis, time is a critical factor.

Communication operations and services that depend on them are critical at all levels of disaster management. Radio communication is essential to sending alert messages, to exchanging and sharing information between among teams or humanitarian actors [5], to defining and coordinating intervention plans, and to massively diffusing information to public/private services and also to the population [6]. Distant monitoring (available 24 hours per day and under all atmospheric conditions) is very important to assess damages, and to quickly detect meteorological, geophysical, or hydrological events (earthquakes, tsunamis, hurricanes, etc.), and to provide information for rescue organization.

New approaches and the use of new technologies are required for more-efficient risk management [7], before, during, and after a potential crisis. Every specific action at each step of the crisis must be taken into account, and dedicated tools are necessary. New methodologies are needed to conceive systems that mix the use of telecommunication tools, remote sensing (for instance) [8], and space/temporal-oriented databases, which apply specific strategies regarding risks [9].

In this context, information-technology (IT) oriented communications, nowadays commonly used in risk-management studies (without prejudging the efficiency of the methods) are a worthy contribution. Many studies and much specific research has thus allowed renewing the range of possibilities, although the efficiency remains to be assessed.

Many technological innovations (social networks, mobile Internet, etc.) are now common in our society. Do they forge a true new trend for crisis and risk managers, taking into account their vulnerability? How can they support the activity before (prevention), during (management), or after (resilience) the crisis?

If one subscribes to the hypothesis that the Internet provides people with better information, the question is to know how this information interacts with the self-risk-management everyone uses to ensure his or her own safety. Which behaviors have been modified, and what define them? To the opposite, what kind of feedback can people send when they are given information from the services in charge of crisis management? Do risk-exposed populations and risk managers mutually learn from themselves? How can possible collaborations that emerge spontaneously or under a controlled status in such conditions be organized?

The use of information technology for risk management is nowadays common, and has become essential. Most major systems have been created to support operations led by risk professionals, on the ground as well as in control centers (CCs). The infrastructure used is compliant to the required level of demand, in terms of needed service, robustness, or cost [26]. However, creating a secure and reliable communication system, available for all actors (information providers, data-analysis specialists, crisis-management centers, emergency teams, the general public), before (forecasting), during (management), and after the crisis (feedback from experience) is a true challenge.

During such a crisis, radio communication depends on:

- Available communication systems;
- Damage to the infrastructure;
- Phenomena occurring in higher layers of the atmosphere: "space weather" (in particular, with HF and VHF communications);
- The kind of event (e.g., wild fires, strong magnetic interference, miscellaneous radiation).

However, a new possible line of development emerges: a direct link between the population and the official authorities [10, 11]. This is made possible by the emergence and spreading of terminals such as smart phones, embedding various sensors and interfaces that acquire, process, and send information on a wireless network. These devices do not meet the professional requirements, and can in no way replace scientific equipment used by risk-management organizations, but they are a new precious auxiliary source of data. Their main point is that they are very common (generally thousands) and positioned in a given area. How can they be used to very early detect the occurrence of a disaster (earthquake, cyclone, tsunami, etc.)? Is it possible to remotely send personalized recommendations to the population, and make the work of rescue teams easier?

A typical scenario would be the following: many persons in an area where natural disasters can occur have a dedicated application installed on their smart phone. This application keeps analyzing the various embedded sensors of the device, in order to detect groups of patterns (for example, sudden movements lasting several seconds). Once the crisis occurs, the smart phone self-configures itself, taking into account the network resources available in the environment, to send an alert message to the control center, including the position, time and every piece of information that could be useful to help rescue teams. Meanwhile, specific advice can be delivered to the owner by using the same communication channel.

Because this kind of smart phone is relatively new (the Apple iPhone from 2007 can be considered as the pioneer of those terminals), it is necessary to refer to the most recent research work to browse a realistic range of the current situation. Thus, the goal of this article is primarily to draw on this range of options by presenting the current situation of the technology involved in such a vision, and then to put forward propositions to define the features of a system allowing the parallel communication mentioned before.

Three entities must be considered. The first entity is the device itself: we have to determine the mean specifications we can rely on. The second entity is the network allowing interconnection of small groups of devices, in order to build a path to an uplink. Finally, the third entity is the macroscopic view of the terrain that can be drawn by control-center experts. This leads to the structure of our article structure. It is thus divided into three parts. We first will deal with the aspects related to the mobile terminal and its usage. We then will shift to the network-communication aspects, between terminals and to a collaborative system. In the last section, we will present our proposition of an architecture enabling such a process.

2. Smart Phones and Risk Management

First, we will present the average technical specifications on which a solution can rely, and then we will focus on terrain usage that is made possible.

2.1 Characterizing Terminals

Despite the potential enabled by smart phones in a crisis situation, the terrain context must be taken into account. Terminal cost remains a barrier in many emerging countries, even if price drops contribute to democratizing equipment [12]. Keeping this in mind, a study of the market shares shows the average technical specifications of a device. More than brand and model, the most representative criteria is the operating system (OS). In late 2012, 68.4% of the market was dominated by Google's *Android*, and 19.4% by Apple with *iOS*. According to Strategy Analytics, the other platforms shared the remaining 12.2% [13].

Android is thus the most common environment. This induces minimal specifications that all manufacturers must respect to build a compliant smart phone. Those specifications vary with system version. According to data from early 2013 [14], *Android Version 2.3*, nicknamed *Ginger Bread*, is the most common version, since it is installed on 45.6 % of terminals. Its requirements are the same as the previous *Version 2.2*, *Froyo*, from 2010 [14]. The minimum specifications are rather high, even in comparison with 2012 standards: Bluetooth, Wi-Fi and 3G connectivity, minimum two-megapixel photo and video sensor, 50 Hz three-axis accelerometer, 10 Hz polling-frequency compass and GPS chip. One can notice that only 10.5% of the devices rely on previous versions of the OS. The previously mentioned specifications can therefore be considered as a reliable basis, as they are the minimum values reached or exceeded by 90% of the users.

Statistics provided by IDC (September 08, 2012) showed a dramatic increase in *Android* market share worldwide. In one year, it gained 22.1% to reach 68%. *iOS*, the second mobile operating system, only had 16.9%, due to a –1.9% loss, resulting in a market share four times lower than the leader. Two other operating systems lost market share: Blackberry (–6.7%) and *Symbian* (–12.5%), which brought those former leaders to 4.8% and 4.4%. The only progressing mobile operating system was Microsoft's *Windows Phone*, gaining 1.2% to win a 3.5% market share. We can thus deduce that *Android* is probably the most adapted platform to rely on, although its growth is very recent. However, a major new trend that could significantly alter this analysis seems to be very unlikely in the near future. That is why we can rely on these figures to select a relevant development platform. Once done, it is possible to focus on the programming aspects.

2.2 Programming Aspects

From a programming point of view, developing applications for the *Android* environment makes use of largely documented and common processes. The model used by Google is far more open than the models provided by Apple and many other actors: it is possible to deploy and test applications without having to move to a validation process imposed by the firm. Proceeding in a similar way with an Apple device such as the iPhone, for instance, requires a bypass action, *jailbreaking*, which is not endorsed by the company, and may not necessarily be realized by all end users.

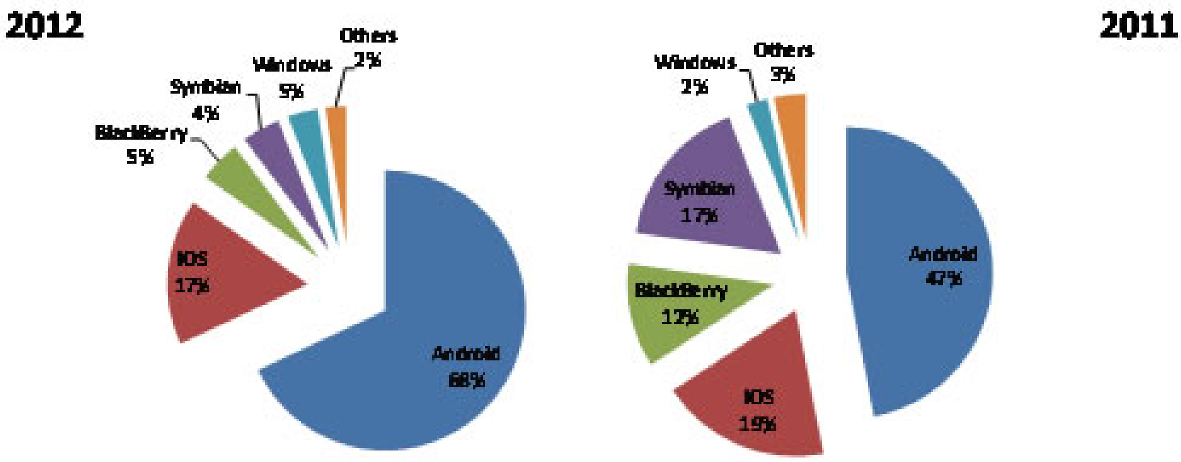

Figure 2. Embedded sensors and their use in disaster detection.

In order to take into account all those terminals not running the *Android* OS, a frequently found proposal in the literature is to use the latter's as a gateway based on a tethering configuration [15].

From a coding point of view, risk-management frameworks (software development environments) have begun to appear. The *RAVEN* project [16a, 16b] is particularly interesting, because it is dedicated to data management in a disaster situation. It implements a model that allows non-specialists to create, edit, and broadcast their own data model from their smart phones.

One could find it rather unfair that the *Android* platform is the main platform. Concerning this particular point, we have to deal with legal aspects, as for the moment the features that are required to achieve our goal (for example, accessing the sensors' management subsystem as a super user) are not officially available in the competitors' environments. However, our hope is to work closely with them to negotiate special rights, once a prototype is ready.

2.3 Using Smart Phones in Operational Conditions

Mobile phones in general [17], and smart phones [55] in particular, were intensively used during recent major emergencies, especially to access the Internet.

The Fukushima disaster became a rich source of information, because of its size, of course, but because it occurred in a country where such equipment is widespread, too [18]. Practically speaking, many phenomena have been observed concerning all types of network communications. Two of them relate to mobile networks: on one hand, the fail rate of calls rose dramatically (up to 95%); whereas on the other hand, data communications resisted perturbations relatively well.

Once the connection was established, people largely used classic and general-purpose services: information Web sites, social networks, etc., even if these cannot replace a dedicated risk-management application. Our proposal to address this situation therefore consists in automatically adding to any communication stream sent from a terminal, data acquired from embedded sensors. Each of the sensors makes sense for remotely defining the specifications of a disaster, as shown in Figure 2.

It is rather difficult to present in detail the technical specifications for each category of sensor (i.e., camera, accelerometer, GPS, etc.), because each manufacturer is free to pick a particular reference to build a device that complies with the Android standard, provided it meets the requirements published by Google. However, such a presentation may not be necessary for now, thanks to the general specifications provided in [14]: typical features are listed in the document, independently of a brand. We cannot rely on dedicated references; we have to deal with versatile equipment.

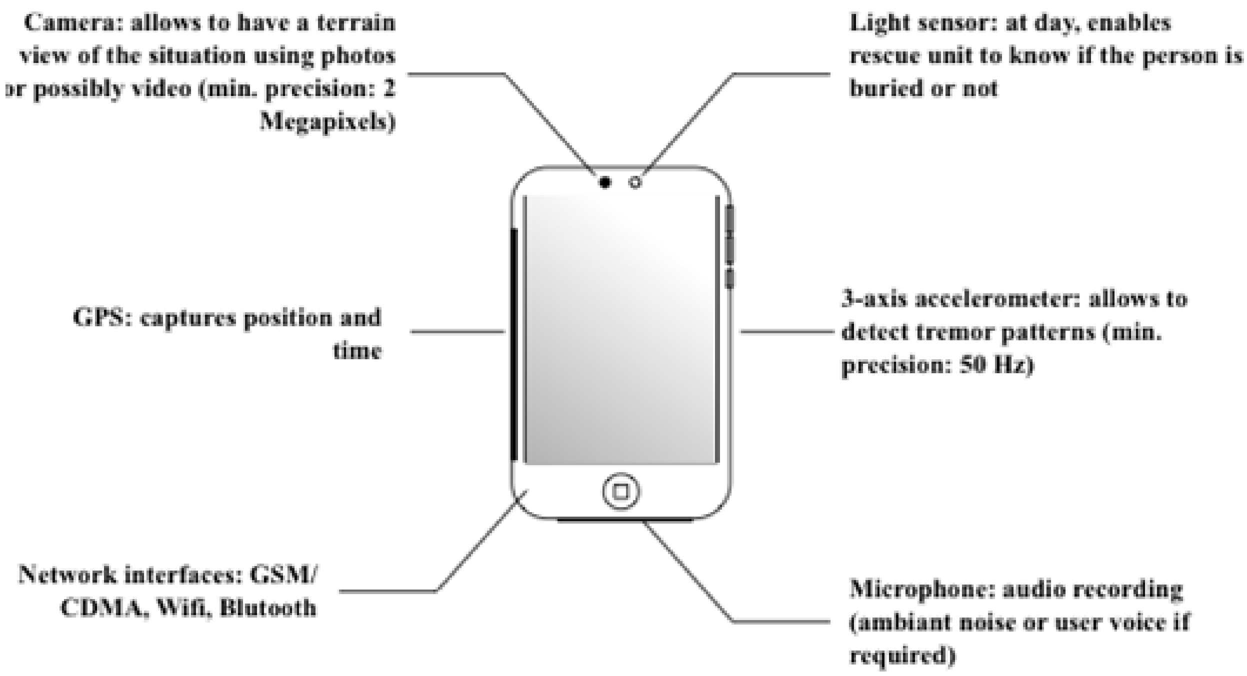

Figure 2. Embedded sensors and their use in disaster detection.

2.4 Accessibility and Human-Machine Interaction Aspects

Designing a specific service accessed from a smart phone in crisis conditions must take into account accessibility criteria in order to be practically used by the population, without considering the data automatically acquired and measured by the terminal. Actually, skill and appropriate levels are extremely variable in terms of age (from child to elder), school grade (literate/illiterate), and perhaps handicap (prior to the event occurring, or resulting from injuries). In this context, relying only on textual information can be a problem. One may consider that vocal communication is the most appropriate means of exchanging information, because it does not require much (human) interpretation, provided everyone shares the same language. Unfortunately, research shows that restrictions apply, due to the organization of such communication under difficult conditions [19].

As far as video is concerned, it may be efficient in many contexts [20]. However, bandwidth and general resource consumption (high processing workload to encode data, file sizes) can worsen the situation (excessive consumption of resources, resulting in high battery use) under bad conditions of the network. Battery saving is a critical factor for extending the lifetime of the overall system.

A complete advanced system, such as the one presented in [21], is a good combination of several types of communication, mixing smart phones, tablets, GPS, GIS (geographic information system), video, and biometrics. However, like other projects mentioned, it was tried in geographically closed environments (fire) and by professional actors. Therefore, because of the lack of experiments involving a non-skilled public, only generic recommendations can be made in terms of the design and evaluation of human-machine interfaces [22]. Those recommendations can be adapted to the technical context of smart phones. Major manufacturers and editors publish guidelines to help developers to offer a homogeneous experience, for example, as far as navigation schemes are concerned, or by relying on known icons or gestures.

2.5 Existing Smart Phone Applications Dedicated to Risk

Taking into account our objectives, we must admit that no application addresses the three aspects of disaster management we defined: crisis detection, a communication link with the population, and rescue-team guidance. Existing solutions focus on the second aspect, in a half-duplex way: from an entity (official or not) to users. One such system is currently in use in fire-prone areas in Australia, with certain limitations [59, 60]. Subscribers are sent text messages and prerecorded sound messages with information regarding the alert, in case of bushfires in the area.

In the same category, the *Disaster Alert* application (see http://www.pdc.org/iweb/ disasteralert.jsp) is one of the most popular. It has reached 500,000 installations on *Android* and probably 250,000 on *iOS* (Pacific Disaster Center Web site estimates; Apple does not communicate statistics). It features a map that shows, in real time, every event that can be considered as a threat for the population.

The *ubAlert* application (only available for *iOS* devices) offers the same service, but is based only on users' reports, without any warranty.

To consider more interactive solutions, it is necessary to focus on more localized projects. The *Disaster Kit* application from NTT Docomo (see http://www.nttdocomo.co.jp/english/info/disaster/disaster_kit/index.html), the predominant Japanese phone operator, thus only addresses Japan. It was downloaded more than five million times. It allows users to report their being in a safe place during the occurrence of a crisis to a central system, which is a complementary approach to the one consisting of looking for missing people. An audio message can be attached to the report. The connection is done by using data channels, in order to cope with the saturation of voice channels, as discussed before. Other similar applications exist, but this application is particularly representative, because it is proposed by an operator who can handle the whole communication process, and it is supported by a robust infrastructure (Disaster Message Board).

Microsoft undertook to transpose the concept to the USA with the *HelpBridge* project, announced in January 2013 (see https://www.microsoft.com/about/corporatecitizenship/en-us/nonprofits/Helpbridge.aspx). However, because it is limited to the *Windows Phone* platform, which has rather low market share, the expected impact is difficult to measure.

Finally, a bunch of informative applications have been proposed, giving checklists and procedures to apply regarding a particular event. In this category, the FEMA application from the Federal Emergency Management Agency (USA) is authoritative, although no interactivity is featured.

3. Communication

Disaster management (or by extension, the control of dynamic complex systems) can only be considered with the integration of human decisions (and therefore, decision makers). The information handled by these decision makers can of course be more or less aggregated, or generally preprocessed by assistance systems, but finally there are always one or more persons in charge, who have to:

- Either interpret the current system state and its future potential states, and pick a preventive action among multiple alternatives (including doing nothing),

- Or decide on a corrective action, according to an occurring disaster.

In this context, maintaining a communication link between the various actors in the crisis rapidly becomes important, in order to provide information at each step of the crisis.

3.1.1 Before the Crisis

Protection and security must be achieved. This is done by identifying the sensitive spots related to cascading consequences, thus redefining the global security policy of the system and an optimal redeployment of the monitoring resources (human, material), and by modeling interdependences and the dynamics of the phenomenon.

3.1.2 During the Crisis

Optimal adjustment of the action plan and mitigation of the impact must be done. Predefined scenarios cannot anticipate the failure of all combinations of p points of a system containing n points. At the very beginning of the crisis, models permitting definition of the initial scope and globally deducing the evolution of the system, in order to find the appropriate action plan, and to therefore the effects (human losses, infrastructure casualties, immaterial damages), are necessary. A common formalism that allows mapping and management of crisis situations is required to ease the collaborative work that gathers all the actors who are involved in the resolution of the crisis.

3.1.3 After the Crisis

The optimal path to a return to a normal situation must be defined. Similarly to PERT[1] diagrams, knowing the interdependences (static view) and cascading consequences (dynamic view) of the considered system permit ordering which points of the system must be reactivated first, and optimizing the allocation of resources to address the crisis.

3.2 Communication in Crisis Management

Communication is crucial in managing risk and crises. Its use goes from the simple need for the population to contact their relatives to the coordination of assistance operations [23]. Because of the characteristics of the situation (heavy loads, etc.), urgency, and the critical nature of the situation, as well as the complete or partial unavailability of the usual infrastructure, alternate solutions must be easily, quickly, and at a reasonable cost deployed to guarantee resilience in terms of communications [56]. Wireless infrastructures are part of the response.

Mobile ad hoc networks, which do not rely on existing infrastructures, can be used. However, their characteristics must be taken into account: their limited capacity, potential external intrusions, or maybe the use of non-permitted frequencies. Many projects and much research work show the strong interest of the scientific community, the actors, and risk experts in this concept [24-27]. Several propositions have been made, according to the planned use of the network [28]:

- Personal area networks (PANs) interconnect terminals and devices belonging to one user on the terrain. For instance, a fireman can simultaneously make use of a gas detector, a geo-localization device, and an oxygen cylinder.

- Incident area networks (IANs) are temporarily deployed to manage a specific incident because of the lack of fixed infrastructure. They allow the transmission of critical data between first-aid workers, and support the coordination in their mission.

- Jurisdiction area networks (JANs) are the main paths that unit traffic going between incident area networks, or not supported by those networks. They are installed by local authorities, or the security organizations for emergency situations. Contrary to incident area networks, they are permanent.

- Extended area networks (EANs) support connectivity between regional and national networks.

3.3 Constraints and Difficulties

Partial or total lack of fixed infrastructure forces terminals to assume communications tasks that are typically not in their main scope [29]. Taking part in traffic relay and transportation is added to the usual information production and access. As transmission range is limited, traffic is conveyed step by step by involving intermediate terminals. Routing operations are performed in a distributed way due to the absence of a central coordinator.

Users' mobility – and, as a result, devices' mobility – induces a dynamic aspect in the network, in terms of users and topology as well as in terms of available resources. Many links or relays may actually be lost during communication. Technological modules used must therefore support

1 The program (or project) evaluation and review technique, commonly abbreviated PERT, is a statistical tool used in project management. It is designed to analyze and represent the tasks involved in completing a given project. First developed by the United States Navy in the 1950s, it is commonly used in conjunction with the critical-path method (CPM).

reconfiguration, and be able to manage failure and adapt themselves to network dynamics. Moreover, the number of participants may change throughout the network's lifetime. Scalability is thus an essential property that the protocols and mechanisms must have.

Diversity in terms of network and equipment requires taking into account the interoperability between network elements [30, 57]. Because of the lack of a unique standard (although the IEEE 802.11 family is supported by most terminals), multiple communication technologies (Bluetooth, Wi-Fi, Wi-Max [58], etc.) coexist in the same radio environment. They share the same resources and have to coordinate with themselves to achieve efficient use of bandwidth. Sometimes, situations result in bridging these technologies to make the data-exchange services persistent. That is why they have to offer interfaces that simplify integrations when they are required.

Generally speaking, devices are poorly equipped in terms of memory, processing ability, storage capacity, and, mainly, energy resources. Communication is one of the most energy-consuming functions. Managing this resource with precision is essential for maximizing the lifetime of the resulting network. A heavy constraint concerning protocols and network mechanisms is hence required: explicit interactions relying on the communication interface must be kept to a bare minimum to save the battery life of devices.

Now, communication needs raise dramatically in crisis situations, and when natural disasters occur. Some services are more stressed than others [18]. As mentioned before, recent experiments show a high perturbation of vocal transmissions, whereas data networks are relatively preserved. These congestions are more critical on an alternative ad hoc network, because performance is limited in comparison to traditional infrastructures. Traffic management and congestion control are therefore essential. Some streams are more important than others and must benefit from a better transport service on the network, in particular when congestion occurs. This form of prioritization is not necessarily implemented on a conventional infrastructure apart from a crisis situation.

Terminals represent active items of the network. They entirely or partially carry out the data-transport service. Opposite to the operator's infrastructure, it is often impossible to physically perform administrative tasks on the user's equipment. Moreover, the users often don't have the skills to do the required operations regarding network configuration themselves. The best solution thus consists in making protocol configuration and network mechanisms simple and, if possible, automatic.

Wireless transmission is more sensitive to interference than wired transmission. Wireless transmission is by itself a source of interference for other transmissions. The consequences and types of the perturbations it generates on the different communication layers are not predictable. A wireless link cannot be confined in a constrained and protected space. Ambient environment-related factors may contribute to interference. The user experience is thus affected when perturbations occur in the transmission media. The proposition then consists in having the best knowledge of the radio operator's environment, and in adapting network-protocol operations on the basis of the resulting model.

Finally, emergency situations lead many different organizations to use the same network [30]. Secure communication is necessary to guarantee that an actor can only access the data with which he is concerned. Anonymity and private life must be preserved, despite wireless communication being opened. For instance, a patient's file in an operating theater should be accessible only by medical staff.

3.4 Technological Components

Research work from the scientific community, industrial actors, and risk experts has shown two trends as far as building-communication infrastructures in the context of disaster management is concerned. The first trend comes from the Internet sphere, and relies on local and extended networks. Given the use of advanced terminals such as smart phones, we will start by focusing on mesh and ad hoc networks. The second trend stems from the use of mobile cellular telecommunications infrastructure.

3.4.1 Mesh and Ad Hoc Networks

Wireless mesh networks (WMNs) offer an almost stable backbone. A wireless mesh network consists of a self-organized network in which nodes form links and maintain connectivity. Traditionally, wireless mesh networks consist of two types of nodes: meshed clients (or simply stations), and meshed routers (or simply routers). Routers constitute the communication infrastructure, and provide transport functions such as routing. They have limited mobility, and form the backbone. Some routers have Internet access, and can thus extend network connectivity. Mobile ad hoc networks (MANETs) are simplified wireless mesh networks in which the roles of router stations are taken by users' mobile devices.

