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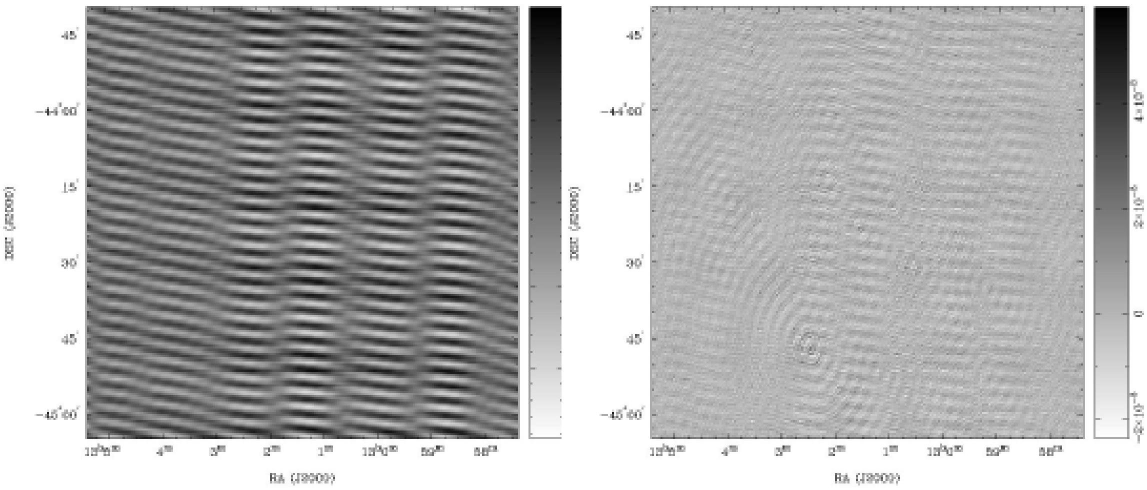

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Contents

Front cover: Radio-astronomy images of an area of the sky containing a few weak point sources. The image on the left is the raw, unfiltered data. It is so comtaminated by radio-frequency interference (RFI) that only the interference can be seen. The image on the right shows the point sources as concentric circles, visible after RFI-mitigation filtering techniques have been applied. A reduction by two orders of magnitude in the rms noise of the unfiltered data has been achieved. See the paper by M. Kesteven.

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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

It is with great sadness that I report that as this issue was going to press, we learned of the death on September 3, 2007, of Dr. A. P. Mitra. Dr. Mitra was an outstanding radio scientist, and a true champion of radio science. He spent much of his career fostering and enabling radio science in developing countries, and helping younger radio scientists. Of course, he was a past President of URSI and an Honorary President of URSI. We will have a proper remembrance of Dr. Mitra's life and work in a subsequent issue.

Our Papers

In his invited *Review of Radio Science* paper from Commission J, Michael Kesteven reviews the status of techniques for mitigating radio-frequency interference (RFI) for radio astronomy. There are two simple reasons why such mitigation is needed. First, radio-astronomy techniques have become much more sensitive over time. Second, the amount of RFI present in the environment has dramatically increased with time. The latter is due both to the tremendous increase in the number of devices using wireless communications, and to the amount and portions of the spectrum used by these devices.

The paper first looks at the effects of RIF on radio astronomy, and points out that there are some self-mitigating factors associated with the nature of the data and the data-processing algorithms used in radio astronomy. The paper then takes an in-depth look at proactive RIF mitigation strategies. These include regulation, the establishment of radio quiet zones, and controlling the observatory environment. Reactive mitigation techniques are subsequently considered. These include an array of methods associated with recording and processing the radio-astronomy data. The paper concludes with an examination of approaches that should be considered for next-generation radio telescopes.

The efforts of Ray Norris, the Associate Editor for Commission J, and Phil Wilkinson in bringing us this paper are gratefully acknowledged.

Our second paper is an interesting examination of the propagation of current along quasi-periodic thin-wire structures. Such structures play several important roles in electromagnetics. They can be used to build antennas and filters, and very-high-power short-pulse sources for applications such as high-power microwave devices. Such periodic transmission-line structures are also used to design metamaterials. The authors, Jürgen Nitsch and Sergey Tkachenko, have included a fair amount of review and tutorial information in this paper, in order to make it adequately self-contained to be easily read. However, there are two elements that differentiate the results presented in this paper. First, the structures considered are quasi-periodic: they are periodic structures consisting of a finite number of identical sections, rather than being infinite. Second, the treatment in this paper specifically includes the effects of losses, including those due to radiation, ohmic losses, and dielectric losses. The approach used is to generalize the Full-Wave Transmission-Line Theory (FWTL) to include losses. The authors are able to derive analytical expressions for the global parameters of the FWTL, and to thereby reduce the equations to a second-order differential equation that is similar to the Schrödinger equation. This both permits well-established mathematical methods to be used to obtain solutions, and also allows some interesting parallels to quantum-mechanical systems to be drawn. The authors then use this theory to analyze propagation along quasi-periodic wiring structures. This leads to a number of interesting results, including an investigation of allowed and forbidden frequency zones associated with such structures. A numerical example is presented to illustrate several of the effects.

In his Radio-Frequency Radiation Safety and Health column, Jim Lin looks at some interesting new results related to the effects of electric, magnetic, and combined fields associated with high-voltage power-transmission lines on dairy cattle. There definitely appear to be effects. However, it is unclear if these effects can be separately associated with electric fields or magnetic fields. It is interesting that some of the effects appear to be beneficial.

We Need Your Papers!