Recent works [29] have shown a growing interest for wireless mesh networks by many researchers. Those works, mentioned hereafter, focus on a limited set of problems:

- Modeling and measuring interference [31]: The aim is to estimate the level of interference in a dynamic wireless environment. Interference essentially defines the final performance level of the network.

- The power and topology controls [32, 33]: Communication at one place impacts the other communications occurring in the area. Power control allows adjusting the transmission power to the minimum required to reach the receiver, so that range is limited, and the number of affected communications is lowered. Topology control consists in selecting the links to activate in order to reduce interference to the smallest level.

- Medium access and scheduling links [34]: Two or more neighboring transmissions (links) using the same radio frequency cannot be activated at the same time; otherwise, collision will occur, and this will prevent the receivers from properly decoding data. Medium access control (MAC) is the procedure run by each node to coordinate direct neighbors in the medium access. Scheduling links stretches this coordination to nodes found beyond the transmission range, step by step.

- Allocation of channels and frequencies [35]: The goal is to attribute one or more frequencies to each node, in order to reduce contention between neighboring nodes.

- Routing [36]: This operation involves the selection and establishment of a path through the network, allowing communication from a source to reach its destination.

- Network planning and deployment: this study focuses on determining the optimal locations of nodes and gateways, and deployment conditions.

These problems have mostly been separately studied. However, terrain experiments show a strong relationship among the various elements of the network architecture [37]. Moreover, results from theoretical models, simulations, and controlled experiments differ, sometimes widely, from those obtained in a real environment. The difference is mainly due to the complexity of interference phenomena. Initiatives [38] have tended to do a joint conception, simultaneously considering two or more problems. Furthermore, other works aimed at improving the theoretical interference model by using measures in a real environment [39, 40]. The main limitation of these approaches remained in the required calculated workload for processing measures in real time, and the lack of a generic model that can be used on any environment. On the other hand, they showed the importance of experimental studies and real deployment in the context of mesh networks: hence, the creation of experimental platforms [41] such as Magnets [42] and WiSEMesh [43].

Operational architectures have thus recently emerged. The Serval project [44], one of the first functional projects, is aimed at providing a communication system relying on smart phones without requiring the existence of a fixed infrastructure. Lifenet [45] is another communication system based on an ad hoc Wi-Fi network. The *OpenGarden* [46] application permits sharing Internet access among several devices.

3.4.2 Mobile Cellular Telecommunications Infrastructure

Telecommunication infrastructures offer extended range to users possessing any kind of phone. They rely on an elaborate distribution of interconnected base stations. A few years ago, the implementation of such solutions required a heavy investment. Nowadays, hardware and software blocks exist to deploy a mobile cellular infrastructure at low cost.

The Range Networks Company [47] proposed a mobile base station priced at US$5,000. This equipment relies on an *OpenBTS* software layer [48], available as an open-source program. An alternative solution – based on a USRP module [49], an *Android* smart phone, *OpenBTS*, and *GnuRadio* [50] – exists, reducing the cost to about US$1,700.

The Village Base Station (VBTS) project [51] is aimed at deploying at a lower-cost base station consisting of a standard computer. On the other hand, *OSMOCOM* (open-source mobile communications) is an open-source software suite dedicated to mobile telecommunication networks. Its goal is to foster research, innovation, and experimentation on such networks. Some projects, such as *OpenBSC*, are more advanced than others.

3.5 Alternative Approaches

The Delay Tolerant Network (DTN) and, more particularly, opportunistic networks are alternative solutions for disaster management [53]. A node may communicate with another node, even if a complete path linking them is missing. An intermediate node can be involved in an opportunistic manner to relay data, if it allows coming closer to the recipient. Data transport is thus done step-by-step according to this scheme, to the final destination. Opportunistic networks exploit node mobility. In this perspective, the Twimight system [25] offers a micro-blogging service similar to *Twitter*, dedicated to emergency and crisis situations.

A report from the French Embassy in Japan [61], following the Fukushima crisis, presented a system allowing smart-phone-to-smart-phone communication. To achieve this, telecommunication provider KDDI developed a process redirecting e-mails sent from an area where standard infrastructure was not available anymore for a given operator by passing through another phone from another operator. Each provider has its own network; that is why the relaying stations are different. In case of a disaster, only one operator can remain active in an area. Thanks to the KDDI process, users from other operators can still send emergency messages. The aim is thus to extend the range of the population that still has access to communication systems during the crisis. The message itself is sent via Bluetooth or infrared interfaces to another phone. The relaying device cannot read the message, in order to preserve privacy.

4. Architecture

An ideal architecture should support the three main actions we previously identified: early detection of a crisis, emission of terrain recommendations for a non-skilled public, and facilitation of the work of professional actors. This proposition relies on two different types of communication networks: the public general-purpose network (independently of the technology: 3G, Wi-Fi, Wi-Max, Bluetooth, etc.), and the network dedicated to risk management. The idea is not to make them directly interact, but to use a gateway that can filter what kind of content shall go from one to the other.

In addition to this factor, two different spatial contexts must be considered: terrain and control center (CC). Once again, it is necessary to take into account two types of links: inside the terrain and uplink to the control center. Given its missions, we make the hypothesis that the latter is correctly protected and equipped so that it is not the most critical point of the communication system: it features dedicated devices to ensure its reliability during tough times.

Let us now move to the different entities defining the architecture for the two spatial contexts put forward.

4.1 Terrain Architecture

The first step in the process is to detect a disaster. The terrain architecture should therefore be permanently active. Each smart phone makes use of its embedded sensors to evaluate the situation, and to trigger a particular action if threshold values are reached. The first module in this part of the architecture consists of proposing an embedded decision system that can output a conclusion from given measurements of various factors.

In this context, the terrain is characterized by highly variable conditions of communication at all levels: the type of radio link, range, data rate, robustness, latency, etc. For a given use, one cannot be sure that the most-appropriate technology is available. That is why we make the proposition to combine all of them and to define a hierarchy, from the most optimal to the most degraded operation. As smart phones embed several types of network interfaces, they are able to select the most appropriate interface, given detected signal conditions. This is a second module to integrate: a system that can diagnose communication conditions, and select the transmission channel that has the best probability to work.

In a second step, each terminal must discover its environment in order to calculate a route to a decision center when a direct link is not possible. This leads to the idea to rely on a mesh of devices that can be peers (other smart phones), as well as different kinds of equipment (Wi-Fi routers, etc.). In the risk context, the system has to be autonomous, and it therefore has to be able to auto-configure itself. This is another module of the architecture: a decentralized and self-configurable communication network.

4.2 Control Center Link

A central authority is needed to emit safety recommendations to the public and to guide rescue teams: hence, the importance of the link with the control center. The control center features a routing and filtering gateway, allowing management of multiple virtual networks in

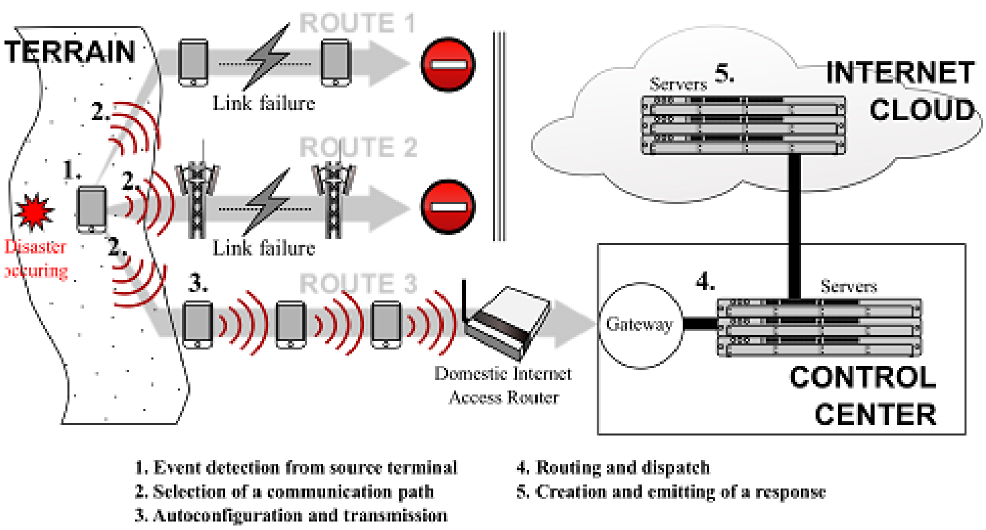

Figure 3. A global architecture showing a typical case.

parallel, so that general public communication, on the one hand, and expert communications, on the other, are not processed the same way (or possibly with the same equipment).

Moreover, the control center must include a connection to the wide-area network (*uplink*), which allows it to outsource many actions to other infrastructures. The recommendation system is an important part of those externalized actions: it has to address a large amount of requests with specific data sets as inputs, sent by each terminal on the terrain. The required processing ability does not need to be physically located in the concerned area: calculus may be realized on a server farm or in the *cloud*.

Guiding rescue professionals to the location of the disaster can be done with this infrastructure, given that information feedback is centralized in the control centre as the primary node.

The main module of our proposal here thus consists in building and adapting to the control center a gateway between the terrain and the Internet's worldwide network. This gateway has to manage multiple layers of service, depending on the available bandwidth, number of requests to process, and has to stream priority according to their source. Finally, the last module is the personalized recommendation system, calculating feedback from the data sent by smart phones, possibly under the control of an agent which may simultaneously address several identical cases, for instance, in the context of a specific area.

4.3 Global Architecture

The global architecture results from the local architectures depicted before. It is presented in Figure 3. A typical case study is proposed. We call the Source Terminal (here, a smart phone) the device that issued an alert from the data it got from its sensors. Only one is shown here, located on the left side of the figure. Of course, the architecture is practically implemented for a whole set of terminals, and one smart phone acting like a relay in the mesh might itself be a source for its own geographical location at the same time.

In this example, the Source Terminal has detected a disaster by overlapping data captured from embedded sensors: accelerometer, camera, microphone, GPS, etc. In this figure (Figure 3), three paths (i.e., succession of network nodes) to join the control center are considered by the Source Terminal, relying on several types of networks: GSM, Wi-Fi, Bluetooth, etc. Paths 1 and 2 are not successful, due to network failure. Path 3 profits from an opportunistic mesh network, and gradually reaches a domestic ADSL/router broadband box that allows it to connect to the control center via the Internet. The gateway plays its filtering and dispatching role on the input and output streams. All links are bidirectional, in order for the processed data to go back on the terrain.

5. Conclusion

Radio science was often confined to solving problems of communications. However, it proposes a large panel of concepts, technologies, and methods allowing creating or optimizing tools for risk managers.

These experts are involved in many large domains of radio science. The contributions and assistance of URSI specialists from all the Commissions allow implementing new operational and efficient approaches for managing the various events that occur in our everyday life. This proposal, dedicated to the technical feasibility of a radio-communication system for risk management, based on both science and engineering, allows building barriers against risks. To complete it, an additional reflection relative to the societal acceptability of the technology must be made. Its aim is to permit taking into account the constraints related to the various human actors.

The implementation must be based on a methodological framework technology diagnostic [54]. A first step is necessary to study the technology and the use made by the public in order to define the mechanisms and an appropriate evaluation strategy. The latter should take into account a study of the normative and regulatory environment to identify present and future constraints. It can be completed by questionnaires, aimed at drawing out the perceptions of the various actors of the process. The results of those two first steps will be used as the basis for a deeper study aimed at analyzing the potential brakes that may limit the deployment of the solution and/or alternative solutions.

The final result of the studies would be a document integrating the societal concerns in the conception process, and the deployment of such a communication system.

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Radio Science's Contribution to Disaster Emergencies

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Abstract

Radio science plays an important role in the first two weeks after a disaster strikes, i.e., in the "response phase." Optical observations are considered complementary. The paper deals with: (i) actions presently taken for ensuring radio propagation and radio navigation in a crisis period; (ii) spaceborne, airborne, and ground-based remote-sensing instruments (in particular, synthetic aperture radars) used for collecting the maximum of relevant data; and (iii) data management, via geographical information systems (GIS), for the decision-making process.

1. Introduction

According to Guhar-Sapir and Hoyois [1], in 2012, naturally triggered disasters (earthquakes, landslides, and severe weather, such as tropical cyclones, severe storms, floods) killed a total of 9,655 people, and 124.5 million people become victims, worldwide. Although those numbers were well below the 2002-2011 annual averages (107,000 people killed and 268 million victims), economic damages did show an increase to above-average levels (US$143 billion).

Figure 1. The disaster-management cycle (source: Australian Development Gateway).

When a natural disaster occurs in a populated zone, a fast and effective organization of disaster management is necessary to assist the affected population, reduce the number of victims, and limit the economic impact [2-4]. Regardless of community size or the nature of the disaster, local government leaders are responsible for overseeing all three phases of the disaster-management cycle: pre-disaster, response, and past disaster (Figure 1). In all phases, one of the first actions to be taken is to set up a disaster cell for coordination. For major risks, this includes national ministries, civil defense, regional and local administrations, nongovernmental administrations involved in disaster management, experts, crisis staffs, a command chain, an information chain, etc. A non-optimal organization causes supplementary losses and delays returning to – or even preventing returning to –normal conditions (http://www.un-spider.org/).

The present paper deals with the "response phase" of the disaster-management cycle, where information must be delivered to the disaster cell in the shortest possible time [5-7]. The detection and the monitoring of the impact and effects of natural disasters are generally done via spaceborne and airborne remote-sensing surveys through radio and optical instruments. However, for the sake of convenience (nighttime IR imagery being more difficult to interpret in specific conditions), only radio observations will be considered. An international charter, (http://www.disasterscharter.org/web/charter/charter), facilitates access to the relevant data. This aims at providing a unified system of space data acquisition and delivery to those affected by natural or manmade disasters.

The architecture of the disaster-management system comprises three working domains, or subsystems, involving experts and complementary scientific disciplines. Their main characteristics are summed up below:

- The "communication" subsystem (Section 2) is essential for sending and distributing alert messages, exchanging of information among all the actors, disseminating information and instructions to public and private services, and taking care of the radio navigation and observation services.

- The "data acquisition" subsystem (Section 3) concerns the acquisition of information provided mainly by radio remote-sensing instruments.

- The "emergency management" subsystem (Section 4) includes (i) a "processing" subsystem, concerning the consolidation of information provided from different sources and broadcasted to operational intervention teams; and (ii) a "management' subsystem, in charge of the management of the databases and, more specifically, of the geographical information system (GIS), which involves optical as well as radio data.

2. Communication

The communication section includes: (i) communication services, (ii) radio navigation and observation services, (iii) communications disruption generated by variations in the space environment during the response phase of a disaster, and (iv) a study in progress on mobile ad-hoc networks.

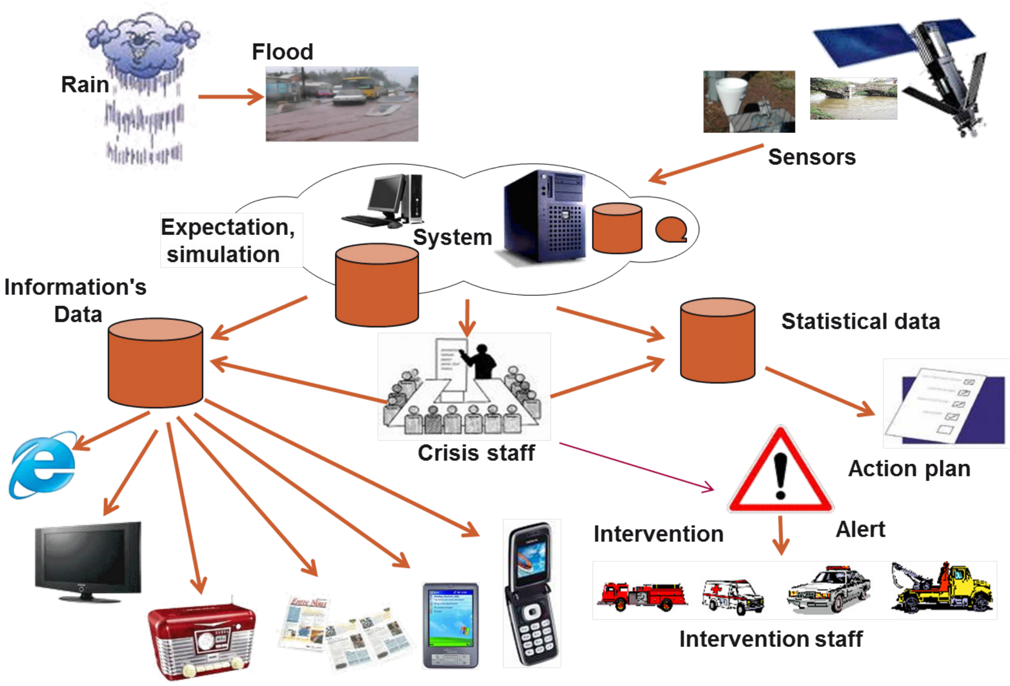

Figure 2. An example of a communication system [7].

2.1 Communication Services

Radio communications have three main functions: connecting the disaster cell, collecting and distributing observation data, and then distributing display analyses and forecasts provided by data-processing centers (see Figure 2). Radio communications play a crucial role for monitoring and management, as well as for forecasting potentially devastating impacts, and identifying appropriate actions to be taken.

According to the location and the needs, different types of communication systems may be used: fixed telephone lines, HF (3 MHz to 30 MHz) and VHF (30 MHz to 300 MHz) systems, mobile phones connected to cellular networks of specialized base stations or to orbiting satellites, etc. The design of secure and safe communication systems, available to all actors (information providers, data-analysis specialists, crisis-management cell, rescue teams, public, etc.), is a real challenge.

During the response phase of the disaster-management cycle, radio communications depend on:

- available communication systems,
- damage caused to infrastructures,
- signal degradation or disruption caused by natural events such as wild fires [10, 11], or variations in the space environment of the Earth, independently of any disaster (see Section 2.3).

Emergency communications system (ECS) and mass notification system (MNS) broadcasts have been developed for providing emergency information to help prevent injuries and save lives.

Following the 1998 Tampere Convention on the Provision of Telecommunication Resources for Disaster Mitigation and Relief Operations, which went into effect on January 8, 2005, it was shown that

> Emergency Telecommunications play a critical role in the immediate aftermath of disasters by ensuring timely flow of vital information which is much needed by government agencies, and other humanitarian actors that are involved in rescue operations and providing medical assistance to the injured

(see http://www.itu.int/ITU-D/emergencytelecoms/). In this regard, the ITU and its partners have long experience in:

- the deployment of satellite communication equipment, as well as for mitigation and preparedness for a rainy season (which is causing severe floods and mudslides), or for mitigation and preparedness in response to possible volcanic eruption;
- the deployment of satellite telephones with solar panels to provide assistance for rescue operations as well as to help restore vital communication links;
- uses of solar panels to provide alternative power in the absence of power infrastructure in the immediate aftermath of a disaster; etc.

2.2 Radio Navigation and Observation Services

Navigation systems include flight management systems (FMS) and global positioning systems (GPS). Global navigation satellite systems (GNSS) are the primary means for obtaining position, navigation, and timing information. GPS, GLONASS, and GALILEO are all global navigation satellite systems. However, the 1215 MHz to 1350 MHz band, which is allocated to radio location services (ground radars) on a primary basis, may be more vulnerable to interference.

Effectively, radio-frequency interference has been detected on global navigation satellite system navigation systems [12]. The high occupancy of the spectrum around the global navigation satellite systems' frequency bands indicates the high probability of out-of-band emissions, harmonics of intermodulation products. Unintentional interference mainly originates from satellite communications, TV broadcasting, radar applications, and ultra wideband (UWB) communications.

As pointed out in [13], observation services are also sensitive to unintentional radio-frequency interference. For instance, this is the case for the synthetic-aperture radar onboard the ESA SMOS mission.

2.3 Communication Degradations and Disruptions Generated by Variations in the Space Environment

When they occur during the response phase of a disaster, communication degradations and disruptions caused by variations in the space environment (i.e., by "ionospheric scintillations" and "space weather events") may make disaster management more difficult.

There are three major sectors of scintillation activity: the equatorial region, and the north and south polar regions. Irregularities in the polar regions are caused by precipitating high velocity auroral particles. In the equatorial regions, irregularities result from bubbles that form at the bottom of the F-region ionization layer. In both cases, they affect radio communication and radio navigation services [9].

Space-weather events are triggered by solar events. They are obviously more important for "extreme events" (once per solar cycle) than for strong events (175 per solar cycle). They have effects of degrading or disrupting communication satellites and wireless systems ([8, 14]), radio navigation [16], GPS operations ([7, 15, 17]), observation services [18], etc.

2.4 Mobile Ad-Hoc Networks

Mobile ad-hoc networks (or MANETs) are one way to provide interoperability between satellites and terrestrial communications. A mobile ad-hoc network may be required only when satellite networks are not well connected to terrestrial networks, for instance at the time of a large-scale disaster that destroys the telecommunication infrastructure [19, 20].

A mobile ad-hoc network a self-configuring infrastructure network of mobile devices (or nodes), connected by wireless links, which does not require any fixed entity or/and any existing infrastructure. The absence of infrastructure forces the nodes to behave as routers, which contribute to the definition and configuration of routes for other nodes. Communications between nodes may be direct or via nodes used as relays. Such a capability is expected to allow setting up information networks and command systems required for aiding operations and exploration, search and rescue operations, monitoring animal movements, remote control of domestic equipment, communicating vehicles, etc. Mesh networks are emerging technologies allowing extending distances and densities. For example, tests have been performed in the context of the European program OASIS (see http://www.oasis-fp-org/documents.html).

Numerous papers have been recently published on mobile ad-hoc networks (see, for instance, [21]). However, one cannot consider that such networks are at the application stage. Moreover, according to the continuous growth of the demands for allocated frequencies, the search for vacant frequency bands may be a serious problem for the future. Cognitive-radio technology may be a way to solve that problem [22]. However, this has not been demonstrated, so far.

3. Data Acquisition

When a disaster strikes, whatever the countries involved, one of the first priorities is to collect relevant airborne and spaceborne remote-sensing data. There is no satellite or constellation of satellites dedicated to disaster management. However, thanks to the international charter "Space and Major Disasters," presently signed by 15 organizations and space agencies (see http://www.disasterscharter.org/web/charter/ charter), a unified system has been set up. This is for both data acquisition and delivery to the public and private services, and for emergency services that may provide assistance.

There is no similar charter for airborne and ground-based data. Equipment and operations are generally under the responsibility of space agencies and/or public security. However they play an important role in the development of methods and techniques, as well as in disaster management.

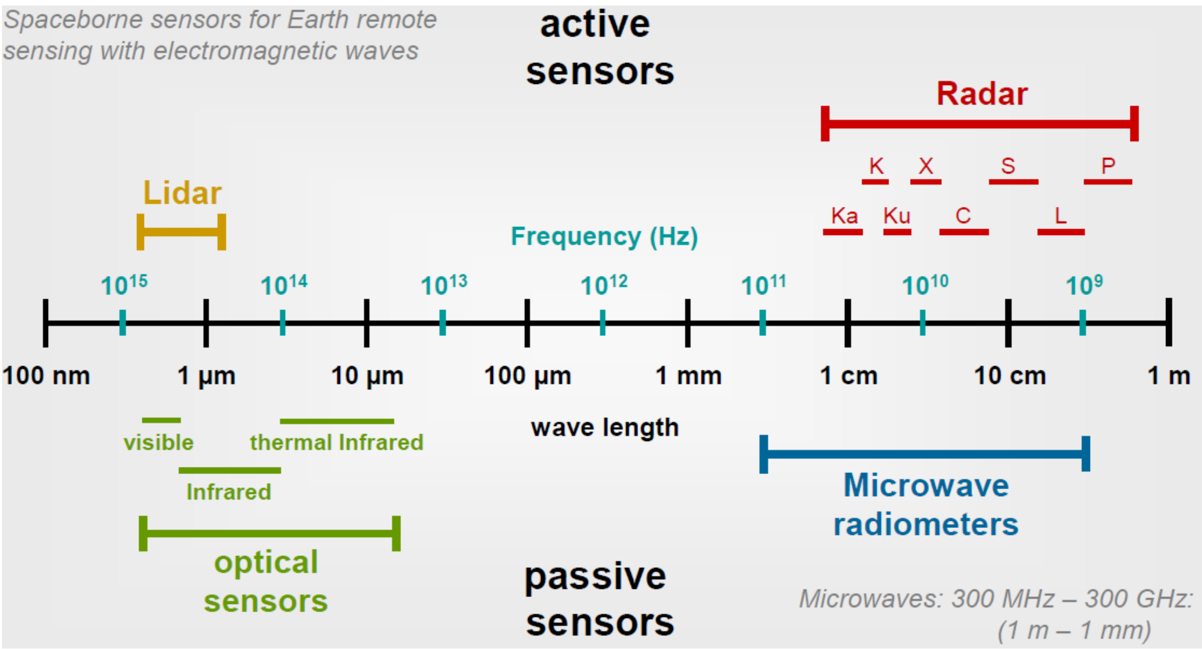

Figure 3. The frequency bands of the passive and active sensors for optical imaging and for radio imaging

3.1 Space Data

Except for the lidar instruments, optical images are produced by passive optical sensors. Even during the response phase of the disaster-management cycle, where rapid acquisition of the data following the event is needed, the spatial resolution of optical images is always better than for radio images. Limitations in the use of optical data are generally caused by the difficulty of interpreting optical imagery, both at nighttime and through clouds, smoke, or haze. In this regard, cloud cover is a serious problem, especially over the humid tropical regions. However, as explained in [23], thermal remote sensing has the advantage of being a branch of remote sensing that deals with the acquisition, processing, and interpretation of data acquired primarily in the thermal infrared (TIR) region of the electromagnetic (EM) spectrum (Figure 3).

Extracting the "Type of information" and the "Data required" from Table 3 of [24], one notes that the space data required are mainly:

- for flood: SAR (synthetic-aperture radar), optical;
- for widespread storm or earthquake-induced landslides: SAR, moderate high-resolution optical;
- for volcanic ash and gases: shortwave infrared, thermal infrared;
- for public information during events: high-resolution optical imagery;
- for ship location: SAR;
- for co-seismic and post-seismic deformation: InSAR (interferometric synthetic-aperture radar).

SAR radars embarked on remote-sensing satellites are very important for disaster management. They may detect all natural (and manmade) geologic, hydrologic, and atmosphere phenomena that may generate hazardous situations (see [25], for instance), as well as their effects on inhabited areas, population situation, etc. The qualities of the images they provide depend on the spatial, spectral, radiometric, and temporal resolutions. Moreover, as regards the environmental conditions, it must be noted: (1) that the sensitivity to the atmospheric absorption starts to be a concern at frequencies above 10 GHz, and is effective above 30 GHz (EHF band); and (2) that if in the case of moderate to severe space weather events (see http://www.swpc.noaa.gov/Data/), low-frequency bands may be sensitive to ionospheric perturbations (in particular at high latitudes and in the equatorial regions), this sensitivity considerably decreases in the highest frequency bands. The commonly used frequency band (and wavelength range) for the SAR satellites, and the main applications, are given in Table 1.

Advanced SAR techniques have been developed for specific applications. Interferometric synthetic-aperture radar (InSAR) is a technique based on phase differences between two or more SAR images, acquired from slightly different positions. The interferogram so obtained may be used for topography representation. Differential interferometric synthetic-aperture radar (DInSAR) allows order accuracy better than the radar wavelength. Polarimetric synthetic-aperture radar (PolSAR) is another extension of SAR imagery. One application is the discrimination between different types of diffusion mechanisms, with applications to the estimation of physical properties of the ground. For the last few years, ESA workshops have been organized around polarimetric SAR interferometry (Pol-InSAR).

3.2 Aerial and Ground-Based Data

Most techniques and instruments may be used on satellites, planes, unmanned aircraft (drones), balloons, helicopters, and on the ground. Aerial observations and observations on the ground are of interest to focus on priority areas, verifying small-scale data interpretations, and providing information about features that are too small for detection by satellite imagery. Observations at different altitudes allow making different types of studies. A few examples are given here.

Ground-based observations of variations in the phase and amplitude of GPS signals, related to variations in the estimated values of environmental characteristic parameters (electronic density, atmospheric density, temperature, humidity, rate, etc.), gave birth to "GPS meteorology." Numerous applications have been found for InSAR, radars, and GPS instruments embarked on airplanes, for instance to satisfy requirements for aviation users. GPS radio occultation of GPS antennas/receivers attached in low-Earth-orbit (LEO) satellites for meteorology gave birth to global navigation satellite systems meteorology. Reports were recently published on global navigation satellite systems observations of the tsunami observed after the magnitude 9.0 earthquake which struck Japan on March 11, 2011 [26].

Frequency Band	Ka	Ku	X	C	S	L	P
Frequency (GHz)	40-25	17.6-12	12-7.5	7.5-3.75	3.75-2	2-1	0.5-0.25
Wavelength (cm)	0.75-1.2	1.7-2.5	2.5-4	4-8	8-15	15-30	60-20

Table 1a. Commonly used frequency bands and wavelength ranges for SAR radars.

Frequency Band	Ka	Ku	X	C	S	L	P
Foliage penetration						✓	✓
Subsurface imaging						✓	✓
Biomass estimation						✓	✓
Agriculture			✓	✓	✓	✓	
Ocean			✓	✓	✓	✓	
Ice			✓	✓	✓	✓	
Subsidence monitoring			✓	✓	✓	✓	
Snow monitoring		✓	✓				
VHR Imaging	✓		✓				

Table 1b.Examples of applications of SAR radars.

A ground-penetrating radar (GPR) system is a geophysical method that uses radar pulses to image sub-surfaces. This nondestructive method operates by emitting EM radar impulses into the ground, or other media, at a high repetition rate, and observing the reflected signals. Subsurface reflection occurs at material with different electrical characteristics. Ground-penetrating radar can be used in a variety of media, including rock, soil, ice, fresh water, pavement, and structures. It can detect objects, changes in material, and voids and cracks. Studies are in progress to assess the ability of ground-penetrating radar to detect damage inside of buildings, bridges, concrete roads and humanitarian mine cleaning [27]. According to the applications and to the frequency band, ground-penetrating radar may be used at the ground, under a helicopter [28], or on a plane [29].

The MIMO (multiple-input multiple-output) concept is now very widespread in the radar domain. The term MIMO radar was used by Fischer et al. [30-32] to refer to a form of multi-channel radar processing, in which several transmitters are transmitting multiple orthogonal or non-coherent waveforms, and several receivers are receiving the echoes reflected by the targets. Applications have been developed for ground-based MIMO radars [33], as well as for airborne MIMO wireless-communication systems [34].

4. Emergency Management

Emergency management commences with both search and rescue, and then stabilization of the overall disaster situation. At any time, the rescue teams need information directly relevant to the situations they have to face: disaster evolution, surviving persons, critical zones, access to refugee camps, spread assistance tools, etc. Required information is provided by a comprehensive data-handling system, called the geographical information system (GIS), which is a computer-based application of technology involving spatial and attribute information, to act as a decision-support tool. It is used here as an information system that integrates files, generally produced by organizations and space agencies

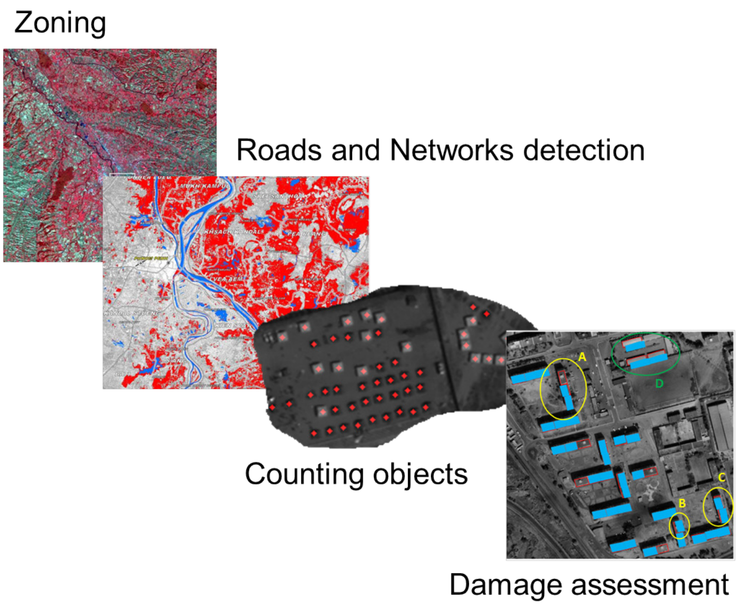

Figure 4. Image-processing functionalities.

involved in the international charter "Space and Major Disasters" (presently signed by 15 organizations and space agencies). It stores, edits, analyzes, shares, and displays geographic information for informing decision makers.

However, there are a few exceptions, such as the photo interpretation of radio and optical images, produced by remote-sensing satellites, which require calling in photo interpreters before feeding the geographical information system and producing a dashboard allowing making relevant decisions.

4.1 Photo Interpretation

Radio as well as optical images, produced by remote-sensing satellites, provide the best information sources for disaster management [35, 36]. They can be quickly collected, and cover wide geographical zones. The photo interpreters can use them to rapidly supply basic maps for the authorities in charge of crisis management. The processing time is of the order of eight hours.

Four types of image-processing functionality are particularly useful to a risk manager. (Figure 4)

4.1.1 Zoning

Zoning consists of partitioning the image according to defined criteria. "Big picture" zoning aims at identifying the main classes of land use, such as urban, industrial, forest, agricultural, or networks (e.g., roads, waterways). Zoning can then be re-applied to a particular area of the image. A typical example is the division of an urban zone into densely and sparsely populated areas.

4.1.2 Counting

Counting the objects present in a zone enables an assessment to be made of the impact of the event. This information provides valuable input to the decisions that have to be made when preparing relief plans. Among the most important data is a count of buildings, which enables the definition of appropriate relief and logistical measures. It also facilitates monitoring of the deployment of refugee camps (official or otherwise), which provides information on the whereabouts of local populations.

4.1.3 Identification of Roads

The identification of roads and, more generally, networks (roads, railways) enables an assessment to be made of access to the affected zone. This information makes it possible to define various routes for the provision of relief.

4.1.4 Damage Evaluation

Damage evaluation is an important phase. It can provide an overview of damage in a zone where a rescue team is needed. It also makes it possible to define the equipment and measures required in the intervention. The principal data resulting from this evaluation are the level of damage to houses, and an estimate of the number of people dead, wounded, or homeless. An evaluation of the damage to the communication network (roads, railways) is also important for the design of the intervention plan.

Detailed maps are produced from the images available at the beginning of the crisis. However, these may

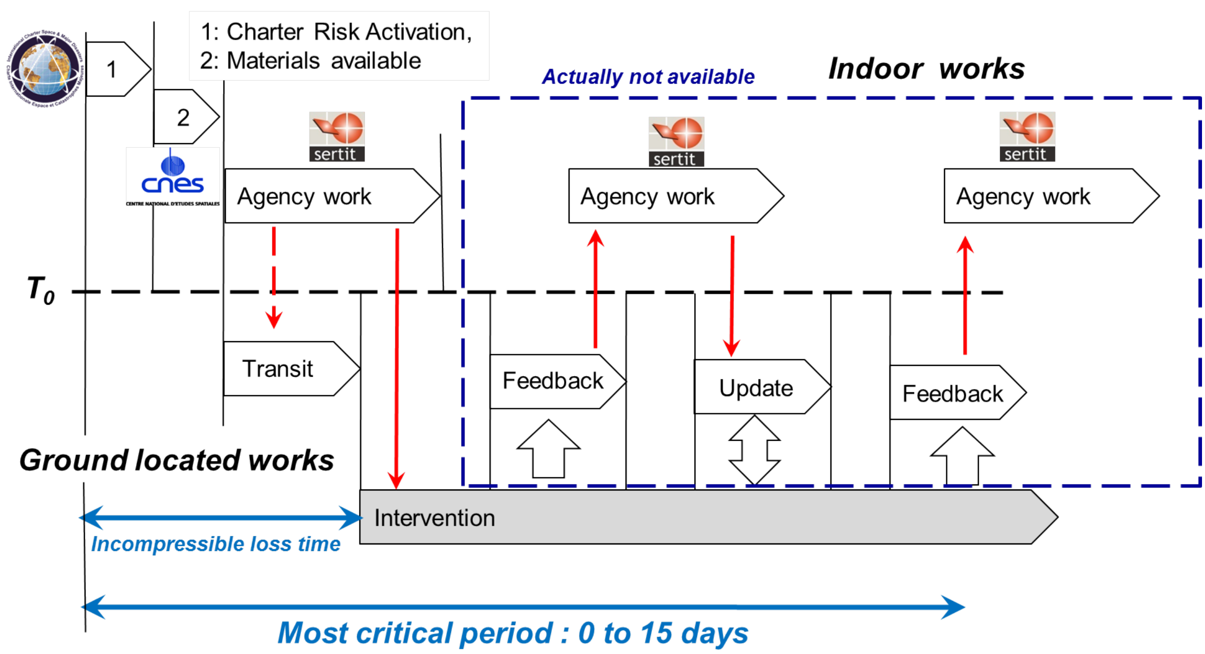

Figure 5. The cycle of satellite image-based mapping [4].

misrepresent the current situation. Figure 5 is a temporal diagram of operations. It shows the organization of feedback, which enables the initial maps to be corrected and updated.

If images of the affected zone prior to the event are available, tools can be rescheduled. This may identify changes that can help to more precisely measure the level and characteristics of damage (total destruction, collapsed roofs, structural damage, etc.). However, when before-and-after images of the disaster are not available, work must be carried out with only one, or a few, post-event images.

4.2 The Development of a Dashboard

A dashboard is developed from information provided by the geographical information system. The dashboard uses space-time location as the key index variable for all other information. Any variable that can be located spatially, and is increasing temporally, can be referenced in a geographical information system. The data system architecture is given in Figure 6.

Examples of data entered into the system include topographic maps, positions given by the global navigation satellite system (GNSS), weather data provided by national weather services, photo-interpreted data, etc. The main objective is the resolution of the crisis generated by a disaster, i.e., the decisions to be made for avoiding or reducing the consequences of the event. The research of the origin of the disaster is delayed to the post-disaster phase. It is indeed at that time that lessons may be drawn to prevent the repetition of the same type of event, or, if this is not possible, to facilitate the crisis management and to reduce its consequences.

5. Conclusion

In the last 10 years, numerous papers have been published on the use of radio-science techniques for disaster management. Those we have here referred to represent a small subset of the published articles on that matter. However, one may expect that they allow drawing conclusions on radio-science techniques presently used during the "response phase" of a disaster, and on directions to be taken in future. In addition, a point to keep in mind is the probability of occurrence of extreme space weather [38]. A few elements are given in the last paragraph.

When disaster strikes and communication links are disrupted, the Tampere Convention (see Section 2) applies. That convention calls on states to facilitate the provision of prompt telecommunication assistance to mitigate the impact of a disaster, and covers both the installation and operation of reliable, flexible telecommunication services. The ITU, requested by the Operational Coordinator, assists in fulfilling the objectives of the convention.

Observation services are susceptible both to unintentional interference originating from satellite communication, TV broadcasting, radar applications, and ultra-wideband (UWB) communication; and to space-weather events. With regard to space weather, the observed effects include degradation of GPS operations, loss of lock in global navigation satellite systems' navigation systems, degradation in spaceborne geo-locations, degradation in SAR data due to the Faraday rotation, etc. Improving the accuracy of satellite navigation systems is a challenge for the future.

The data required for disaster management include space data, and aerial or ground-based data. Space data

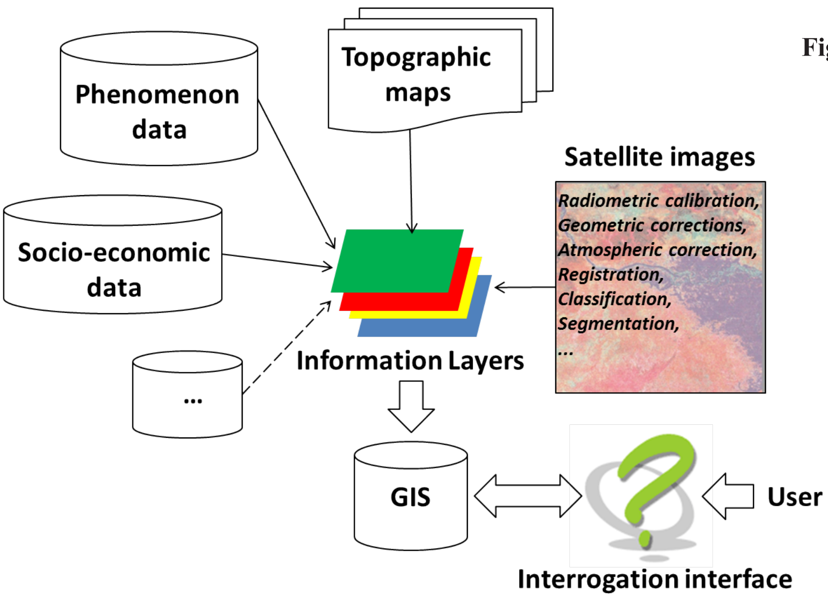

Figure 6. An example of a data-system architecture [4].

are derived from electromagnetic equipment embarked on satellites. During the response phase of the disaster-management cycle, where a maximum of observation data is required, radio images are preferred to optical images. Optical images have higher space resolution (lower wavelength), but may have interpretation problems. Advanced SAR techniques (InSAR, DlnSAR, PolSAR, Pol-INSAR) have been developed for specific applications. Over the past few years, the number of projects for the acquisition of aerial remote-sensing data (i.e., images taken from planes, balloons, helicopters, drones, etc.) has exploded. The basic techniques are the same. They have the advantage of focusing on priority areas and small-scale studies, and to be complementary. However, for GPR (ground-based penetrating radar) techniques, used as well at ground level as onboard a helicopter or a satellite, the results obtained are required to be fully interpreted.

Emergency management commences both with search and rescue, then stabilization of the overall disaster situation. At any time, the rescue teams need information directly relevant to the situations they have to face: disaster evolution, surviving persons, critical zones, access to refugee camps, spread assistance tools, etc. Required information is provided by a comprehensive data-handling system, called the geographical information system (GIS). The key point is the data to be entered into the system (topographic maps, positions given by the GSS systems, weather data provided by national weather services, photo-interpreted data) and the management of files reaching that system with different time delays.

In closing, it would be interesting to review recent published papers on the probability of occurrence of an extreme solar-terrestrial disturbance, such as the solar storm of 1859 (also known as the Carrington Event) and on potential consequences, on a global scale, on electrical-distribution networks, satellite systems, radio communication, radio navigation, etc. The Carrington event is the only documented extreme event of the last 150 years. As written in [37], on the morning of September 1, 1859, as Richard C. Carrington was observing sunspots on the solar disk, a particularly large and complex active region destabilized, launching an extremely fast coronal mass ejection (CME) towards Earth. The coronal mass ejection and its associated disturbance rammed into the Earth's magnetosphere, generating one of the largest magnetic storms in recorded history. Several authors have speculated on the consequences that an event at least as large as the 1859 Carrington Event could have on our society. By using a Poisson occurrence probability, Pete Riley [37] shown that the probability of another Carrington Event occurring within the next decade could be as high as 12%. By listing the magnetic storms recorded at Kakioka Magnetic Observatory and using a model based on maximum sunspot number, Ryuho Kakatoa [38] estimated that the probability was estimated to be 4% to 6%. In parallel, E. W. Cliver and W. F. Dietrich [39, 40] are investigating the limits of extreme space-weather activity by studying the largest SEP episodes in the modern area. The investigations are still at the early phase.

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History of Flux-Density Calibration in Radio Astronomy

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Abstract

In the course of the last sixty years, radio astronomers have scanned the sky and catalogued millions of cosmic sources, over the entire radio-frequency range from 10 MHz to 1 THz. For the interpretation of the received radiation, it is essential that the observed intensity can be related to an *absolute flux-density scale*, in order to obtain quantities *intrinsic* to the source. The establishment of such a scale has been a painstaking effort over many years, leading to a current accuracy of a few percent over most of the observable frequency range. In this paper, we describe the history of these efforts. We begin with the observations of a few strong sources with small calibrated antennas in the 1960s. We continue up to the recent definitive improvements obtained with large antennas, including interferometer arrays, and spaceborne telescopes operating in the millimeter and sub-millimeter wavelength domains. The review contains an extensive list of references.

1. Introduction: The Need for Absolute Measurements

In the early years of the Jansky-VLA radio telescope in New Mexico, an astronomer on the way to the site drove a part of the 40 km long straight stretch of US Route 60. In the dark, the astronomer might see a car light on the invisible horizon, and wonder how far the distance to the car would be. If the astronomer knew the wattage of its headlight and possessed an eye with calibrated brightness sensitivity, this could be figured out. Alternately, if the astronomer knew the distance, the observed apparent brightness could be turned into the intrinsic brightness of the car's headlight. Even if the distance were unknown, a calibrated measuring device (detector) would provide at least the apparent intensity of the source. Upon arriving at the telescope, the astronomer was faced with a similar problem. In order to turn the output signal of the telescope into a quantity intrinsic to the source, the sensitivity of the telescope – that is to say, the gain of the antenna and of the receiver system – needed to be known.

In contrast to the astronomer's colleague, the experimental physicist, the observational astronomer is unable to influence the parameters of the physical process the astronomer wants to study. The only measurable data are the properties of electromagnetic radiation emanating from the object of the astronomer's observation. The astronomer can measure the intensity, and possibly the polarization state, as functions of frequency and time. The details are dependent on the sensitivity, along with the frequency and time resolution of the observing device, the telescope and its focal-plane instrument, the last usually called the receiver.

As illustrated in the first paragraph, there exists the difficulty of transferring the measured signal into quantities that are intrinsic to the source. For this, one needs first of all the distance to the object, a notoriously severe problem for sources of continuum radio radiation. Here, the radio astronomer needs the help from his or her "optical" colleague, for instance through the spectroscopic determination of the redshift, and hence distance of the object. There then remains the need to calibrate the received signal in an absolute measure of flux density or brightness temperature. This requires knowledge of the gain of the radio telescope (antenna), and the calibration of the measured antenna temperature at the entrance of the receiver. While the latter can be readily achieved by the so-called "hot-cold-load" comparison method [1], to be discussed below in Section 2.4, the former is practically impossible to determine for a radio telescope of large size reckoned in wavelength.

The lack of knowledge of antenna gain could be circumvented if there were a sufficient number of celestial sources with accurately known absolute intensities over a large frequency range and distributed somewhat evenly across the sky. In fact, this is the usual way in which radio astronomers calibrate the measured flux density of an object, by comparing its signal with that of a known *calibration* *source*. The establishment of such a set of calibration sources has been a multi-pronged effort over several decades. It has now reached an accuracy of the order of a few percent over almost the entire frequency range accessible to radio-astronomical observation, roughly from 20 MHz to 1 THz.

It is the purpose of this paper to present the historical development of the subject, by describing the technical efforts needed for achieving its goal, and by summarizing the road towards the current state of affairs in the establishment of an *absolute flux-density scale* at radio wavelengths. Reviews of absolute intensity calibrations in radio astronomy were presented by Findlay [2] and Ivanov and Stankevich [3].

We summarize the process of obtaining the absolute flux density of the strongest radio sources by the use of antennas, the gains of which have been determined by calculation or Earth-bound measurements. These *primary calibrators* are the strongest sources in the constellations Cassiopeia (Cas A), Cygnus (Cyg A), Taurus (Tau A), and Virgo (Vir A). Their strengths can be reliably measured with antennas of an aperture area of the order of 10 m^2 The gains of such antennas can be calculated in the case of a dipole or horn, or measured on a test range of several hundreds of meters at typical frequencies of the order of 1 GHz. Unfortunately, the strongest sources all exhibit a significant angular size, which requires corrections to the measured signal when observed by large radio telescopes with angular resolutions of the order of the source's angular size or smaller.

The bulk of radio sources is very much weaker than the primary calibrators. Direct comparison between weak and strong objects requires the careful calibration of the gain of the receiver system over a large dynamic range. To avoid this, a set of "secondary calibrators" of intermediate intensity has been created, by accurate relative measurements with respect to the primary calibrators. These are then used as calibrators for the observation of weak objects. The secondary calibrators are normally extragalactic sources of small, or "point-like," angular extent. This avoids size corrections in the flux-density determination, even with observations of high angular resolution, as with interferometers and synthesis telescopes. On the other hand, several of the original secondary calibrators have shown time variability in their luminosity. An important effort has thus been to limit the set of calibration sources to those with stationary flux density. The results of this program were recently published by Perley and Butler [4]. They presented an absolute flux-density scale with an accuracy of a few percent over the frequency range from 1 GHz to 50 GHz. The achievement of this milestone has prompted the writing of this historical review.

It should be noted that the detail of the radio *spectrum*, i.e., the flux density as a function of frequency, is one of the essential – and often, the only – data in the study of continuum radio sources such as quasars, supernova remnants, and HII-regions. It is thus important that a reliable flux-density scale over an extended frequency range be established. It has been customary, based on theoretical grounds and supported by observations, to express the spectrum of a source by a power-law function. The *spectral flux density*, *S*, as a function of frequency, ν, can thus be written as $\log S = a + b \log \nu + c \log^2 \nu + \ldots$. Plotted on a log-log scale, many sources exhibit a straight line ($c = 0$). The parameter *b* is called the *spectral index*, often denoted by α. These parameters provide information on the physical mechanism responsible for the radiation. Curved spectra with $c \neq 0$ are more informative, but a reliable measurement of *c* requires an accurate calibration.

By the time of the publication of large catalogues of radio sources in the early 1960s, spectral flux density was normally expressed in *flux units*, with $1\ \mathrm{fu} = 10^{-26}\ \mathrm{Wm^{-2}Hz^{-1}}$. Although not fitting in the SI system of units, this was adopted in 1973 by the International Astronomical Union as the *unit of flux density*, and given the name *Jansky* ($1\ \mathrm{Jy} = 10^{-26}\ \mathrm{Wm^{-2}Hz^{-1}}$). Its use has been widely adopted across the electromagnetic spectrum, well beyond radio astronomy.

2. Determination of Antenna Gain

Radio astronomy was born in 1932 by Karl G. Jansky's discovery of Galactic radiation at a frequency of about 20 MHz [5]. A follow-up was made by Grote Reber, who built a 9.6 m-diameter paraboloidal dish in his backyard, and successfully mapped part of the sky at the frequency of 160 MHz [6]. After World War II, groups of radio and radar engineers started to use their equipment to look at the "sky," notably in England, Australia, and the USA. The frequency range used was from several tens to a few hundreds of MHz, covered with dipole-array antennas, which were often used in an interferometer configuration to improve the angular resolution. Where dish antennas were available, notably in Europe and the USA, the frequency range was extended to higher frequencies. These eventually reached several gigahertz around 1950, and lead to the detection of the spectral line of neutral atomic hydrogen at 1420 MHz in 1951 by Ewen and Purcell [7a] and Muller and Oort [7b].

It must be considered a lucky circumstance that the strongest cosmic radio sources, Cas A and Tau A, being supernova remnants, and Cyg A, a radio galaxy, emit predominantly synchrotron radiation, which exhibits a spectrum at radio wavelengths with increasing intensity towards lower frequencies. This enabled researchers to detect them in the early stages of their instrumental developments. Eventually, observational radio astronomy reached a point where accurate knowledge of the spectrum was needed to study the details of the physical process by which the sources radiate. This involved consideration of the absolute calibration of the observed flux density, and the need to have antennas with a well-known gain.

Two types of antennas allow a theoretical calculation of the gain from physical dimensions: the dipole and the pyramidal horn. Their characteristics are summarized in the following sections.

2.1 The Dipole and Dipole Array

The derivation of the radiation characteristics of a dipole can be found in any textbook on electromagnetic theory, e.g., [8]. As an illustration, we mention here the results for an elementary electric dipole and a wire antenna, fed in the middle and a half-wavelength long, the so-called half-wave dipole. The radiation power patterns of these are represented by

$$P_{el} \propto \sin^2 \theta \quad \text{elementary dipole} \tag{1}$$

$$P_{hw} \propto \left[\frac{\cos(\pi \cos\theta/2)}{\sin\theta} \right]^2 \quad \text{half-wave dipole} \tag{2}$$

The pattern is uniform in the plane perpendicular to the dipole, and has its maximum in the equatorial plane. The meridional patterns of the expressions above are shown in Figure 1. Integrating over the patterns, the gains are found to be:

$$G_{el} = 1.50 \ (1.76 \text{ dB}) \ \text{elementary dipole,}$$

$$G_{hw} = 1.65 \ (2.17 \text{ dB}) \ \text{half-wave dipole.}$$

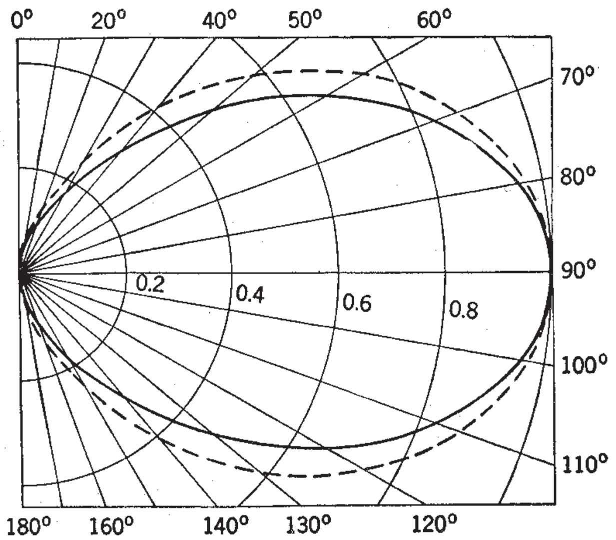

Figure 1. The meridional polar power diagram of the half-wave dipole (full line) and the elementary dipole (dashed). The half-power beamwidth of the half-wave dipole is about 80°.

The fortuitous increase of flux density of the strongest sources towards low frequencies made it possible to use dipoles, suspended over a reflecting ground plane, as an antenna. In most cases, a pair of half-wave dipoles was used as an interferometer, or an array of half-wave dipoles was used, which provided a higher antenna gain.

It is of some interest to mention here the possibility of obtaining absolute calibration by the use of an interferometer consisting of a large, sufficiently sensitive, but uncalibrated element, and a small, absolutely calibrated second element. This was pointed out and applied by Seeger [9], who obtained an absolute flux density of Cas A at 400 MHz with an interferometer consisting of a horn with a calculated gain and a 7.5 m diameter "Würzburg" reflector antenna. The interferometer was needed because the gain of the small horn was insufficient to make a direct absolute total-power measurement. Later, big horns were constructed specifically for such absolute measurements, as shall be described below.

With this method, the observation of the source involves two steps:

1. Interferometric measurement with the small, calibrated antenna and the large antenna;

2. Total power measurement with the larger, sufficiently sensitive, but uncalibrated reflector.

We obtain the following output signals, expressed in power, P. The total power measurement of the large antenna is

$$P_t = S\, g_t A_t ,$$

and the output of the interferometer of the horn and large antenna is

$$P_h = S\left(g_t A_t g_h A_h\right)^{0.5} ,$$

where S is the unknown flux density of the source, g_t and g_h are the electronic gains of the two receivers on the antennas, and A_t and A_h are the effective areas of the large antenna and the horn, respectively. The electronic gain can be accurately measured (to be discussed below). Accounting for those, we can write the following expression:

$$A_t = \left(\frac{P_t}{P_h}\right)^2 \frac{g_h}{g_t} A_h . \tag{3}$$

Alternatively, one can eliminate A_t and obtain the flux density, S.

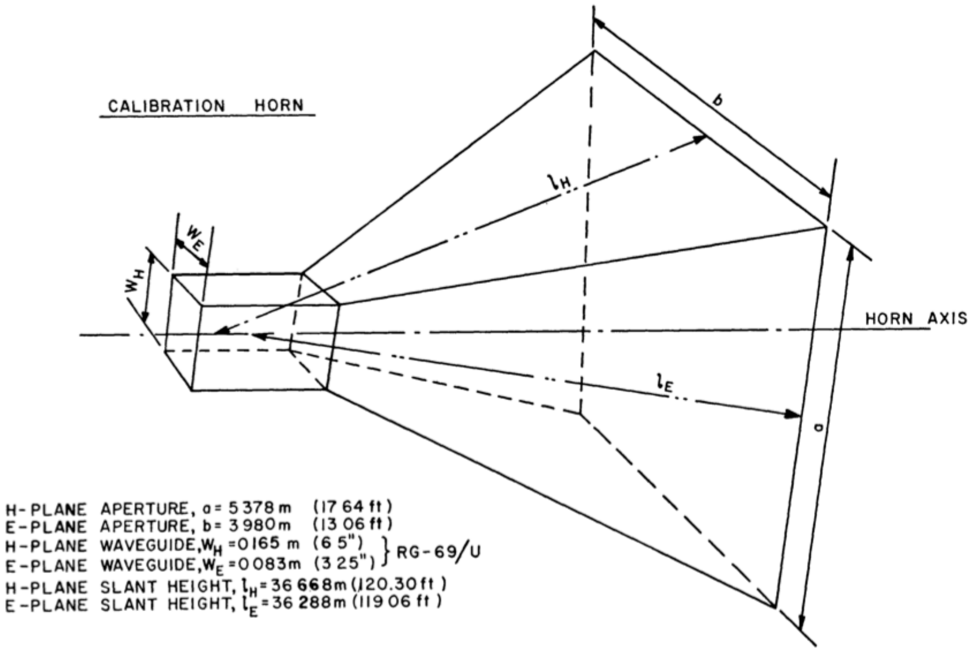

Figure 2. Illustrating the geometry of the pyramidal horn. The numerical data in the drawing pertain to the Little Big Horn at NRAO (see text; after Findlay et al. [16]).

Wyllie [10] used the large Molonglo Cross antenna in Australia by forming interferometers between the two sections of the E-W arm of the cross, and a reference antenna consisting of an array of 16 half-wave dipoles, separated by 0.75 wavelength, placed 0.25 wavelength above a reflecting ground screen. The gain of this dipole array was computed, based on theory by Schelkunoff and Friis [11], and measured to be 76.2 (18.82 dB), to an accuracy of better than 3%. The measurement of the beam pattern confirmed the calculated gain. In this case, the actual observations were done with

1. Three interferometer pairs (a reference antenna with each of the east and west arms of the cross, and between the two arms); and

2. An interferometer between the reference antenna and the whole E-W arm, plus a total power measurement with the full arm.

From these data, the unknown gain of the large cross arms was eliminated, leading to an absolute measurement of the flux density of the relatively weak source. We return to this later.

2.2 The Pyramidal Horn Antenna

Schelkunoff presented the gain of an electromagnetic pyramidal horn in his well-known book, *Electromagnetic Waves* [12]. If we denote the aperture width in the H plane by a, in the E plane by b, and corresponding slant lengths by l_a and l_b, we have the following equations for the gain (Figure 2). For the E-plane sectoral horn,

$$G_E = \frac{64 a l_b}{\pi \lambda b}\left[C^2\left(\frac{b}{\sqrt{2\lambda l_b}}\right) + S^2\left(\frac{b}{\sqrt{2\lambda l_b}}\right)\right], \quad (4)$$

and for the H-plane sectoral horn,

$$G_H = \frac{4\pi b l_a}{\lambda a}\left\{\left[C(u) - C(v)\right]^2 + \left[S(u) - S(v)\right]^2\right\}, \quad (5)$$

where

$$u = \frac{1}{\sqrt{2}}\left(\frac{\sqrt{\lambda l_a}}{a} + \frac{a}{\sqrt{\lambda l_a}}\right),$$

and

$$v = \frac{1}{\sqrt{2}}\left(\frac{\sqrt{\lambda l_a}}{a} - \frac{a}{\sqrt{\lambda l_a}}\right),$$

and $C(x)$ and $S(x)$ are the well-known Fresnel integrals. The gain of the pyramidal horn takes the form

$$G = \frac{\pi}{32}\left(\frac{\lambda}{b} G_H\right)\left(\frac{\lambda}{a} G_E\right). \quad (6)$$

These gain expressions have been checked by careful laboratory measurements, and have shown general agreement to about 1%. In some cases, such measurements were extended to rather large horn antennas, as in the work of Jull and Deloli [13] on the horn-paraboloid with an aperture of $8\ \mathrm{m}^2$ at the Algonquin Radio Observatory in Canada.

2.3 The "Artificial Moon" Method

A major problem in the accurate measurement of the gain of a large aperture antenna is the finite distance to a terrestrial signal source. When the source is closer to the antenna under test than the so-called far-field distance, the incoming phase front is not closely an equiphase surface. A number of corrections then need to be made, which are strongly dependent on the distance between the source and the antenna. The far-field distance is defined as

$$R_f = 2D^2/\lambda , \qquad (7)$$

where D is the diameter of the antenna and λ is the wavelength. For $D = 10$ m and $\lambda = 10$ cm, this distance is already 2 km. Rarely will there be a possibility to place the source at a decent elevation angle, of the order of 10°, so that ground effects can be ignored.

Nevertheless, in the early 1960s, Troitskii and Tseitlin [14], at the Radiophysical Research Institute in Gorkii (now Nizhny Novgorod), Russia, introduced a method of calibrating relatively small antennas by moving a black disc in and out of the antenna's beam at a certain distance from the antenna (Figure 3). They coined the name *artificial moon* method for this procedure. In their first experiments, they chose a distance equal to the far-field distance, and a size of the black screen that subtended an angle significantly smaller than the primary beamwidth of the antenna. Later, the method was developed to allow measurements in the near-field region of the antenna by introducing correction factors. It has been applied over a large frequency range, from roughly 300 MHz to 10 GHz. Several antenna sizes were used to obtain sufficient signal-to-noise ratio (SNR) for the accurate measurement of the antenna temperature of the strongest sources, such as Cas A, Cyg A, and Tau A.

This method differs from the usual antenna test range in that it uses an extended "blackbody" source as transmitter, instead of a monochromatic, point-like signal source. The "broadband" radiation from the black disc is accepted over the full bandwidth of the receiver system, which will later be used to measure the intensity of a cosmic source. The choice of using a source of finite angular extent means that it "fills" part of the primary beam-lobe of the antenna. If the disc subtends a solid angle of Ω_d as seen from the antenna, and is smaller than the antenna's main-beam solid angle, Ω_m, we can define the *effective* disc solid angle as

$$\Omega'_d = \int_{\Omega_d} f(\theta,\phi)\, d\Omega , \qquad (8)$$

where $f(\theta,\phi)$ is the antenna's beam. The measured antenna temperature difference between the situation with the disc and with the disc removed can be written as

$$\Delta T_A = (T_D - T_B)\Omega'_d , \qquad (9)$$

where T_D and T_B are the temperatures of the disc and the sky background behind the disc, respectively.

If the black disc just fills the full main beam to its first null, the measured antenna temperature difference is $\Delta T_A = \eta_B (T_D - T_B)$, where η_B is the *beam efficiency* of the antenna. In this case, one thus measures the antenna's beam efficiency, η_B, instead of the aperture efficiency, η_A as in the case of a point source. The aperture efficiency can be calculated from the measured beam efficiency from the equation

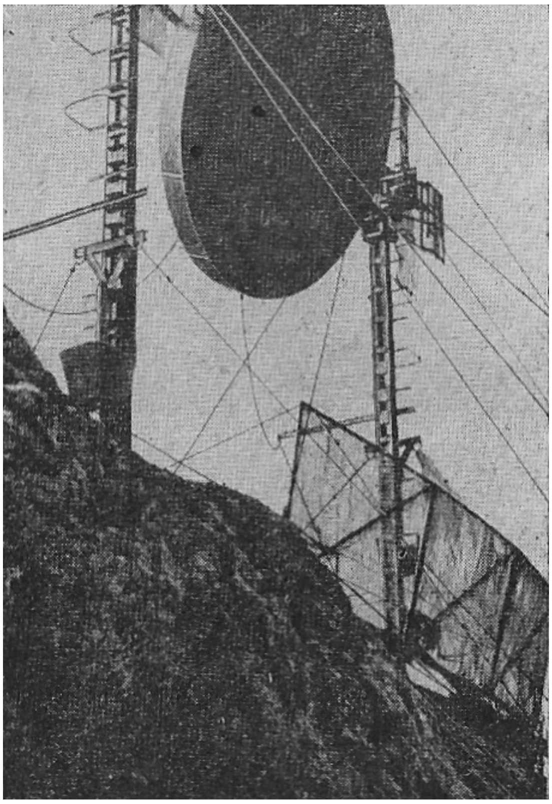

Figure 3. The "artificial moon," a round "black disc" suspended between towers on a promontory at some distance from the antenna under test. The cable network allowed the disc to be moved in and out of the beam, without significantly changing the influence of the installation on background radiation.

$$\eta_A = \frac{\lambda^2}{\Omega_m A_g} \eta_B , \tag{10}$$

where Ω_m is the main-beam solid angle, and A_g is the geometrical area of the reflector's aperture.

Note that one also needs to determine the main beam's solid angle. This requires knowledge, either by calculation or measurement, of the main beam to the level of the first null in its pattern. This is not a trivial matter, in practice. For details on this aspect, see, for instance, Baars [15, Section 5.3.3].

2.4 Receiver Calibration

As was mentioned earlier, the recorded signal at the output of the receiver system needs to be expressed in an equivalent increase of the *antenna temperature*, T_A, measured at the input port of the receiver. For a point source, the relationship between source flux density, S_ν, and the antenna temperature is given by the relation

$$S_\nu A = 2kT_A , \tag{11}$$

where A is the absorption area of the antenna, and $k = 1.38 \times 10^{-23}\,\mathrm{WK^{-1}Hz^{-1}}$ is Boltzmann's constant. The calibration of T_A is normally achieved by the so-called *hot-cold-load* method. By connecting the input of the receiver alternately to matched resistive loads at different and well-known physical temperatures, the sensitivity scale of the receiver can be expressed in terms of the equivalent temperature of the input signal (Figure 4).

To avoid errors due to possible nonlinearity of the amplifier chain in the receiver, one chooses the temperature difference between the two loads to be of the same order as the expected antenna temperature from the source. While in principle simple, this measurement needs careful consideration of proper matching between the receiver and the changing inputs from loads and antenna, as well as any losses in the intermediate connections. The trace of a single observation of Cas A with the Little Big Horn (LBH) at NRAO Green Bank [16] illustrates the procedure (Figure 5).

3. Review of Absolute Measurements

3.1 Summary of Methods of Measurements

Many absolutely calibrated observations of the strongest sources were obtained in the period 1960-1970. Source catalogues were becoming available over a growing range of frequencies. The establishment of reliable radio spectra over a substantial frequency region was essential for the astrophysical interpretation of the observations. We now summarize the absolute measurements of flux density that were obtained, separated by the different methods and equipment.

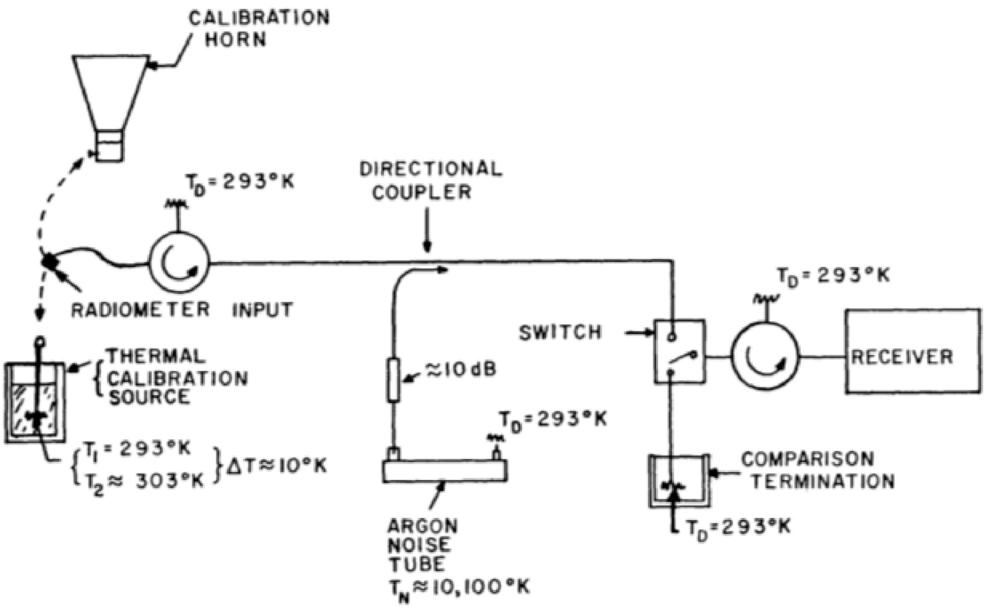

Figure 4. The receiver layout with calibration devices (noise tube and thermal calibration source) of the Little Big Horn experiment at NRAO, Green Bank (after Findlay et al. [16]).

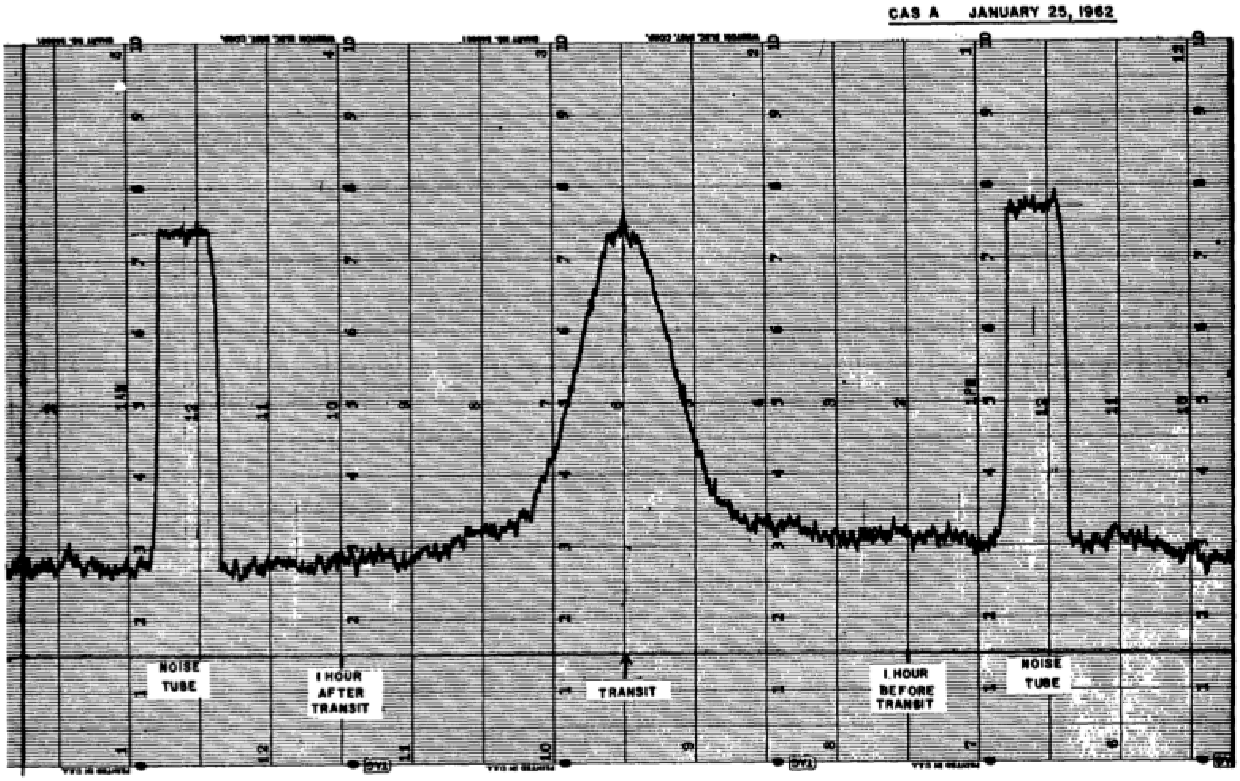

Figure 5. An example of the drift scan of Cas A through the beam of the Little Big Horn, with calibration marks from the noise source on both sides (after Findlay et al. [16]).

3.1.1 Low Frequency: Dipoles

Parker [17] carried out a carefully conducted experiment in 1966 in Cambridge, UK, at frequencies of 38.0 MHz, 81.5 MHz, and 152.0 MHz, with a simple interferometer consisting of two single dipoles. The theoretical calculations of gain and antenna pattern were compared to pattern measurements using Cas A and Cyg A, leading to the conclusion that the gain was accurate to 2.5%. Other accurate dipole measurements were reported by Roger et al. [18] at 22 MHz, and Viner [19] at 26 MHz. The quoted accuracies were in the 4% to 5% range. Somewhat less accurate (10% to 14%) results were given for the work by Bridle [20] at 10 MHz and Braude et al. [21] at five frequencies between 12 MHz and 25 MHz. In the latter program, the large array in the Ukraine was used in a similar manner as by Wyllie, described above. Wyllie [10] used the Molonglo Cross antenna in Australia at 408 MHz for absolute measurements of the flux density of a number of relatively weak sources (30 Jy to 70 Jy) with a reported accuracy of 5%.

3.1.2 Mid to High Frequencies: Horns and Horn-Paraboloids

Observations of the strongest sources from about 300 MHz up to 16 GHz were made with horn antennas. The first was by Charles Seeger [9], who used an interferometer of a horn and a 7.5 m reflector to measure the absolute flux density of Cassiopeia A at 400 MHz at the Dwingeloo Observatory in 1955. In a footnote to his short paper, he "strongly recommended that horns be used as antenna gain standards in radio astronomy whenever it is desired to measure absolute flux densities to an accuracy of better than 1 dB." His own single measurement of Cas A yielded a flux density of 5620 Jy (epoch 1955.6), with an estimated maximum error of 15%. Actually, he should have obtained about 7000 Jy, which is 25% above his measurement, and perhaps illustrates the difficulty of making absolutely calibrated observations. At the IAU Symposium No. 5, "Radio Astronomy," in 1955, Seeger [22] emphasized the importance "to establish the spectra of a few *reference sources*." He presented the situation with the Cas A spectrum, which was based on some 15 observations with quoted accuracies of 10% to 30%. He noted, "Absolute flux density measurement appears to be simple...but has turned out to be unexpectedly difficult."

In any case, the superiority of the horn antenna for accurate absolute calibration was recognized, and by the mid-1960s, several horns were in use for this purpose.

Around 1960, in Canada, Broten and Medd [23] and McCrae and Seaquist [24] used horn antennas at 3200 MHz and 320 MHz, respectively, quoting an error of 5%. At the National Radio Astronomy Observatory (NRAO) in Green

Figure 6. The Little Big Horn at the NRAO, Green Bank. The aperture was 5.4 m × 4.0 m, and the length was about 36 m. Cas A crosses the beam daily, and a measurement of its flux density is made at 1440 MHz (NRAO/AUI/NSF).

Bank, Findlay built the Little Big Horn (Figure 6). This was a fixed antenna, used to daily measure the flux density of Cassiopeia A to an accuracy of 2% to 3% at a frequency of 1440 MHz for a period of several years in the early 1960s, and again in 1969-1971 [16, 25].

Medd [26] used a horn-paraboloid at the Algonquin Radio Observatory in Canada at frequencies of 3200 MHz, 6660 MHz, and 13490 MHz. This horn was carefully analyzed and measured by Jull and Deloli [13], who obtained agreement between theoretical calculation and measurement of the gain to about 1% accuracy. Allen [27] observed with the horn at Lincoln Laboratories at 8250 MHz and 15500 MHz. Finally, the horn-paraboloid at the Bell Labs in Holmdel, NJ, delivered data at 1415 MHz [28], 4080 MHz [29, 30], and 16000 MHz [31, 32]. This is the same horn with which Penzias and Wilson separated the cosmic microwave background of 2.7 K from the other sources of noise in their system (Figure 7). The errors quoted for these observations, which were carried out between 1962 and 1970, ranged between 2% and 5%.

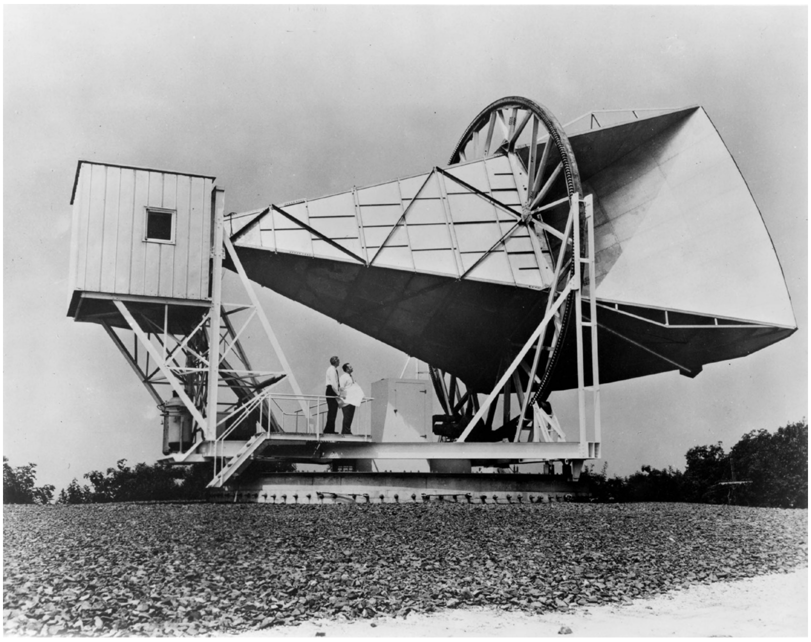

Figure 7. The large horn-paraboloid at the Bell Telephone Laboratories in Holmdel, New Jersey. The aperture was 6 m × 6 m, and its length was about 15 m. Absolute flux densities of Cas A were obtained at 1415 MHz, 4080 MHz, and 16000 MHz. The cosmic microwave background was detected with this instrument by Penzias and Wilson in 1965. The antenna at its original site was designated a National Historic Landmark in 1988 (AT&T).

3.1.3 Mid Frequencies: Artificial Moon

The *artificial moon* (AM) method has been described in Section 2.3. It should be noted that refinements in the experimental method led researchers to apply corrections to earlier measurements made before 1963. However, all data published up to the mid-1970s had quoted errors in the 3% to 6% range. Many measurement series of Cas A were reported over the frequency range from 550 MHz to 9380 MHz by Bondar et al. [33], Dmitrenko et al. [34], and Vinogradova et al. [35]. Ivanov and Stankevich [3] presented an extensive survey of the subject, entitled "Absolute Flux Scale for Radio Astronomy," in the Russian journal *Radiofizika* (1986). Despite the publication of a translation in English (*Journal Radiophysics and Quantum Electronics*), the article appears to have drawn little attention among Western radio astronomers. An important feature of the Cas A measurements with the artificial moon method is the slightly but consistently steeper spectrum than that obtained by using "Western" measurements with horns.

Ivanov and Stankevich argued that the horn measurements showed inconsistencies within the measurements by each of three different author groups [26-32]. The current author found no inconsistency in any of the three groups of data. The published gain values at the different measurement wavelengths follow quite precisely the expected wavelength-squared relation. There are good arguments to trust the calculations of horn gain, and moreover, several of the horn gains were also experimentally determined. On the other hand, all artificial moon measurements were carried out with essentially similar equipment and identical procedures to correct for systematic errors, such as background subtraction, "blackness" of the disc, Fresnel-field correction, atmosphere, etc. Any error in these corrections would propagate through all measurements, and could introduce an undetected systematic effect.

3.2 Secular Decrease of Cassiopeia A and Taurus A

3.2.1 Cassiopeia A

Cassiopeia A is a rather recent supernova remnant (CE 1680). Shklovskii [36] calculated an expected secular decrease in its flux density of approximately 2% per annum, which in his simple source model was independent of frequency. Based on data collected over 12 years at a frequency of 81.5 MHz, Högbom and Shakeshaft [37] determined a rate of decrease of $1.06\% \pm 0.14\%$ per year. Data at higher frequencies became available, and by the mid-1960s, a generally accepted value of the secular decrease was $1.1\% \pm 0.15\%$ per year. In the early 1970s, evidence was growing that the secular decrease was frequency dependent. Based on accurate relative measurements, Baars and Hartsuijker [38] obtained a value of $0.90\% \pm 0.12\%$ at 1.4 GHz and 3 GHz, significantly smaller than the updated value from Scott et al. [39] of $1.29\% \pm 0.08\%$ at 81.5 MHz. Further data obtained by Dent et al. [40], Read [41], and Stankevich et al. [42] confirmed the frequency dependence of the secular decrease. Based on these data, Baars et al. [43] derived the following relationship for the secular decrease of the flux density of Cassiopeia A as a function of frequency:

$$d(\nu) = 0.97(\pm 0.04) - 0.30(\pm 0.04)\log \nu , \qquad (12)$$

with d in percent per year and ν in GHz.

The group around Stankevich at Gorkii has made an exhaustive study of the evolution of the Cas A spectrum, mainly based on observations with the *artificial moon* system. Stankevich et al. [44] summarized their work in

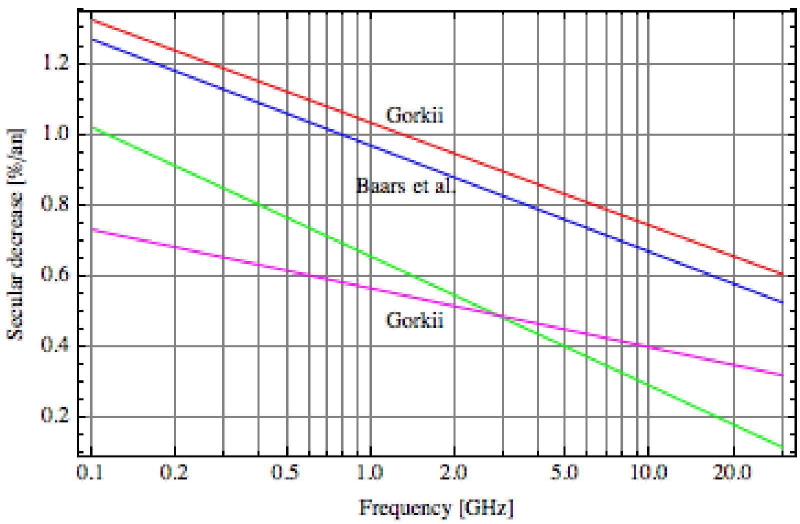

Figure 8. The secular decrease in the flux density of Cas A in percent per year as a function of frequency. The red and blue lines refer to measurements at Gorkii and the derivation by Baars et al. over the period 1960-1975. The green line applies to 1969-1984. The magenta line is for the period after 1984 to 2000 from the Gorkii data.

1999, and arrived at a secular decrease in the range from 0.5 GHz to 10 GHz for the period 1961-1975 given by

$$d(\nu) = 1.035 - 0.29 \log \nu \qquad (13)$$

with d in percent per year and ν in GHz. Both results are shown in the graph of Figure 8. They appear to be offset from each other by about one sigma, while the slopes are nearly equal. Note that the data sets are quite different. Only two Gorkii data points were used in the blue Baars et al. result, while only Gorkii data were included in the red line.

From their extended study of Cas A, the group at Gorkii concluded that the secular decrease is not uniform over time, and also appears to vary over frequency [44]. The green line in Figure 8 shows their analysis for the period 1969-1984. The flux decrease has slowed down at all frequencies, and apparently somewhat faster at high frequencies. The fit to the data for the period after 1984, presumably up to the late 1990s, is shown as the magenta line, indicating an accelerated decay at centimeter wavelengths and a slower decay at decimeter wavelengths. This suggests a strong overall drop in the secular decrease rate after 1969 and a change in frequency dependence after 1984. Observations near 15 GHz by O'Sullivan et al. [45] supported some of this trend, as did the value of $0.394\% \pm 0.014\%$ per year at 30 GHz, determined from 2001-2004 by Hafez et al. [46].

The time- and frequency-dependent behavior of the luminosity of Cas A complicates the use of its radio spectrum as a basis for the establishment of an absolute flux-density scale. In Section 4, we discuss the absolute spectrum of Cas A, which is based on many measurements in the frequency range from roughly 100 MHz to 30 GHz. It is fortuitous that all those data were collected in the period between 1960 and 1973, the large majority between 1965 and 1970. The good agreement in the secular decrease over that relatively short period between the Gorkii group and Baars et al. supports the reliability of the Cas A absolute spectrum. Because the main purpose of the present paper is to illustrate the historical development of the *absolute flux-density scale*, we shall not discuss the interesting aspects of the evolution of Cas A, as shown in the observations after 1970, any further.

3.2.2 Taurus A

Taurus A is the remnant of the supernova of CE 1054, and it is a well-studied source at radio wavelengths. Because of its intensity, it has also been observed with small, absolutely calibrated antennas. A small secular decrease has been measured of $0.17\% \pm 0.02\%$ per year at 150 MHz and 950 MHz [47], $0.167\% \pm 0.015\%$ per year at 8 GHz [48], and $0.22\% \pm 0.07\%$ per year at 33 GHz [46]. This suggests a time- and frequency-independent secular decrease of about 0.2% per year over the period 1970-2004.

4. Towards an Absolute Flux-Density Scale

4.1 Development Over Time, Improvement of Accuracy

4.1.1 Reliable Source Spectra

In one of the first papers on "the spectra of radio stars," Whitfield [49] pointed to the need to construct the spectra (the dependence of flux density on frequency) of the new radio sources to help understand their characteristics and to separate different classes of sources by the difference in spectral index. He suggested the use of Cas A, being the strongest source, as a standard against which the relative intensities of other sources could be determined by measuring the ratio. To transfer those to absolute flux densities, the Cas A spectrum would need to be absolutely known. He used five available absolute measurements between 38 MHz and 400 MHz to derive a power-law spectrum for Cas A with a spectral index of -0.8. It is interesting to note that the flux-density scale most widely used over the last 35 years and discussed in detail below is based on a value of -0.792.

Around 1960, extensive catalogues of radio sources became available through the surveys conducted notably at Cambridge, Jodrell Bank, Caltech, and CSIRO. Most of these were done at frequencies between 80 MHz and 1400 MHz. Essentially all authors referred to the difficulty of putting the observed intensities on an absolute flux-density scale. Seeger [9] had already mentioned this problem.

In an important step towards establishing reliable spectra of a large number of radio sources, Conway, Kellermann, and Long (CKL) [50] considered observations in the frequency range of 38 MHz to 3200 MHz. An absolute flux-density scale was obtained by a somewhat convoluted procedure, whereby an available absolute measurement of Cas A at a particular observing frequency (38 MHz, 400 MHz, 1420 MHz, and 3200 MHz) was used as the basis. They picked seven sources of moderate strength, fitted a power law through the flux densities at 38 MHz, 410 MHz, and 1420 MHz, and consecutively defined the flux-density scale at the intermediate frequencies (178 MHz, 240 MHz, 710 MHz, and 958 MHz), so that the mean flux density of the seven sources at each frequency fitted the power law.

Kellermann [51] observed about 200 sources, mainly from the 3C and Sydney catalogues, at frequencies of 475 MHz, 710 MHz, 958 MHz, 1420 MHz, and 2841 MHz with the Caltech interferometer. For the flux-density calibration, he established an absolute spectrum of Cas A, applying a 1% per year secular decrease of its flux density at all frequencies. From this Cas A spectrum, contrary to the individual absolute measurements used by CKL, he then established *preliminary* (his emphasis) calibrations of Cyg A, Tau A, and Vir A at all frequencies where accurate ratios with respect to Cas A were available. As a final step he used existing, accurate ratios of five moderately strong sources (3C123, 3C348, 3C353, 3C380, 3C409) with respect to the four *primary calibrators* to determine their power-law spectra. The *secondary* calibrators formed the basis for the calibration of all other sources up to 1420 MHz. Kellermann's method minimized the effects of systematic errors in the individual absolute calibrations of Cas A.

Kellermann, Pauliny-Toth, and Williams (KPW) [52] presented the spectra of the entire revised 3C catalogue between 38 MHz and 5000 MHz in 1969. The flux-density scale was based on the Cas A spectrum, which was derived from 15 accurate absolute determinations available at the time. Also there, a set of four secondary standards with straight spectra (3C218-Hya A, 3C274-Vir A, 3C348-Her A, and 3C353) was selected.

4.1.2 Absolute Antenna Gain Calibration

In the same period – the late 1950s and early 1960s – there was great activity in the construction of large and more-precise reflector antennas for radio astronomy. This was soon followed by large paraboloids used as ground stations in satellite communication and deep-space tracking. From the engineering side, the interest grew to fully characterize the new antennas and to study their behavior in operation. It was a natural step for radio astronomers to use the strongest radio sources as broadband signal radiators for their antenna measurements. Soon, managers and engineers of communication and deep-space tracking ground stations used the strong radio sources as test transmitters and the radio astronomical methods for the characterization of the antennas. These methods are discussed in detail in [15].

The stronger the test source, the more accurate would it be possible to characterize the antenna parameters. In the early days, the sun was often used for this purpose. However, the sun is far from an ideal calibrator. At long wavelengths, its intensity is extremely variable, and its angular diameter of about a half degree is much larger than the beamwidth of the large antennas operating at short, cm wavelengths. It was thus natural to concentrate on the strongest sources, Cas A, Cyg A, and Tau A. These were the sources of (forced) choice when, during the 1963-64 winter, Peter Mezger, with his assistants Heinz Wendker and the author, undertook to characterize the NRAO 300-ft and 85-ft telescopes in Green Bank at the short (beyond design specification) wavelengths of 10 cm and 2 cm, respectively. The antenna beamwidths in these cases are about 4 to 5 arcminutes, comparable to the angular sizes of Cas A and Tau A.

To obtain as accurate a measurement of antenna gain as possible, it was decided to make a comprehensive study of the available absolute measurements of these sources, carefully applying all necessary corrections for polarization and angular size. Once this was done, up to the highest measurement frequency of 15 GHz, significantly improved absolute spectra of the three strongest sources were obtained by inclusion of several recently published accurate absolute measurements, and locally performed additional relative measurements among the strong sources, at frequencies above 3 GHz. The submission of this work for publication met with strong objection from the referee of the *Astrophysical Journal* on the argument that the paper did not contain any new astrophysical insight. In the end the *Astrophysical Journal*'s Editor accepted the authors' argument that the time had arrived to treat observational radio astronomy as a quantitative experimental science (Baars, Mezger, Wendker (BMW), [53]).

The characterization of the antennas provided useful input to the understanding of their behavior, and some hints as to the feasibility of the homologous structural design method, which was being developed at NRAO by von Hoerner [54] at the same time. For instance, the loss of gain at small elevation angles of the reflector could be partially recovered by an adjustment of the position of the feed along the axis of the antenna (axial focusing). This meant that the antenna deformed to approximately a paraboloid, albeit with a different focal length.

As an example from outside astronomy, in the mid-1970s, the European Space Agency (ESA) launched the Orbiting Test Satellite (OTS). It was desired to measure on Earth the absolute power transmitted by its beacon at 12 GHz, in order to check any influence of the launch and deployment on the OTS system. It was also desired to provide a source of known intensity from the OTS for other ground stations in the new satellite band at 12 GHz. For this to be successful, ESA needed at least one ground station to be fully calibrated. The author was asked to help in achieving this with the aid of the strong radio sources. In the spring of 1977, the gain of the 12-m diameter antenna at the Fucino station in Italy was determined with an absolute accuracy of better than 5%.

4.2 Extension of Frequency Range

In the latter part of the 1960s, several accurate horn measurements of Cas A were made up to frequencies of 20 GHz. Absolutely calibrated measurements with dipoles were made at low frequencies of 38 MHz, 81.5 MHz, and 152 MHz. A large amount of data between 0.5 GHz and 9.4 GHz also became available from the group at Gorkii, using their *artificial moon* method.

When Ard Hartsuijker and the author compared their measurements of the ratios of the flux density between the strongest sources, obtained with the Dwingeloo telescope at 21 cm and 11 cm wavelengths in the period 1968 to 1971, with those of several observers at epoch 1956-1961 made with telescopes of the same size (and hence, equal beamwidth), they obtained a value of $0.9\% \pm 0.1\%$ per year for the decrease in flux density at both frequencies. This value was significantly smaller than the recently updated value of 1.29% per year at 81.5 MHz [39]. Realizing that a frequency-dependent secular decrease would influence the spectrum as derived by BMW, and thereby source flux-density scales, they undertook a new analysis of the Cas A absolute spectrum, including all new data up to 1971 (Baars and Hartsuijker (BH) [38]).

Taking values for the secular decrease of 1.3%, 1.1%, and 0.9% in the frequency ranges < 300 MHz, 300 MHz to 1200 MHZ, and > 1022 MHz, respectively, they reduced all data to epoch 1965, which was the approximate midpoint of all measurements used in the analysis. The resulting spectrum of Cas A could be fitted closely with a single power law with spectral index $-0.787\% \pm 0.006\%$ up to 16 GHz, if one took into account that the 38 MHz point was already influenced by the downward tendency of the spectrum indicated by observations at even lower frequencies.

Apart from suggesting frequency dependence in the decrease of the Cas A flux density, these authors also commented on the corrections to be made to the existing flux-density scales from CKL, Kellermann, and KPW. These were significant at frequencies below 1 GHz. For instance, the CKL scale at 400 MHz needed an upward correction of 9.2%. This was confirmed by Conway and Munro [55], who compared the CKL scale with the scale by Wyllie [10], which was based on absolute measurements of five sources of medium intensity (~40 Jy). They concluded that CKL was $8.7\% \pm 1.6\%$ low. Although these authors mentioned the BH paper in their article, they apparently overlooked the conclusion in that paper about the necessary correction factors. It is of some interest to note here that the CKL scale near 400 MHz was strongly influenced by the absolute measurement of Seeger [9], which, as we have noted above, was more than 20% low. If the early data point from Seeger had been more correct, the adjustment of the CKL scale some six years later would perhaps not have been necessary.

The KPW scale did require smaller corrections on the basis of the BH scale, less than 3% above 1 GHz, increasing to about 8% at 178 MHz.

The importance of the work by Wyllie [10] should be emphasized here, because he established an independent scale at 408 MHz that does not depend on Cas A. His method was described in Section 2.1. On his scale, the flux density of Cas A was 6555 Jy (epoch 1965.0) at 408 MHz, while the BH spectrum yielded 6450 ± 75 Jy, 1.5% below Wyllie's value. (On the final BGPW scale, to be presented in the next section, the flux of Cas A was 6492 Jy, within 1%.) The secondary standards on Wyllie's scale were thus closely consistent with the scale based on the Cas A spectrum.

The overall situation with the reliability of the Cas A spectrum appeared significantly improved by the BH spectrum. However, it remained difficult to connect the different surveys of ever-weaker sources to it, and alternative schemes of calibration were proposed. Beverley Wills [56] (in some papers by the Gorkii group, she was assumed to be masculine) published in 1973 a slightly different approach to the available absolute measurements of Cas A. In particular, she used only the early artificial-moon measurements of the early 1960s, which later were subjected by the authors to some corrections based on their work around 1970. BH used predominantly those later measurements. The spectrum of Cas A is slightly flatter in Wills' analysis. As in the works by Kellermann and colleagues, mentioned above, she selected a group of sources of intermediate strength to form the basis for a general flux-density scale.

In the years 1972-73, there were efforts to reach a general agreement on a *standard spectrum* of Cas A, and on a set of secondary standards for general use in the flux-density calibration of weak sources. The goal was to achieve a formal decision by URSI (General Assembly, Warsaw, 1972) or the International Astronomical Union (IAU, General Assembly, Sydney, 1973) to harmonize the flux-density scale. This was particularly important for the extensive source catalogues obtained with the new, powerful, large telescopes and synthesis arrays. There was some discussion at the URSI Assembly in 1972, but it did not lead to the adoption of an "officially accepted" standard Cas A spectrum or a set of secondary standards.

4.3 Extension to Weaker Sources

The interest in a further improvement of the situation with Cas A arose with this author after the publication by Dent et al. [40] of the secular decrease at 7.8 GHz being only $0.70\% \pm 0.1\%$ per year, determined over an eleven-year period. Together with data at 3.06 GHz and 9.4 GHz from Stankevich et al. [42], there appeared to be evidence of a frequency dependence of the decrease, and a fit to the available data was shown above (Equation (12)). Obviously, the data used by BH needed to be corrected for this effect, however small it might be. In addition, new accurate absolute data had become available at low frequencies between 10 MHz and 25 MHz, which could be used to clarify the downwards trend of flux density suggested by the accurate data point from Parker [18] at 38 MHz. In their latest publications, the Gorkii group had also indicated that their older measurements were in need of some correction, although the actual values of the corrections were not given (at least, not in the translated material that was available).

The author thus started to work on a revision of the BH spectrum of Cas A in the course of 1974. It was not clear how useful this would be for the actual practice of defining a flux-density scale for the large amount of data being produced by the surveys with the newest telescopes, such as the Effelsberg 100-m telescope, and the Synthesis Telescopes at Westerbork and Cambridge. It seemed that the BH paper did not have all that much of an impact on the

Source	Frequency Interval	Spectral Parameters		
		a	*b*	*c*
Cas A (1965.0)	22 MHz – 300 MHz	5.625±0.021	–0.634±0.015	–0.023±0.001
	300 MHZ – 31 GHz	5.880±0.025	–0.792±0.007	–
Cyg A	20 MHz – 2 GHz	4.695±0.018	+0.085±0.003	–0.178±0.001
	2 GHz – 31 GHz	7.161±0.053	–1.244±0.014	–
Tau A	1 GHz – 35 GHz	3.915±0.031	–0.299±0.009	–
Vir A	400 MHz – 25 GHz	5.023±0.034	–0.856±0.010	–

Table 1. The spectral parameters of the primary calibrators.

calibration habits of most observers. Clearly, one needed to build a bridge to a set of sources of intermediate intensity to act as *secondary calibrators*. These sources would preferably have the following characteristics:

1. Be sufficiently strong to serve as calibrator, but sufficiently weak to avoid linearity problems for the calibration of the very weak sources in the newest surveys;

2. Have a simple power-law spectrum over a substantial part of the radio spectrum;

3. Be constant in intensity over time and have a known, preferably zero, degree of polarization;

4. Be "point-like" for the largest interferometer baselines to avoid the need for size corrections;

5. Preferably have an accurately known position so as to be also useful for antenna pointing and baseline determination of interferometers.

Such a program was initiated at the Max-Planck-Institut für Radioastronomie (MPIfR) in Bonn, where Reinhard Genzel did the bulk of the work, guided by Ivan Pauliny-Toth and Arno Witzel. After joining the MPIfR in 1975, the author became involved in this project, which eventually led to the *calibration paper* by Baars, Genzel, Pauliny-Toth, and Witzel (BGPW), published in *Astronomy and Astrophysics* in 1977 [43].

4.3.1 The Absolute Spectrum of Cassiopeia A

In the BGPW paper, the spectrum of Cas A, along with the spectra of Cyg A and Tau A, were brought up-to-date by including new accurate measurements since 1972, replacing the old artificial-moon data by newer data, and considering the frequency dependence of the secular decrease in Cas A. An important result of the analysis was the confirmation of a downwards bending of the spectrum at frequencies below about 300 MHz. The best fit for the entire spectrum was obtained by a second-degree function between 20 MHz and 300 MHz, and a straight power-law spectrum from 300 MHz to 30 GHz. The spectral data, including those for Cyg A, Tau A, and Vir A are given in Table 1. The parameters *a*, *b*, and *c* are to be used in the equation for the flux density, *S*:

$$\log S = a + b \log \nu + c \log^2 \nu \,, \qquad (14)$$

with *S* in Jy and ν in MHz.

The spectra of these four sources, together with the data points from 200 MHz upward, are shown in Figure 9.

The authors of BGPW restricted the use of artificial-moon measurements to the period after 1967, because earlier artificial-moon measurements needed corrections, which were not described. Moreover, they also limited the number of data points to roughly the same as the number of horn data points, evenly distributed over the frequency range between 500 MHz and 9800 MHz. Using only the horn data points, the spectrum was slightly flatter ($b = -0.782$), while that of only artificial-moon data was a bit steeper ($b = -0.807$): they intersected near 2.5 GHz.

4.3.2 The Secondary Calibration Sources

The second part of the BGPW paper contained accurate spectra of about a dozen *secondary standard sources*. These were obtained from accurate ratios with respect to the primary standard sources. At the higher frequencies (> 5 GHz), Vir A, being of intermediate strength, served in this process as a convenient secondary calibrator. Flux-density ratios were collected, both from the literature and by additional observations, at eleven frequencies over the range from 0.4 GHz to 15 GHz. The derived spectra had an absolute accuracy of better than 5%. Three of the sources (3C48, 3C147, and 3C286) were also suitable for the calibration of interferometers of moderately high resolution, and have been universally used for this purpose. The BGPW paper also presented an updated table of correction factors to earlier flux-density scales. Finally, it included a table of the flux density of 14 secondary calibrators at eight widely used *standard* observing frequencies.

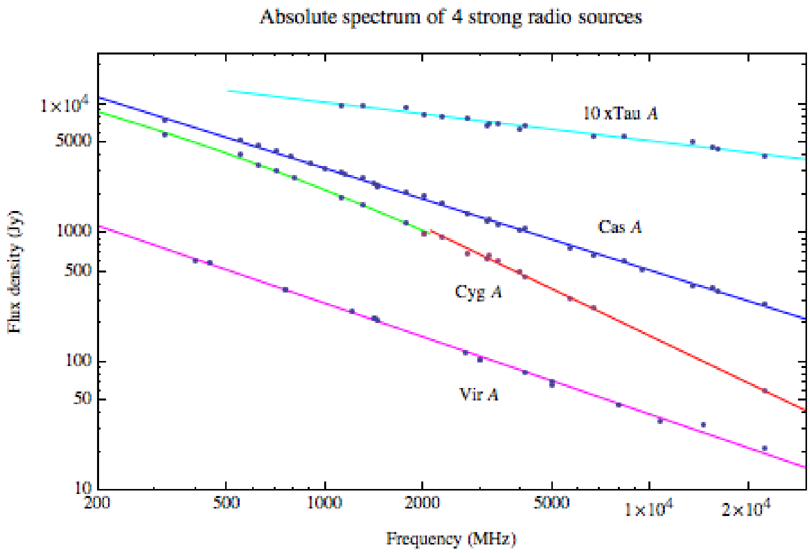

Figure 9. The absolute spectrum of Cas A from 300 MHz to 25 GHz, based on 30 absolute measurements with horn or artificial moon, as well as the absolute spectra of Cyg A and Tau A, and the semi-absolute spectrum of Vir A.

It was probably mainly through the accurate data on already widely used secondary calibrators that the paper was generally accepted as the basis for the flux-density calibration of radio-source observations. It has been cited more than 1700 times since its publication. Obviously, most observers were content. However, with the growing amount of data, made with sensitive and high-resolution telescopes, it became clear that several of the secondary standard sources showed significant variability over time. The extrapolation to frequencies above 20 GHz was also not perfect. Ott et al. [57] improved the consistency of the set by new observations over a wide frequency range up to 43 GHz. They found 3C286 and 3C295 to be very constant in flux density, and used these as a link between the BGPW scale and the other secondary calibrators.

4.4 Extension to Higher Frequencies and a New Scale

Despite some adjustments and corrections to the set of most-suitable secondary standards, the basic BGPW flux-density scale remained generally used over the last 35 years. The scale essentially became detached from the evolution of the Cas A spectrum over time. One could say that Cas A had fulfilled its purpose, and could further be studied on is own merit by making high-angular-resolution maps, and following in detail its decrease in flux density. The author is aware of one high-accuracy absolute measurement at 32 GHz by Mason et al. [58]. The measured flux density was 194.5Jy ± 2.5Jy at epoch 1998.4. The BGPW spectrum predicts a flux density of 205 Jy at epoch 1965, suggesting a decrease of only 10 Jy over more than 30 years, or an annual decrease of about 0.15%. This is considerably smaller than expected from Equation (13), but is perhaps consistent with the later values given by the Gorkii group (see Figure 8). It can also be an indication of a deviation of the spectrum from the straight power law valid to 25 GHz. There are indeed indications from the Wilkinson Microwave Anisotropy Probe (WMAP) data (23 GHz to 94 GHz) that the spectrum flattens over that frequency range (Weiland et al. [59]).

The emergence of large and powerful mm-wavelength telescopes in the 1980s increased the need to extend the flux-density scale to frequencies well in excess of 100 GHz. This aspect will be discussed in the next section. Although the powerful synthesis arrays and VLBI networks were primarily interested in accurate positions of point sources for the position calibration of new sources, their sensitivity pushed detection limits into the millijansky region, which put additional requirements on the accuracy and reliability of the existing secondary calibrators.

At the NRAO Very Large Array (VLA) in New Mexico, Rick Perley and Bryan Butler used the frequency flexibility and high sensitivity of the VLA over almost 30 years (1983-2012) to monitor the set of secondary calibrators with respect to each other and with respect to the planet Mars. This led to an accurate flux-density scale from 1 GHz to 50 GHz (Perley and Butler [4]), which we will now summarize.

Source	*a*	*b*	*c*	*d*
3C123	1.8077±0.0036	–0.8018±0.0081	–0.1157±0.0047	0
3C196	1.2969±0.0040	–0.8690±0.0114	–0.1788±0.0150	0.0305±0.0063
3C286	1.2515±0.0048	–0.4605±0.0163	–0.1715±0.0208	0.0336±0.0082
3C295	1.4866±0.0036	–0.7871±0.0110	–0.3440±0.0160	0.0749±0.0070

Table 2. The coefficients of the fitted spectra for the four steady sources.

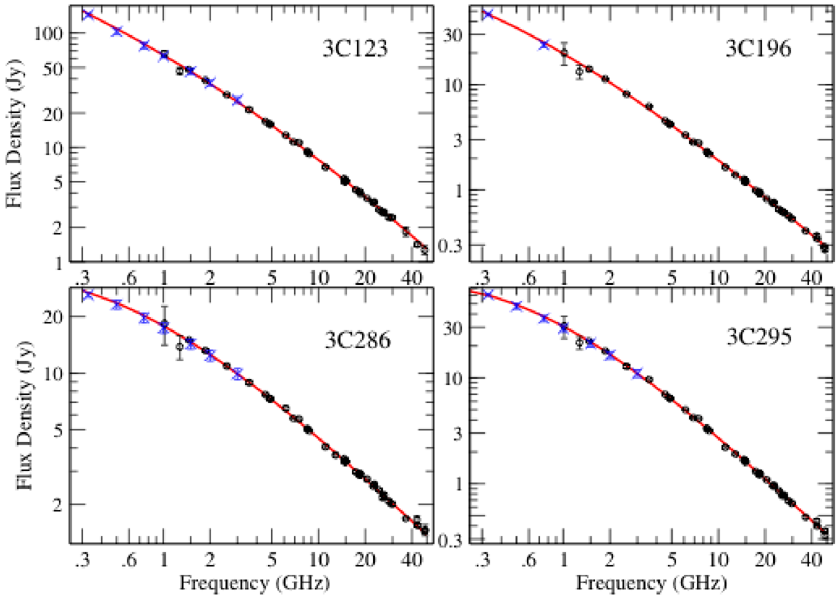

Figure 10. Spectra of the four non-variable standard calibrator sources. The black dots are measurements based on the Mars model. The red line is the best fit, according to Table 2. Data based on the BGPW or Scaife and Heald scale are indicated by a cross. Note the excellent fit of these data to the spectra (after Perley and Butler [4]).

The program started in 1983, with the complete secondary calibrator list from BGPW. The seven most compact of these were carried through the entire program. Over time, other objects were added, including several planets. Observations were carried out in all frequency bands of the VLA, nine in total, covering the frequency range from 300 MHz up to 50 GHz. Data were collected during nineteen sessions of typically two days, up to early 2012. The planet Mars was used as a high-frequency standard, and the absolute calibration of Mars by WMAP made it possible to put the flux-density scale over the entire cm-wavelength range on an absolute basis. This also enabled a direct comparison with the BGPW scale. The measurements of the source intensity ratios showed that four sources (3C123, 3C196, 3C286, and 3C295) were constant in output to better than 1% over the duration of the program. These were put on the Mars scale to serve as *semi-primary standards*, with an estimated error of 1% in the range 4 GHz to 15 GHz, increasing to 2.5% at 1.5 GHz, 2% at 22 GHz, and 3% at 43 GHz. This small error, and the extension of the frequency range, constituted an improvement over the BGPW scale. However, a comparison with the BGPW scale showed a difference of less than 2% over the BGPW frequency range from 300 MHz upwards. It thus appears that observers who used BGPW over the last 35 years do not need to recalibrate their data.

The parameters for these four standard sources are shown in Figure 10 and in Table 2. The coefficients in the table pertain to a cubic-polynomial fit to the measured data of the form

$$\log S = a + b\log\nu + c\log^2\nu + d\log^3\nu\,, \qquad (15)$$

where the flux density, S, is in Jy, and the frequency, ν is in GHz.

4.5 Low Frequency (<300 MHz) Calibration

With the emergence of large interferometric arrays, operating with a wide bandwidth over the frequency region from about 20 MHz to 400 MHz, exemplified by LOFAR [60] and the future Square Kilometre Array (SKA) [61], the flux-density scale for that range has received closer scrutiny in recent years.

The reliability of the absolute Cas A spectrum below 150 MHz has been put in doubt as a result of the detection of short-term variations in its flux density, notably at frequencies below 80 MHz [41]. This also leads to uncertainty in the rate of secular decrease at the low frequencies and, by implication, the validity of the assumed functional form of the secular decrease over the broad frequency range up to tens of gigahertz.

To avoid this complication, Roger, Bridle, and Costain [62] constructed a flux-density scale for low frequencies based on Cyg A. This early scale was 5% below the later BGPW scale at 22 MHz. The PAPER collaboration (Parsons et al. [63) based their calibration at 150 MHz on the BGPW spectrum of Cyg A, as did Cohen et al. [64] for the VLA survey at 74 MHz. The BGPW spectrum of Cyg A in the low-frequency region was based on direct absolute measurements, mostly with interferometer systems, which minimized the influence of the considerable background brightness structure in that area of sky. Cyg A appears indeed to be the best choice of primary standard between 20 MHz and 500 MHz.

Scaife and Heald [65] addressed the need for an accurate broadband flux-density scale at low frequencies, and presented model spectra of six bright 3C radio sources in the frequency range of 30 MHz to 300 MHz. They also avoided the problem of Cas variability and put the spectra on the scale of Roger [62], which was based on Cyg A. The deviation of their scale with respect to the BGPW scale was less than 10%. This difference might have been made smaller by the use of the BGPW absolute spectrum of Cyg A as the basis for the scale. In any case, the model spectra of the proposed six "secondary" calibration sources (3C196, 3C286, and 3C295 overlap with the Perley and Butler group) formed a good initial basis for flux-density calibration from 30 MHz to 300 MHz with LOFAR and other large low-frequency telescopes.

5. The Millimeter Wavelength Region

5.1 Early Efforts, Planets

Radio astronomers normally designate the frequency range from 30 GHz to 300 GHz as the millimeter-wavelength region. Above 300 GHz extends the sub-millimeter region. (The terahertz range starts at 1 THz, or 0.3 mm wavelength, although in branches outside astronomy, the term terahertz appears to be applied from about 300 GHz upwards.) The first small reflector antennas of about 5 m diameter, specifically designed to work up to a frequency of at least 100 GHz (a wavelength of 3 mm) appeared in the mid-1960s at the University of Texas and the Aerospace Corporation. Receiver technology for this frequency range was in its infancy. Nevertheless, the NRAO undertook to build a mm-wavelength telescope of 10 m diameter, capable of operation at 1 mm wavelength. This *36-ft telescope* was situated at 2000 m altitude on Kitt Peak, Arizona, to exploit the superior atmospheric conditions of this dry and cloudless region. After the detection of the spectral line of carbon monoxide at 115 GHz with this instrument by Wilson, Jefferts, and Penzias [66], millimeter astronomy became a "hot" subject, and in the following decades a number of large and accurate mm-wavelength telescopes came into operation.

The exploration of the mm-wavelength range necessitated the extension of the flux-density scale to higher frequencies. A straightforward extension of the spectra of existing calibration sources posed a serious difficulty. All secondary standard sources, exhibiting a negative spectral index, were too weak to fulfill their purpose, while sources like Cas A and Tau A were *extended* sources with respect to the narrow beamwidth of the mm-wavelength telescopes, and showed considerable structure in their brightness distribution.

The planets provided an attractive alternative for standard sources. Their approximate blackbody spectrum assured increasing flux density at higher frequencies, and their angular size appeared suitable for the 10-m class of mm-wavelength telescope. However, there are also complications in the use of the planets, caused by variations

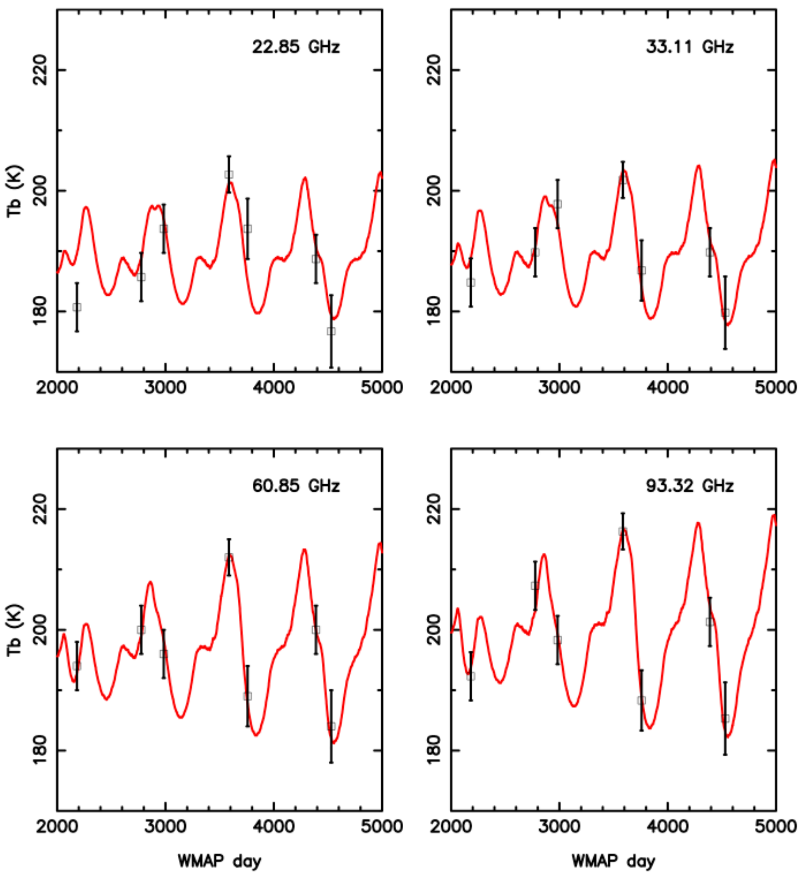

Figure 11. The brightness temperature of Mars at four frequencies, as predicted from the Rudy model over a seven-year period, shown as a continuous line, slightly adjusted to the WMAP observations shown as the black data points. The regular oscillations were due to a combination of the orbital motions of the Earth and Mars, the inclination of Mars, and the Martian seasonal variations (after Perley and Butler [4]).

in the distance (Mars), frequency dependence caused by planet's atmosphere (Venus, Jupiter), or orientation (Saturn's rings). It was thus necessary to determine their mm-wavelength spectrum by direct measurement with a calibrated antenna system. Bobby Ulich and colleagues took this up with the 4.9 m telescope in Texas, which in 1967 had been relocated to the 2000 m high site of Mt. Locke in Western Texas (Ulich et al. [67]). They calibrated the antenna with the aid of a transmitter at a distance close to the far-field limit at 3.5 mm and 2.1 mm, and observed several planets with quoted absolute accuracies of better than 10%. After moving to NRAO, Ulich used the new 36-ft telescope to improve the situation, and in 1981, proposed a set of *millimeter-wavelength calibration sources* for the range from 30 GHz to 150 GHz, with accuracies between 5% and 10% [68]. This was about as good as one could do at the time.

With the growing body of planetary observations, it became clear that none of them was without some difficulties. Observations in the 1980s with the larger millimeter and sub-millimeter telescopes and the VLA showed that Mars was the most suitable candidate to serve as primary calibrator at mm-wavelengths. First of all, it is the only planet whose observed brightness temperature is as expected from solar heating. In addition, important data on the Martian surface characteristics were provided by space probes (Viking, Mariner, Mars Global Surveyor), which allowed a detailed thermal model of the Martian surface to be constructed (Wright [69], Rudy et al. [70]). These models showed that the brightness temperature of Mars varies considerably with time, due to its position with respect to the sun and its distance and inclination with respect to the Earth, but these are readily calculable.

The space-borne observatories WMAP, Herschel, and Planck were all designed with the aim to achieve very high absolute intensity calibration, of the order of 1%. Notably, the seven-year run of WMAP provided essential data for the comparison with the planetary thermal models. This is illustrated in Figure 11, which shows the model predictions from Rudy as a function of time (in "WMAP days"), and WMAP data points at four frequencies between 22 GHz and 93 GHz. The best fit was obtained by adjusting the Rudy model by 2.6%, 3.0%, 1.5%, 1.3%, and 1.3% at 22 GHz, 33 GHz, 41 GHz, 61 GHz, and 93 GHz, respectively. One could see that the fit is excellent, but also that using Mars as a routine calibration source involves an elaborate time-dependent procedure.

Using these excellent data, Perley and Butler [4] based their flux-density scale on Mars. They achieved a total error of 2.5% at 1.5 GHz, 1% at 4 GHz to 15 GHz, 2% at 22 GHz, and 3% at 43 GHz. The WMAP accuracy was about 2% at 22 GHz, improving to 0.5% at 93 GHz. Data from the Herschel and Planck satellite telescopes extended the absolute calibration of Mars to about 1 THz with an accuracy of a few percent.

Similarly to the situation in the cm-wavelength band, also at mm-wavelengths, the somewhat cumbersome primary calibrator has been used to establish a set of *secondary calibrators* by accurate ratio determinations. Dominant here are the planets Uranus and Neptune. In connection with the sub-millimeter space missions of Herschel and Planck, detailed models of their radiation spectrum were made, which were well confirmed by observations with these telescopes. The measured brightness-temperature spectra of these bodies are not exactly "blackbody" because the wavelength dependence of the penetration depth at which the brightness is sampled. Also, Uranus exhibited a slow variation in brightness, due to the change in the sub-Earth-point latitude (Kramer et al. [71]). The accuracy of the absolute scale based on these objects was quoted as 4%. A few compact Galactic thermal sources (DR21, NGC7027, MWC349, W3(OH)) were used as secondary calibrators, but they required regular crosschecks with the primary standards because of time variability.

The accurate absolute calibration at millimeter and sub-millimeter wavelengths owed much to the space observatories mentioned above. From their position at the L2-Lagrangian point in the solar system, they avoided several of the external influences, which make highly accurate calibration from the Earth difficult. Thanks to these telescopes, the accuracy of flux-density calibration in the mm-regime is now comparable to that in the cm-region, at a level of a few percent.

5.2 ALMA Flux-Density Calibration

Around the turn of the century, three proposals for a large interferometric array, to be located at a very good site (high and dry), were joined into one global collaborative project by the initiatives from North America (NRAO in the USA and Canada), Europe (coordinated by ESO, with the participation of, at the time, ten countries), and East Asia (Japan and Taiwan) [72]. The result was the Atacama Large Millimeter/submillimeter Array (ALMA), hosted by Chile on the 5000 m high Chajnantor plateau in the northern Atacama Desert. It is an interferometric synthesis telescope consisting of 50 reflector antennas of 12 m diameter, configurable with baselines varying from 20 m up to 15 km. The antennas are equipped with low-noise cryogenic receivers, covering the entire frequency range from 30 GHz to 950 GHz, distributed over 10 bands. A small "compact array" of four 12-m antennas and a dozen 7-m dishes provide data in the spacing area below 100 m. At the time of writing (early 2014), all 66 antennas have been accepted, and most are equipped with receivers covering up to seven receiver bands. Currently, observations are being made with 45 antennas. It is expected that by the end of 2014, the full array will become available.

In the original specification, made in 2000, a goal of 1% in flux-density calibration was mentioned. The electronic system has been designed to approach this goal by extensive calibration devices and carefully executed focal-plane optical arrangements. A major problem for an interferometric array operating at mm-wavelengths is the influence of the troposphere. Even at the superb ALMA site, the remaining water vapor along the line of sight fluctuates both in time and in the space across the array baselines, causing phase fluctuations in the interference fringes that are indistinguishable from any phase variation due to the astronomical object. These fluctuations are partially removed by alternatively observing the target source and a nearby known point source as a phase reference. The total system phase calibration is achieved with the aid of a grid of about 30 point sources evenly distributed over the sky.

By including solar-system objects in the grid, the flux-density scale is established, and the phase calibrators also serve as secondary flux-density calibrators. The scale is thus tied to the objects Mars, Uranus, Neptune, some of the planetary moons, and the asteroids Pallas, Vesta, and Ceres. The primary calibration object is Uranus, using the emission model ESA4 for its brightness. The comparison with the calibration of the Planck and Herschel space telescopes via the Mars emission model fits within 5%.

Currently, a realistic goal for absolute intensity calibration is better than 5% over the entire frequency band (80 GHz to 950 GHz). Improvements will be achieved through regular accurate relative measurements of the different objects, and detailed comparison with the theoretical emission models. A relative accuracy of 3% over the entire frequency range appears achievable. The original goal of 1% for the absolute flux-density scale may be unrealistic, but with much effort, 3% might be reached.

6. Conclusion

Obtaining reliable, accurate, quantitative results has always been, and remains to be, a major problem for the observational astronomer. A notable example is the decades-long effort to reach agreement on the value of the Hubble constant [73]. Radio astronomers have been concerned about the calibration of the intensity of radio sources from early on, not the least because radio data are being collected over several decades of wavelength, compared to the one octave in optical astronomy. Establishing a reliable spectrum over a large frequency range is essential for the interpretation of the radiation mechanism.

Perhaps also caused by their background as experimental physicists, the pioneers of absolute flux-density measurements made an essential contribution to the quantitative level of radio astronomy. Their work was, in John Findlay's words, "utterly boring but extremely important." The choice of Cas A, being the most-intense object, as original primary standard source was natural. However, the time variability of its strength made it less suitable for this purpose, albeit providing interesting data about its astrophysics. Nevertheless, a flux-density scale based on Cas A was established over a significant frequency range of roughly 30 MHz to 30 GHz, which was used for more than 30 years. The strong interest in higher frequencies, up to 1 THz, has shifted the primary-standard role to the planets, in particular Mars. The advances in detailed planetary-emission models, confirmed or slightly adjusted by the extremely accurate calibration of the space-borne telescopes WMAP, Herschel, and Planck, provide an absolute flux-density scale based primarily on Mars with an accuracy of a few percent from 30 GHz up to several hundreds of GHz. With the good overlap of this scale with the Cas A-based scale at lower frequencies, observations over the entire radio-wavelength regime enable the determination of intrinsic source intensities with an accuracy of a few percent.

Returning to the VLA observer on the way along US Route 60 to the VLA, the observer will still be wondering how far away is the oncoming vehicle, but the observer need not be too worried about the true intensity of the objects being observed.

7. Acknowledgement

At NRAO in 1964, Peter Mezger initiated my interest in the subject. In writing this review, I became again aware of the importance of the tedious work by the colleagues who measured absolute flux densities with special antennas. Regular discussions over the years with Rick Perley kept my interest in this field active. I thank him, Richard Hills, Ruediger Kneissl, Carsten Kramer, and Ken Kellermann, as well as the referees, for helpful comments and suggestions.

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Radio-Frequency Radiation Safety and Health

Reevaluating Research on Cell Cultures Exposed to Low-Frequency Electromagnetic Fields

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Abstract

A systematic measurement has shown that the background static and ELF magnetic fields in biological incubators can vary by orders of magnitude within a single incubator and between different incubators. Measured incubator fields varied from below levels that the IARC had classified as possibly carcinogenic to humans (0.3 µT to 0.4 µT) to as high as 240 µT, above the Earth or natural geomagnetic field range (23 µT to 65 µT). The significance is that studies of biological effects of ELF field exposure on cell cultures involved magnetic fields ranging from 0.1 µT to 50 µT. The inconsistency or variability of in vitro laboratory data prompted many to declare that there was no compelling evidence that biological effects are causally related to ELF magnetic-field exposure. Most in vitro investigations involving cell cultures in the laboratory were unaware of and therefore did not account for the large variations in background static and ELF magnetic fields in cell-culture incubators. Given the potential confounding of unspecified incubator fields, it seems only reasonable to reassess the data and reevaluate the validity of any conclusions to date, positive or negative. Are we back to square one? In some sense, it may be so: the reported background static and ELF magnetic-field variations in cell-culture incubators could be a game changer.

The first study, published in 1979, suggested that long-term exposure to residential 50/60 Hz electromagnetic fields (EMF) may be associated with childhood leukemia risk [1]. A large number of epidemiological studies have been completed since then, worldwide. Results were evaluated in two pooled analyses [2, 3], which showed that an excess risk may exist for average exposures exceeding 0.3 µT to 0.4 µT. It is noted that the authors cautioned that it was unclear whether the results of their analyses could be interpreted as showing a causal relationship between magnetic fields and childhood leukemia.

Subsequently, in 2002, the World Health Organization's (WHO) International Agency for Research on Cancer (IARC) reviewed reported scientific research. They reached the conclusion that current evidence was sufficiently strong to support a classification of possibly carcinogenic to humans for extremely low frequency (ELF) electromagnetic fields, including those employed for electric power transmission and distribution [4]. Nevertheless, in 2007, WHO, in its Environmental Health Criteria on ELF fields, concerning childhood leukemia, indicated that while there may be a weak association between exposure to residential 50/60 Hz magnetic fields and childhood leukemia risk, a combination of some degree of confounding, chance, and selection bias could explain the results [5].

It is fair to say that the WHO's Environmental Health Criteria on ELF fields had a pivotal influence on the most recent International Commission on Nonionizing Radiation Protection's (ICNIRP) recommended guidelines for low-frequency EMF exposure [6]. The ICNIRP guidelines are orders of magnitude above the values of 0.3 µT to 0.4 µT at which IARC had classified low-frequency EMF as possibly carcinogenic to humans. The published ICNIRP guidelines contained a statement that said, "The epidemiological and biological data concerning chronic conditions were carefully reviewed and it was concluded that there is no compelling evidence that they are causally related to low-frequency EMF exposure." To great extent, this conclusion was the precipitation of inconsistencies in results from animal and cell culture studies. Some of them were likely due in whole or in part to differences in experimental methodologies, procedures and protocols, and, perhaps, individual investigators. The absence of a clearly identified biophysical mechanism of adverse interaction of ELF-EMF with biological systems was also an obvious contributing factor.

In 2020, a case in point at the close of the US-Congress-mandated EMF RAPID research program – the lack of consistency from laboratory studies – led the National Institute of Environmental Health Sciences (NIEHS), the study's managing agency, to discount the many epidemiological studies linking ELF-EMFs to childhood leukemia. NIEHS had officially counseled that there was no leukemia risk for children from nearby power lines. However, confronted by criticism, the NIEHS later backed off, and rescinded the advice [7].

An especially vexing issue has been inconsistent results obtained from in vitro laboratory experiments employing seemingly comparable instrumentation, methodology, procedure, and protocol, or the inability of researchers to repeat experiments showing biological effects of low-level EMFs at both ELF and radio frequencies. More to the point, there were failures to replicate in studies specifically designed to repeat laboratory findings in 50/60 Hz magnetic-field experiments.

Biological incubators for cell cultures are commonly used in the laboratory for in vitro studies of the effects of ELF magnetic-field exposure on cells during exposure, and indeed, both for sham exposure and control preparations. A recent report of a systematic measurement campaign showed that the background static and ELF magnetic fields in biological incubators can vary by orders of magnitude within a single incubator and between different incubators [8]. These variations were observed within the same incubator in different locations that were centimeters apart from each other, as well as between incubators that were identical (the same model from the same manufacturer) and located at different areas in the same laboratory. Measured incubator fields varied from below levels that IARC had classified as possibly carcinogenic to humans (0.3 μT to 0.4 μT) to as high as 240 μT, above the Earth or natural geomagnetic field range (23 μT to 65 μT).

While not commonly recognized, these findings in and by themselves were not surprising, and are understandable. However, the findings by and large escaped notice from most previous investigations. Few if any researchers have taken variations of ambient static or time-varying EMF inside the incubators into their experimental design. Seasoned investigators are well aware of the potential influence of ambient EMF, and take appropriate measures to control for the ambient field at the frequency of interest. Recognizing its importance on the experimental outcome in general, most are careful to determine and specify the exposure field and its variations.

The significance of the reported background static and ELF magnetic-field variations in biological incubators lies in the fact that most studies of effects of low-frequency field exposure on cell cultures involved magnetic fields ranging from 0.1 μT to 50 mT [8]. While not always consistent – indeed, often contradictory – reported effects included cell proliferation, differentiation, and apoptosis or programmed cell death, as well as production of reactive oxygen species, free radicals, and heat-shock proteins. This inconsistency or variability of in vitro laboratory data prompted many to declare or opine that there is no compelling evidence that biological effects are causally related to ELF magnetic-field exposure.

It is a fair assessment that most, if not all, in vitro investigations involving cell-culture studies in the laboratory were unaware of – and therefore did not account for – the large variations in background static and ELF magnetic fields in cell-culture incubators.

Until now, the debate has not considered variations of background magnetic field in incubators. Since the fields under investigation often are in the same range as the background variations (0.1 μT to 50 mT), there is no guarantee that the exposed and sham exposed cells are subjected to the same ambient field conditions, even in the same laboratory. The problem is compounded by variations between laboratories. Given the reported subtle and variable biological responses of cells exposed to ELF magnetic fields and the potential confounding of unspecified incubator fields, it seems only reasonable to reassess the data and reevaluate the validity of any conclusion arrived at to date. Are we back to square one? In some sense it may be so: the reported finding could be a game changer.

What would be needed to move forward is a new set of research efforts, where the intended and background exposures are precisely characterized for all cells exposed in cell-culture incubators. It is an essential and may be the only realistic way to address the reproducibility of in vitro studies for effects of EMF exposure on cells in culture.

There is a paucity of data on the influence of ambient incubator magnetic field on the response of cells exposed, on top of any applied experimental magnetic fields inside the incubators. The inconsistent results may or may not be due to differences in other methodologies or protocols that already have been examined. However, the confounding of ambient magnetic field is a salient issue, pleading to be carefully dealt with both for reported negative and positive findings.

The potential confounding of background incubator magnetic field is fundamental in this area of scientific investigation, clearly long overlooked: researchers must do all that is possible to check it out. It should not be a matter of one's belief. Like it or not, science and scientific progress is not always a straightforward march, even though some, perhaps many, may wish to reject any positive experimental results because they could not be replicated consistently and reliably (to wit, the weight-of-evidence argument), and because, to date, there is no widely accepted theoretical model of low-level, ELF magnetic-field interaction with biological systems.

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Dynamic Coupling Between Earth's Atmospheric and Plasma Environments

by Tilmann Bösinger, James LaBelle, Hermann J. Opgenoorth, Jean-Pierre Pommereau, Kazuo Shiokawa, Stan C. Solomon, and Rudolf A. Treumann (eds.), (Space Science Series of ISSI, Volume 42), New York, Springer, 2013, ISBN 978-1-4614-5676-6, £153.00.

If you ever wanted to know almost everything about recent progress and highlights of research on the Earth's upper atmosphere, this book is an excellent choice for you. The breathtaking content of the *Dynamic Coupling Between Earth's Atmospheric and Plasma Environments* nears the capacity of an encyclopedia, with topics ranging from the troposphere through the stratosphere and middle atmosphere, to the ionized upper atmosphere and beyond, into near-Earth space. The book combines broad overviews written by senior authorities, with reviews prepared by senior scientists and research papers from young scientists, in a staggering 609 pages. In fact, the book is a collection of 21 individual papers that reflect the presentations given during a workshop at the International Space Science Institute (ISSI) in Berne, Switzerland, which has an outstanding reputation for its scientific book collection.

For example, the book covers recent results from the C/NOFS, CHAMP, FORMOSAT, COSMIC, and ENVISAT space missions. These are understood in the context of neutral atmospheric motions, e.g., tides, winds, and gravity waves, and the Earth's atmospheric electro-magnetic environment, e.g., geomagnetism, the atmospheric electric field, and electromagnetic waves, from a fraction of one Hz up into the GHz range. I in particular enjoyed reading the three chapters on "The Near-Earth Plasma Environment" by Robert Pfaff, "A Review of Low Frequency Electromagnetic Wave Phenomena Related to Tropospheric-Ionospheric Coupling Mechnisms" by Fernando Simōes et al., and "Lightning Related Transient Luminous Events at High Altitude in the Earth's Atmosphere: Phenomenology, Mechanisms, and Effects" by Victor Pasko et al. These three contributions stand out as a result of their overall balance, breadth, and detail. In fact, these three chapters cover almost 30% of the entire book, and they are definitely a worthwhile read.

The quality of the book is magnificent. It is evident that a lot of effort was spent to produce extremely informative figures, most of them in color, and to eradicate any typos to enable a most enjoyable and undisturbed reading experience.

However, there are surprises. For example, the wording "Space Weather," which is used to describe the coordination of upper-atmosphere research to support risk mitigation in the space industry, and which recently advanced into the UKs National Risk Register, is virtually absent from the book. Similarly, everybody looking for the latest news on newly discovered terrestrial gamma-ray flashes (TGFs) emanating from the top of thunderclouds and subsequently entering near-Earth space, or scientists looking for an explanation of the benefits arising from the use of GPS signals for upper-atmosphere remote sensing, might be disappointed, and have to search elsewhere.

Most regrettably, the book does not have a subject index, which inhibits a convenient navigation throughout the book. As a result, it is not necessarily evident what is the added value of collecting the 21 individual papers into one single book, given that the papers have been previously published in *Space Science Reviews* (**168**, 1-4, 2012). An e-book version with digital navigation tools might have been a better choice, with the added benefit of maximizing the enjoyment by zooming into the astonishing level of detail provided by the figures.

In summary, the book offers advanced readers an encyclopedic overview of recent progress. It highlights research on the Earth's upper atmosphere, which is most conveniently accessed through a digital version of the book.

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International Radio Telescope Projects

by Jacob W. M. Baars, CreateSpace Independent Publishing Platform, April 17, 2013, paperback: vii + 160 pp., ISBN-10: 148393327X; ISBN-13: 978-1483933276; $29

The author, who is well known both to radio astronomers (for, among other achievements, a frequently-cited reference on radio-source flux densities: [1]) and to antenna engineers, chronicles here his experience in large radio-telescope projects over a professional career that spanned nearly four decades. For most of that period, Baars worked for the Max-Planck-Institut für Radioastronomie (MPIfR), under one of its Directors, Peter Mezger. The stated goal of the book is to provide radio astronomers, antenna builders, and managers with information on large radio-telescope projects. The information is intended to go beyond what appears in professional journals, and so should appeal to engineers and historians, in particular. Much of the material is drawn from Baars' own diaries, composed as the events described were taking place. As such, the book offers an interesting perspective on how the large telescopes came to be.

The major telescope projects in which the author played a leading role were the 25-m parabolic dishes of the Westerbork Synthesis Radio Telescope (WSRT); the 30-m millimeter radio telescope (MRT) on Pico Valetta, Spain; the 10-m sub-millimeter telescope (SMT) on Mount Graham, Arizona; and the 50-m large millimeter telescope (LMT) on Cerro la Negra in Mexico. Each of these projects, presented in chronological order, is described in a chapter of the book. A further chapter is devoted to testing the 12-m prototype elements (two competing designs) for the Atacama Large Millimeter (sub-millimeter) Array (ALMA). Finally, there are chapters devoted to the author's introduction to radio astronomy at the National Radio Astronomy Observatory (NRAO) in Greenbank, West Virginia, and shorter visits to a number of radio-astronomy facilities around the world.

To me, the most revealing parts of the book concern the interactions between individuals, the talent as well as shortcomings of people involved, their personal ambitions, prejudices, likes, etc. While this will probably surprise no one with a bit of management experience, it is striking how, time after time, the people working on (and especially those "guiding") a project were more of a challenge (if not an outright obstacle) to progress than the considerable technical problems that had to be overcome. In this area, I would compliment the author for his openness and, as far as an outsider can judge, objectivity.

A case at point is the Sub-millimeter Telescope (SMT, later the Heinrich Hertz Telescope) on Mount Graham, which may be equally well known for the red squirrel subspecies (*Tamiasciurus hudsonicus grahamensis*), inhabiting the mountain's upper flanks, whose presence delayed progress for years. The saga of the SMT/HHT birth pangs, mostly resulting from clashes of personality, totters between epic drama and banal soap opera. The project directors (the "two Peters:" MPIfR's Mezger and Steward Observatory's Strittmatter) had, after a "tedious procedure," agreed that the first SMT Observatory Director would be Baars, who would serve in that capacity for three years, to be succeeded by a Director Designate, Bob Martin. Both Baars (who only wanted a limited-term appointment) and Martin were satisfied they could work within this arrangement. However, Mezger did not think Martin suitable for the job of Observatory Director, and he became critical of the whole operation to get the SMT up and running. In 1993, just before the official dedication of the Mount Graham Observatory, he criticized the project's "low efficiency and slow progress" in an address to an incredulous staff. The following year, at a council meeting, Mezger "attacked Bob Martin and me [Baars] on just about everything in the most vehement way, mostly without regard for the actual situation." Half-a-year later, after Martin had succeeded Baars, there followed an attempt to bring in someone new with "managerial, personnel and fiscal authorities which surpassed those of...Director [Martin]." The project struggled on, awaiting promised receivers for the highest frequencies that were seriously delayed (or never delivered), and under "increasing tension between the MPIfR and SMT O[bservatory], fed by Mezger's dislike of Martin and his ever increasing tendency to micromanage the activities at the telescope." In the spring of 1995, Mezger proposed creating a new post of Deputy Director, to be appointed by the MPIfR; this move was rejected by the Council. In the end, Mezger sort of got his way, but not before declaring that his friendship with Baars was at an end ("…in German: 'ich kündige unsere Freundschaft'! In Germany this means that we would henceforth not address each other with the familiar 'Du', which we had done since our days at NRAO in the mid sixties"). Despite this ominous threat, Baars and Mezger remained friends, which they are to this day, according to the author.

I feel that the book is a bit uneven as far as the presentation of technical details is concerned. For example, when it comes to the WSRT 25-m dishes, we read that they "are of a particularly simple and beautiful design." However, hardly anything is said about what it is that makes the design simple (and beautiful). There is a brief description of how the dishes were assembled in a specially built hangar (still very visible on the ground at the observatory), using precision templates, but apart from a photograph, the reader learns little about the innovations that went into these relatively lightweight dishes. What might also have been mentioned is that while the dishes were specially built for the purpose of aperture synthesis, so they cover the minimum required hour-angle range (12 hours), this has its downside when it comes to using the instrument for other types of observation.

In considering the MRT, I was a bit disappointed to read, "It is not my purpose to give here a detailed description of the telescope design...." I would have thought that this is exactly what telescope designers and engineers would be interested in, notwithstanding the fact that some of the material appears in the professional literature cited in the book. In this chapter, as elsewhere, the importance of industrial partners is evident, and the author does a good job of describing the multi-facetted interactions between scientists and engineers from academe, and their various industrial colleagues. Here, as throughout the book, illustrations (many from private collections) help the reader follow the project's progress. The MRT, which came early in Baars' career, was probably the most successful of his projects (leaving aside ALMA), and clearly the one in which he takes greatest pride.

If one just considers the MRT, SMT, and LMT, not to put too fine a point on it, there seems to be a steady decline in what these instruments have achieved. I doubt that this was simply the result of greater and more complex technical challenges. While there is probably not one single cause, I suspect that a major factor was the increased diversity of the partners forming the consortia that built the telescopes. The MRT was largely a German effort, the SMT had some American input, while the LMT has tried to marry American practicality with Mexican practice: a true clash of cultures.

The text is clearly written, though not devoid of the odd "Dutchism" (one of several examples, p. 20: "So, I saw no other way as to copy a trick of him..."). A moderate number of typos and similar errors slightly disturb the flow of the text. A more serious defect is the absence of a subject index. The fairly detailed Table of Contents is useful, but is no substitute for a good index. A name index is helpful, but not complete (among a number of omissions I noted, the names of Mäder and Beckmann [misspelled as Beckman] mentioned on p. 44 are not listed for that page in the name index). However, these minor criticisms aside, the book will be of interest to historians, and those students of big science who want to learn how (and perhaps sometimes, how not) to get large high-tech projects from drawing board to steel, carbon fiber, and silicon.

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CONFERENCE REPORTS

Report on the 2013 Asia-Pacific Radio Science Conference AP-RASC 2013

Tapei, Taiwan, 3 - 7 September 2013

1. Introduction

The "Asia-Pacific Radio Science Conference" (AP-RASC) is the Asia-Pacific regional URSI conference held between the URSI General Assemblies and Scientific Symposia. The objective of AP-RASC is similar to that of the URSI General Assembly and Scientific Symposium (URSI GASS). It is to review current research trends, present new discoveries, and make plans for future research and special projects in all areas of radio science, especially where international cooperation is desirable. At the AP-RASC conferences, a particular emphasis is placed on promoting various research activities in the countries of the Asia-Pacific region. Subject areas covered by AP-RASC are broad and similar to those of the URSI GASS, which contain topics covered by URSI Commissions A-K.

The history of AP-RASC goes back to the year 2001, when the conference was held for the first time in Tokyo, Japan, based on initiatives by the Japan National Committee of URSI. The following is the list of the AP-RASC meetings that have been organized so far:

AP-RASC 2001: August 1-4, 2001, Tokyo, Japan

AP-RASC 2004: August 24-27, 2004, Qingdao, China (CIE)

AP-RASC 2010: September 22-26, 2010, Toyama, Japan

AP-RASC 2013: September 3-7, 2013, Taipei, Taiwan

The 2013 Asia-Pacific Radio Science Conference (AP-RASC 2013) in Taipei, Taiwan, was the fourth AP-RASC. A total of 618 papers were accepted for presentation, and distributed into the scientific program in a well-balanced manner. The conference was a great success, with 566 scientists attending from 28 countries, and 583 papers being presented.

During AP-RASC 2013 in Taipei, several business meetings were organized, where there was an in-depth discussion on future directions of the AP-RASC meetings, including the venue of the next AP-RASC in 2016. It was decided that starting from the year 2016, the name of AP-RASC will become the "URSI Asia-Pacific Radio Science Conference" (URSI AP-RASC), and URSI will be more involved in conference organization. The next URSI AP-RASC, namely the 2016 URSI Asia-Pacific Radio Science Conference (URSI AP-RASC 2016) will be held in Jeju Island, South Korea, August 22-26, 2016.

In this article, we shall make a comprehensive report on various activities and results of AP-RASC 2013. This includes the conference organization, statistics of the conference, technical programs, young scientist programs, special events, business meetings, special issues, and future AP-RASC. We hope that this report will be useful for scientists working in the URSI community.

2. Organization of the Conference

2.1 Dates and Venue

The conference was held September 3-7, 2013. All of the conference events except for the conference banquet were held at Howard International House, Taipei, Taiwan (http://intl-house.howard-hotels.com/). The conference banquet was held at the Grand Hotel, Taipei, Taiwan (http://www.grand-hotel.org/main/ Default.aspx?lang=en-US).

2.2 Sponsorships

The conference was sponsored by the International Union of Radio Science (URSI), in cooperation with National Taiwan University; National Central University; Chunghwa Telecom Co., Ltd.; Institute for Information Industry; and Academia Sinica Institute of Astronomy and Astrophysics. Financial support for the conference was provided by URSI; the National Science Council, the Bureau of Foreign Trade; Academia Sinica; the National Space Organization; the Taiwan Telecommunication Industry Development Association; the Far Eastern Y. Z. Hsu Science and Technology Memorial Foundation; the Global Science Instruments Co., Ltd.; and the Taipei City Government.

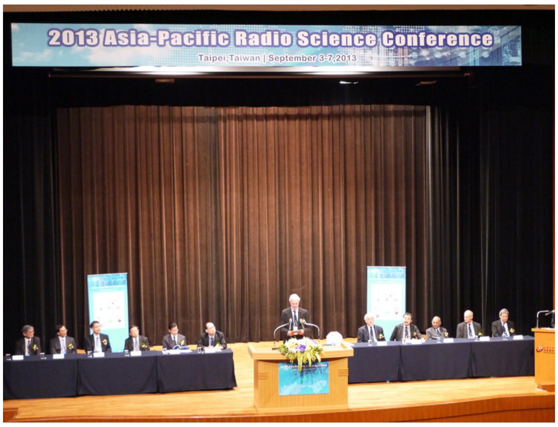

Figure 1. The opening ceremony.

2.3 Conference Web Site and Program

The conference Web site was http://aprasc13.ntu.edu.tw/. The conference program (file size: 85.4 MB) is available at http:// aprasc13.ntu.edu.tw/ConferenceProgram.pdf.

3. Structure of the Committees

The central organization for the conference was as follows: the Honorary Conference Chair was P. Wilkinson, President of URSI; the General Chair was L.-C. Lee, President, China (SRS) National Committee of URSI; the General Co-Chairs were S.-C. Lu, ex-Chair and CEO, Chunghwa Telecom Co., Ltd., and R.-B. Wu, President, Institute for Information Industry, and Professor, National Taiwan University. In order to run the conference, we formed various international and local committees.

3.1 International Committees

The AP-RASC 2013 International Advisory Committee (IAC) comprises members of the URSI Board, the Chairs of URSI Commissions A-K, and the Presidents of the URSI Member Committees in the Asia-Pacific region. The role of this committee was as follows: To make suggestions from the global viewpoint on organizing the conference and running it smoothly; and to distribute the conference information worldwide in the URSI community.

The AP-RASC 2013 International Organizing Committee (IOC) comprised the Presidents of all the URSI Member Committees. The role of each IOC member was to attract scientists (including young scientists) working in the URSI community of his/her country for their participation in AP-RASC 2013.

The AP-RASC 2013 Young Scientist Program Committee (YSPC) comprised the Chair of the AP-RASC

Figure 2a. An opening address by Chi-Huey Wong, President of Academia Sinica

Figure 2b. An opening address by Lou Chuang Lee, AP-RASC 2013 General Chair.

Figure 2c. An opening address by Phil Wilkinson, President of URSI and AP-RASC 2013 Honorary Conference Chair.

Figure 2d. An opening address by Ching-Ray Chang, Vice President, National Taiwan University.

Figure 2e. An opening address by Jing-Yang Jou, President, National Central University.

Figure 2f. An opening address by Kazuya Kobayashi, Chair, AP-RASC Standing Committee.

Standing Committee, members of the URSI Board, Chairs of URSI Commissions A-K, and official members of URSI Commissions A-K in the China (SRS) National Committee of URSI. The role of the YSPC was to review applications for the Student Paper Competition (SPC) and the Young Scientist Award (YSA), and to then select the Student Paper Competition winners and the Young Scientist Award recipients.

3.2 Local Committees

In addition to the international committees stated above, we formed various local committees in Taiwan. The major role of the Steering Committee was to be involved in fund raising. The major role of the Organizing Committee was to make the preparations and onsite arrangements for the conference. The role of the Technical Program Committee (TPC) was to make a decision on acceptance/rejection for all the submitted papers, and to prepare the technical program of the conference in a well-balanced manner. In order to place an emphasis on contributions from the host country, we formed the AP-RASC 2013 TPC on a domestic basis. It is to be noted that the structure of the TPC will become different in the new edition of the URSI AP-RASC meetings starting from the year 2016, and TPC members will be invited internationally, in order for the conference to be more international. For future URSI AP-RASC, it is important that Chairs and Vice Chairs of URSI Commissions A-K will be involved in the preparation of the technical program.

4. Statistics of the Conference

There were a total of 618 accepted papers, with corresponding authors from 27 countries. There were 583 presented papers, with corresponding authors from 25 countries. The total number of registrants was 576, from 28 countries. The total number of participants was 566, from 28 countries.

5. Opening Ceremony

The opening ceremony was an important event. It was held on the second day of the conference, from 9:00-9:50 on Wednesday, September 4, 2013, in the Convention Hall, of the Howard International House. Opening addresses were given by Chi-Huey Wong, President of Academia Sinica; Lou-Chuang Lee, AP-RASC 2013 General Chair; Phil Wilkinson, URSI President and AP-RASC 2013 Honorary Conference Chair; Ching-Ray Chang, Vice President, National Taiwan University; Jing-Yang Jou, President, National Central University; and Kazuya Kobayashi, Chair, AP-RASC Standing Committee. The opening ceremony was video recorded. The 45-minute-long video file can be downloaded from http://www.elect.chuo-u.ac.jp/kazuya/AP-RASC2013_OpeningCeremony.php (783 MB). Some photos taken during the Opening Ceremony are shown in Figures 1 and 2.

6. Technical Program

Three General Lectures by prominent scientists were arranged as follows (see Figure 3):

Figure 3a. A general lecture by Makoto Ando, Tokyo Institute of Technology, Japan.

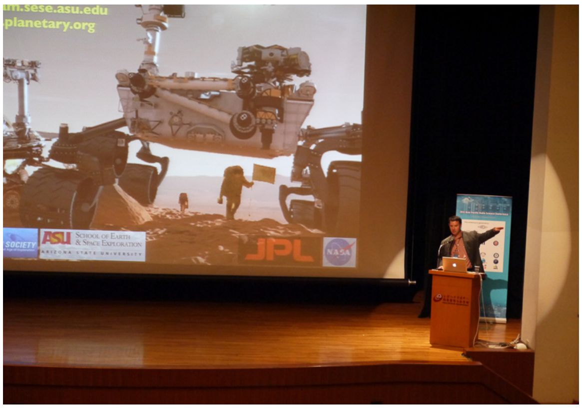

Figure 3b. A general lecture by Jim Bell, Arizona State University, USA.

Figure 3c. A general lecture by Chao-Han Liu, Academia Sinica, Taiwan.

1. "Antennas and Propagation Studies for Realizing Millimeter-Wave Communication Networks," Prof. Makoto Ando, Tokyo Institute of Technology, Japan

2. "Roving on Mars: Latest Results from the NASA Curiosity and Opportunity Missions," Prof. Jim Bell, Arizona State University, USA

3. "Study of the Upper Atmosphere by FORMOSAT Missions," Prof. Chao-Han Liu, Academia Sinica, Taiwan

6.2 Regular Sessions, Workshops, and Special Sessions

During the conference, 62 oral sessions with 514 papers, and two poster sessions with 104 papers, were organized. In addition, three workshops were organized, as follows:

- Asia-Pacific Workshop on Time and Frequency 2013 (Plenary with four lectures, joint session with 41 papers, lab tour)
- The 14th Workshop on mm & sub-mm Wave Receiver Technology in East Asia (22 papers)

- Harmonization of Scientific and Commercial Radio Uses (four papers, panel discussion, wrap-up)

There were two special sessions: "Distinguished Lectures on Antennas and Propagation" with three papers, and "Advances in EM Education in Taiwan" with five papers.

6.3 Exhibition

In addition to the technical sessions, an exhibition was also organized. The exhibitors were Chunghwa Telecom Co., Ltd.; Global Science Instruments Co., Ltd.; the Institute for Information Industry; and the National Space Organization, NARL.

7. Young Scientist Program

The AP-RASC 2013 Young Scientist Program consisted of the Student Paper Competition (SPC) and the Young Scientist Award (YSA). We received 4,750 Euros from URSI central funds and 8,500 Euros from URSI Commissions. These were used to cover part of the expenses for running the Student Paper Competition and Young Scientist Award programs. The AP-RASC 2013 Young Scientist Program was a great success, and the financial support from URSI was greatly appreciated.

7.1 Student Paper Competition (SPC)

A total of 19 students applied for the Student Paper Competition, and five finalists were selected before the conference. The Student Paper Competition special session, open to all participants, was scheduled on the first day of the conference. The Student Paper Competition finalists made oral presentations at this special session (see Figures 4 and 5). Members of the Young Scientist Program Committee present at the conference site evaluated presentations by the Student Paper Competition finalists. When the session was over, the AP-RASC 2013 Secretariat immediately compiled the evaluation results based on the scores of the

Prize	Name	Affiliation	Country
First	Takuma Izumi	The University of Tokyo	Japan
Second	Kun-Han Lee	National Central University	Taiwan
Third	Hao-Chung Cheng	National Taiwan University	Taiwan
Finalist	Naohiro Kohmu	Osaka University	Japan
Finalist	Jue Wang	The Ohio State University	United States

Table 1. The results for the first, second, and third prizes in the Student Paper Competition.

Figure 4. Professor Yen-Hsyang Chu, Chair of the AP-RASC 2013 Young Scientist Program Committee, opens the Student Paper Competition special session.

Figure 5. A presentation by Mr. Takuma Izumi, the University of Tokyo, Japan, Student Paper Competition First Prize winner.

finalists. During the discussion at the AP-RASC 2013 Young Scientist Program Committee meeting held after the special session, the winners were selected as shown in Table 1. At the Award Ceremony held during the conference banquet on September 5, 2013, each of the three winners received prizes (a certificate and prize money), and a certificate was also presented to each of the non-winning finalists.

7.2 Young Scientist Award (YSA)

A total of 47 young scientists applied for Young Scientist Awards, and 20 recipients were selected. At the Award Ceremony, each of the Young Scientist Award recipients received a certificate.

8. Special Events

8.1 Welcome Reception

The Welcome Reception was held from 18:00-20:30 on Tuesday, September 3, 2013, at the Garden Cafeteria on the first floor of the Howard International House. Approximately 300 persons joined the welcome reception, and the conference participants had a good time, with nice food and drinks.

8.2 Student Paper Competition/ Young Scientist Award Party

The Student Paper Competition/Young Scientist Award Party was held from 17:40-20:30, Wednesday, September 4, 2013, in the Howard International House. The finalists of the Student Paper Competition and the recipients of the Young Scientist Award were invited to join the party. All of them enjoyed the program of the party, and a general discussion with members of the URSI Board and the AP-RASC 2013 Committees.

8.3 Student Paper Competition/ Young Scientist Award Tour

A special tour was arranged for the Student Paper Competition finalists and the Young Scientist Award recipients. This tour went by bus from the Howard International House National Central University (NCU) at Chung-Li, where the attendees enjoyed a tour of the campus. They then visited the Center for Space and Remote Sensing Research at NCU, followed by lunch. They visited the Chung-Li VHF Radar Station at NCU, and then took a bus to the National Space Program Office (NSPO) at Hsin-Chu. After visiting NSAP, they took a bus to Taipei for a banquet at the Grand Hotel.

8.4 Conference Banquet

The AP-RASC 2013 conference banquet was organized on the third day of the conference. A total of about 300 persons attended the banquet. In addition, the Student Paper Competition finalists and the Young Scientist Award recipients were invited to join. The banquet was held in the Grand Ballroom, of the Grand Hotel. The banquet opened with a traditional dragon and lion dance and Taiko performance, followed by a photo session. Welcome addresses were given by Pan-Chyr Yang, President, National Taiwan University; Ruey-Beei Wu, AP-RASC 2013 General Co-Chair; Subra Ananthakrishnan, URSI Vice President; George Uslenghi, URSI Vice President; and Paul Lagasse, URSI Secretary General. A traditional Chinese music concert followed. The award ceremonies for the Student Paper Competition and the Young Scientist Awards was then held, followed by additional traditional Chinese music. The banquet closed with the announcement of AP-RASC 2016. Figures 6-10 are various photos taken during the conference banquet.

Figure 6. The banquet begins with a traditional dragon and lion dance/Taiko performance.

9. Business Meetings

During the Conference, the following five business meetings were organized: AP-RASC 2013 Young Scientist Program Committee Meeting; International Advisory Committee and International Organizing Committee Joint Meeting I; International Advisory Committee and International Organizing Committee Joint Meeting II; AP-RASC Business Meeting I; AP-RASC Business Meeting II. At all of these meetings, there were fruitful discussions and a number of important decisions were made.

Figure 7a. The banquet welcome address by Pan-Chyr Yang, President, National Taiwan University.

Figure 7b. The banquet welcome address by Ruey-Beei Wu, AP-RASC 2013 General Co-Chair.

Figure 7c. The banquet welcome address by Subra Ananthakrishnan, URSI Vice President.

Figure 7d. The banquet welcome address by George Uslenghi, URSI Vice President.

Figure 7e. The banquet welcome address by Paul Lagasse, URSI Secretary General.

Figure 8. The award ceremony for the Student Paper Competition. The Student Paper Competition winners with Prof. L.-C. Lee (AP-RASC 2013 General Chair), Prof. P. Wilkinson (AP-RASC 2013 Honorary Conference Chair and URSI President), and Prof. Y.-H. Chu (Chair, AP-RASC 2013 Young Scientist Program Committee).

10. Special Issues

Two special issues have been arranged for papers based on papers presented at AP-RASC 2013. The special issue in the URSI *Radio Science Bulletin* (to appear in June, 2014) will be a collection of papers by finalists selected by the Student Paper Competition program. The guest Editors will be Yen-Hsyang Chu, National Central University, Taiwan (Chair, AP-RASC 2013 Young Scientist Program Committee), and Ping-Cheng Yeh, National Taiwan University, Taiwan (co-Chair, AP-RASC 2013 Young Scientist Program Committee). The special issue in *Radio Science* will be a collection of excellent papers presented at the conference. The guest Editor will be Hung-Chun Chang, National Taiwan University, Taiwan (Chair, AP-RASC 2013 Technical Program Committee). This special issue will appear sometime in 2014.

Figure 9. The award ceremony for the Young Scientist Award (YSA). The Young Scientist Award recipients with Prof. R.-B. Wu (AP-RASC 2013 General Co-Chair), Prof. H.-C. Chang (Chair, AP-RASC 2013 Technical Program Committee), and Prof. Y.-H. Chu (Chair, AP-RASC 2013 Young Scientist Program Committee).

11. 2016 URSI AP-RASC

During AP-RASC 2013 in Taipei, several business meetings were organized, where the future directions of the AP-RASC meetings, including the venue of the next AP-RASC in 2016, were extensively discussed. It was decided that starting from 2016, AP-RASC will become an URSI flagship conference. Its name will become the URSI Asia-Pacific Radio Science Conference (URSI AP-RASC). It is important to note that URSI will be more involved in the organization of the future AP-RASC meetings. At the AP-RASC 2013 International Advisory Committee and International Organizing Committee Joint Meeting II, the venue of the next AP-RASC in 2016 was selected. The 2016 URSI Asia-Pacific Radio Science Conference will be held in Jeju Island, South Korea on August 22-26, 2016. We wish that URSI AP-RASC will keep expanding and many more scientists will contribute to the future AP-RASC meetings.

Figure 10. The announcement and presentation of AP-RASC 2016 (Jeju Island, South Korea, August 22-26, 2016) by Prof. Sangwook Nam, President, South Korea National Committee of URSI.

12. Conclusions

In this article, we have reported the details of various activities and achievements of the 2013 Asia-Pacific Radio Science Conference (AP-RASC 2013), which was held in Taipei, Taiwan, September 3-7, 2013. AP-RASC 2013 was the fourth AP-RASC. It was a great success, with a large number of papers and participants. We would like to emphasize that starting from 2016, the name of AP-RASC will become the URSI Asia-Pacific Radio Science Conference (URSI AP-RASC), and URSI will be more involved in conference organization. The South Korea National Committee of URSI has already set up the Local Organizing Committee for URSI AP-RASC 2016 and its key members are now working hard for conference arrangements. We do hope that URSI AP-RASC 2016 will lead to a great success under the new organization structure. Please plan on attending URSI AP-RASC 2016 in South Korea!

13. Acknowledgments

First of all, we would like to express our appreciation to National Taiwan University and National Central University for taking the role of host universities for organizing AP-RASC 2013. The Conference would never have been successful without their support and suggestions. Financial support from a number of organizations, institutions, and companies, including National Science Council, Bureau of Foreign Trade, Academia Sinica, National Space Organization, and Taipei City Government, are greatly acknowledged. It is also important to mention that from the very beginning, during the course of preparation for the conference, the URSI Board, the URSI Commissions, and the URSI Secretariat made lots of valuable suggestions. We are deeply indebted to this central body of URSI for their generous and constant support for AP-RASC 2013 from both the organizational and financial aspects. Thanks are also due to all the URSI Member Committees for their assistance in organizing the Conference. We would like to extend our appreciation to Dr. W. Ross Stone, Editor of the URSI *Radio Science Bulletin*, for providing us with an opportunity for publication of this report. Finally, we would like to thank the session conveners, session chairs, speakers of general lectures, and participants for their important contributions to the conference, which have played an essential role in its great success.

14. Full Report and Contact

Readers may refer to the full version of this article, which contains a detailed report. It can be obtained from the following link: http://www.elect.chuo-u.ac.jp/kazuya/AP-RASC2013_FullReport.pdf

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RCRS 2014 Conference

Pune, India, 2 - 5 January 2014

URSI encompasses a wide area of radio science, covering "Electromagnetic Metrology,"'Fields and Waves," "Radio Communication Systems and Signal Processing," "Electronics and Photonics," "Electromagnetic Environment and Interference," "Wave Propagation and Remote Sensing," "Ionospheric Radio and Propagation," "Waves in Plasma," "Radio Astronomy," and "Electromagnetics in Biology and Medicine" in its ten Commissions. "The Regional Conference in Radio Science" (RCRS2014), organized under the auspices of INSA and URSI, was held during January 2-5, 2014, in the lovely surroundings of Symbiosis Institute of Technology (of Symbiosis International University), Lavalle, about 20 kilometers from Pune city.

There were a total of 165 participants. The number of registered participants was 133, and there were 135 papers presented.

What distinguished this meeting from our previous national URSI meetings was that there were representative papers from all ten Commissions of URSI, and all the ten committee members were present and chaired various meetings. As a result, we had an excellent multidisciplinary meeting, which is not so in most other conferences. There were three parallel sessions that had (1) Commissions A, E, J, and K together; (2) Commissions B, C, and D together; and (3) Commissions F, G, and H together. There were also plenary talks for all participants, some of which were from our senior colleagues from abroad. Prof. Jocelyn Bell Burner, who discovered pulsars, was a notable speaker at the conference. It is well known that her adviser got the Nobel Prize for the discovery. We also had Prof. Kazuya Kobayashi from Japan, the General Secretary of the Asia-Pacific Radio Science Conference (which takes place every three years) as a speaker, along with Profs. Willem Baan from The Netherlands, Vikass Monebhurrum from France, and T. K. Sarkar from the USA. There were also many senior Indian scientists who reviewed their respective areas.

In the final panel discussion, it was decided that we should continue this type of meeting at least once in two years, if not at shorter intervals.

A total of about Rs 800,000 were spent, apart from the free infrastructure/logistical support from SIT. We were been left with about Rs 100,000 for the next meeting. The JNU group has invited the next meeting to be held at their campus in New Delhi in November 2015. Since the response was very encouraging, it was decided that from the next meeting onwards, we will have a tie-up with an indexed journal for publishing worthwhile papers from the RCRS conference. The term "regional" actually refers to all the neighboring countries around India, and includes Africa (we had only one participant from Nigeria, Africa). Hence, it was suggested that we change the name of the conference series to the Indian URSI conference or some such name, to reflect its international character.

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Report on the 6th VLF/ELF Remote Sensing of Ionospheres and Magnetospheres Workshop 2014

Dundin, New Zealand, 20 - 23 January 2014

General Information

The sixth workshop of the URSI/IAGA Joint Working Group on VLF/ELF Remote Sensing of the Ionosphere and Magnetosphere (VERSIM) took place in Dunedin, New Zealand, on January 20-23, 2014. The workshop was organized by the Department of Physics, University of Otago. More details can be found on the workshop Web site (http://www.physics.otago.ac.nz/ versim/ VERSIM_workshop_Dunedin_2014.html). The scientific sponsorship and financial support for this workshop was provided by the International Union of Radio Science (URSI), the International Association of Geomagnetism and Aeronomy (IAGA), and the United States Air Force Office of Scientific Research, Asian Office of Aerospace Research and Development (AFOSR/AOARD).

The Scientific Program Committee consisted of Craig J. Rodger (University of Otago, Dunedin, New Zealand); János Lichtenberger (Eötvös University, Budapest, Hungary); Jacob Bortnik (University of California, Los Angeles, USA); Jyrki Manninen (Sodankylä Geophysical Observatory, Sodankylä, Finland); Yoshiharu Omura (Kyoto University, Kyoto, Japan); David Shklyar (Institute of Space Research, Moscow, Russia); Ondřej Santolík (Institute of Atmospheric Physics and Charles University, Prague, Czech Republic); and Jean-Pierre Raulin (Mackenzie Presbyterian University, São Paulo, Brazil). The Local Organising Committee consisted of staff from the Physics Department, University of Otago, including Neil R. Thomson, Ian Whittaker, Aaron Hendry, Kathy Cresswell-Moorcock, and Jason Neal. It was chaired by Craig J. Rodger, with János Lichtenberger as a non-local advisory member.

Figure 1. The VERSIM 2014 conference picture outside the University of Otago clocktower building.

Figure 2. Israel Silber of Tel Aviv University (Israel) was nominated for the IAGA Young Scientist Award, having given the best presentation by an early-career researcher.

Participants

The workshop attracted 35 participants from 14 countries, ranging from New Zealand to Finland (ordered by latitude). It included 10 students/early career researchers (aged under 35) from seven countries Figure 1. The list of participants and the scientific program can be downloaded from the conference Web site.

Abstracts and Sessions

58 abstracts were received. They are listed online on the Abstract and Programme Book on the conference Web site. The Scientific Program Committee organized these into 3.5 days of oral sessions, consisting of 46 presentations (including six invited presentations), and a poster session with 12 posters.

Scientific Highlights

VERSIM workshops are now a strong feature of the VERSIM community, and are well supported by the membership with many very strong presentations. We were particularly excited to have participation of so many colleagues from the United States and India at the 2014 workshop. Our invited speakers covered the following topics:

- Initial results from the electric- and magnetic-field instrument suite and integrated science (EMFISIS) on the Van Allen probes (Craig Kletzing, USA)
- "Generation Mechanism of Whistler-Mode Chorus Emissions" (Yoshiharu Omura, Japan)
- Height and sharpness of the ceiling of the Earth-ionosphere waveguide (Neil Thomson, New Zealand)
- Measurements and implications of the source altitude of terrestrial gamma-ray flashes (Steven Cummer, USA)
- Energetic electron precipitation from inside and outside of the plasmasphere during space weather events (Mark Clilverd, UK)
- The physics of lightning-induced electron precipitation (LEP) (Michael Rycroft, UK)

A number of cutting-edge presentations occurred, including frequent use of observations from NASA's Van Allen probes, the first observations of Transient Luminous Emissions in India, evidence of anti-matter produced in lightning discharges, and a link between whistler-mode wave electron precipitation and polar surface climate.

Figure 3. The VERSIM 2014 participants watch seals during the conference excursion (we also saw two types of penguins, as well as an extremely large sea lion).

Figure 4. Enjoying the conference meal at the Orokonui Ecosanctuary.

The Scientific Program Committee nominated Israel Silber of Tel Aviv University (Israel) Figure 2 for an IAGA Young Scientist Award on the basis of his presentation, "Links Between Mesopause Temperatures and Ground Based VLF Narrowband Radio Signals."

URSI Financial Support

URSI Commissions H and G provided EUR2000 to support our meeting. This was primarily used to support the registration and accommodation costs of participants from developing countries and/or early career scientists, who also enjoyed a subsided registration fee. This allowed all early-career scientists to participate in all the aspects of the workshop program, both scientific and social. As part of our social program, we took a harbor cruise to the heads Otago Peninsula, to see some of the local wildlife, and visited a local penguin and seal colony Figure 3. The conference dinner took place at the Orokonui Ecosanctuary Figure 4, with all participants able to attend, and many bringing guests.

Next Workshop

Two bids were received to host the next workshop, from the Indian Institute of Geomagnetism putting forward Mumbai, and the South African National Space Agency putting forward Hermanus. These colleagues are now preparing additional information on their offers, such that a final decision can be made as to the location and timing of the 7th VERSIM Workshop.

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URSI CONFERENCE CALENDAR

May 2014

EMC'2014 - 2014 International Symposium on Electromagnetic Compatibility
Tokyo, Japan, 13-26 May 2014
Contact: E-mail: emc14-contact@mail.ieice.org, http://www.ieice.org/~emc14/

June 2014

EUSAR 2014 – 10th European Conference on Synthetic Aperture Radar
Berlin, Germany, 2-6 June 2014
Contact: Mr. Jens Fischer (DLR), EUSAR 2014 Executive, Oberpfaffenhofen, 82234 Wessling, Germany, Fax: +49 8153-28-1449, E-mail: eusar2014@dlr.de, http://conference.vde.com/eusar/2014

August 2014

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

ICEAA 2014 - International Conference on Electromagnetics in Advanced Applications
Palm Beach, Aruba, 3-9 August 2014
Contact: Prof. P.L.E. Uslenghi, Dept. of ECE (MC 154), University of Illinois at Chicago, 851 So. Morgan St., Chicago, IL 60607-7053, USA, E-mail: uslenghi@uic.edu, http://www.iceaa.net/

URSI GASS 2014 - XXXIst General Assembly and Scientific Symposium of the International Union of Radio Science
Beijing, China CIE, 16-23 August 2014
Contact: URSI Secretariat, Sint-Pietersnieuwstraat 4, B-9000 Ghent, Belgium, E-mail: info@ursi.org, http://www.chinaursigass.com and http://www.ursi.org

Metamaterials 2014 - Eight International Congress on Advances Electromagnetic Materials in Microwaves and Optics
Copenhagen, Denmark, 25-28 August 2014
Contact: Prof. R.W. ZIOLKOWSKI, Dept. of Electrical and Computer Engineering, University of Arizona, 1230 E. Speedway Blvd., Tucson, AZ 85721-0104, USA, Fax : +1 520 621-8076, E-mail : ziolkowski@ece.arizona.edu http://congress2014.metamorphose-vi.org

September 2014

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

October 2014

RADAR 2014 - International Radar Conference 2014 - "Catching the invisible"
Lille, France, 13-17 October 2014
Contact: Ms. Monique DECHAMBRE, LATMOS, Quartier des Garennes 11, Bd des Garennes F 78280 Guyancourt, France, monique.dechambre@latmos.ipsl.fr and exporadar2014@see.asso.fr
http://www.radar2014.org

November 2014

APMC 2014 – Asia-Pacific Microwave Conference
Sendai, Japan, 4-7 November 2014
Contacts: Prof. Noriharu Suematsu [Chair, Steering Committee] c/o Real Communications Corp., 3F Shinmatsudo S bldg., 1-409 Shinmatsudo, Matsudo 270-0034, Japan, Fax: +81-47-309-3617, E-mail: 2014secrt@apmc2014.org, http://apmc2014.org/

November 2014

APMC 2014 – Asia-Pacific Microwave Conference
Sendai, Japan, 4-7 November 2014
Contacts: Prof. Noriharu Suematsu [Chair, Steering Committee] c/o Real Communications Corp., 3F Shinmatsudo S bldg., 1-409 Shinmatsudo, Matsudo 270-0034, Japan, Fax: +81-47-309-3617, E-mail: 2014secrt@apmc2014.org
http://apmc2014.org/

January 2015

International Conference on Foundations and Frontiers of Computer, Electrical Engineering : commemorating 150 years of Maxwell's Equations
Hooghly, Westa Bengal, India, 9-10 January 2015
Contact: Prof. B.N. Biswas, Sir J.C. Bose School of Engineering, Supreme Knowledge Foundation Group of Institutions, 1, Khan Road, Mankundu, Hooghly-712139, West Bengal, India

May 2015

URSI Mid-Atlantic Meeting 2015
ExpoMeloneras Convention Centre, 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

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

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