We continue to have good input of *Reviews of Radio Science* papers from many of the URSI Commissions, and we will be bringing you the papers associated with the Tutorial and General Lectures from the General Assembly. However, in the last few months we have seen a reduction in the number of submitted papers. Please consider submitting a paper to the *Radio Science Bulletin*. If you have a paper on a topic that is likely to be of interest to radio scientists in general, this *Bulletin* is an excellent method of reaching them. We are able to publish papers with no delay other than the time required for peer review (and any resulting revision), and we have no page charges. Our papers are also abstracted and indexed in INSPEC, so your paper should be found by anyone searching within the field.

If you have a paper, please send it to me (submission as a PDF for review purposes is fine). If you hear an interesting presentation at a conference that you think would make a good contribution to the *Bulletin*, please urge the author to submit it to the *Bulletin*.

The XXIX General Assembly of URSI

Once again, I'll remind you that the triennial XXIX General Assembly of URSI will be held in Chicago, Illinois, USA, August 7-16, 2008. The call for papers appears in this issue. The deadline for submissions is January 31, 2008. The Web site should be open for accepting submissions by the time you receive this issue:

http://www.ece.uic.edu/2008ursiga

All radio scientists are welcome to submit papers to the General Assembly. This is your once-every-three-year chance to share your work with the preeminent radio scientists from all over the world. Also, in addition to the Young Scientist awards, this General Assembly will have an extensive Student Paper Competition. Details, application, and submission information are available for all of these on the Web site. Make your plans now to be a part of this important event.

URSI Honorary President Dr. A.P. Mitra passed away

Dr. A. P. Mitra (Ashesh Prosad Mitra) passed away in the early hours of September 3, 2007 in New Delhi at the age of eighty-one. Dr. Mitra was former Director General of CSIR and Secretary, DSIR (1986-91). Earlier he was the Director, National Physical Laboratory (1982-86).

Dr Mitra was born in Calcutta on February 21, 1927. He was a brilliant student all through his education career. After passing M.Sc. in Physics from University of Kolkata, he joined Prof S. K. Mitra, the doyen of ionospheric research in India, for D.Phil. degree at a time that was considered the golden era of Indian ionospheric science.

During the last decade, Dr. Mitra had concentrated on global environmental changes from human activities and their consequent impacts on biosphere. Dr Mitra has led the investigating teams of several international and national global change related programmes.

Dr. Mitra was a recipient of *SS Bhatnagar Award* in 1968. In recognition of his eminent contributions, the Government of India had conferred on him the *Padma Bhushan award* in 1989. He was a Fellow of all three Academies of India, a 'Fellow of the Royal Society (FRS)' and 'Fellow of Third World Academy of Sciences (TWAS)' and of the International Academy of Astronautics and Past President of the National Academy of Sciences. He was Vice-President of URSI during 1981-84, URSI President during 1984-87 and 'Honorary President' of URSI since 2002. Dr. Mitra was an URSI Representative at IGPB (the International Geosphere-Biosphere Programme) and Chairman of the Standing Committee on Developing Countries.

In April of this year Dr. Mitra was invited to the Strategy meeting to discuss the development of radio science in developing countries with the members of the Coordinating Committee. He then announced the establishment of the "Regional Centre on Radio Science" in New Delhi. Dr. Mitra suggested improving URSI relations in the African region and involving URSI in the Global Change program.

He has over 200 research publications and a number of books to his credit and guided over 20 Ph.D. students.

Dr. Mitra is survived by his wife, Mrs Sunanda Mitra and two daughters and two granddaughters.

A more detailed obituary will be published in the December issue of the Radio Science Bulletin.

XXIX General Assembly of the International Union of Radio Science Union Radio Scientifique Internationale (URSI)

August 07-16, 2008
Hyatt Regency Chicago Hotel on the Riverwalk
151 East Wacker Drive, Chicago, Illinois 60601, USA

Call for Papers

The XXIX General Assembly of the International Union of Radio Science (Union Radio Scientifique Internationale-URSI) will be held at the Hyatt Regency Chicago Hotel in downtown Chicago, Illinois, USA on August 07-16, 2008.

The XXIX General Assembly will have a scientific program organized around the ten Commissions of URSI and consisting of plenary lectures, public lectures, tutorials, invited and contributed papers. In addition, there will be workshops, short courses, special programs for young scientists and graduate students, programs for accompanying persons, and industrial exhibits. More than 1,500 scientists from more than fifty countries are expected to participate in the Assembly. The detailed program, link to electronic submission site, registration form and hotel information will be available on the General Assembly Web site:

www.ece.uic.edu/2008ursiga

Submissions: All contributions must be submitted electronically via the link provided on the General Assembly Web site. The site will open in July 2007 and will close on January 31, 2008.

Submission Deadline: January 31, 2008.

Authors Notification: Authors will be notified of the disposition of their submissions by March 31, 2008. Accepted contributions will be scheduled for either oral or poster presentation.

Contact: For any questions related to the XXIX General Assembly, please contact the Chair of the Local Organizing Committee:

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XXIX General Assembly of URSI, Chicago, Illinois, USA – August 07-16, 2008

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UNION RADIO-SCIENTIFIQUE INTERNATIONALE

INTERNATIONAL UNION OF RADIO SCIENCE

AWARDS FOR YOUNG SCIENTISTS

CONDITIONS

A limited number of awards are available to assist young scientists from both developed and developing countries to attend the General Assembly of URSI.

To qualify for an award the applicant:

1. must be less than 35 years old on September 1 of the year of the URSI General Assembly;
2. should have a paper, of which he or she is the principal author, submitted and accepted for oral or poster presentation at a regular session of the General Assembly.

Applicants should also be interested in promoting contacts between developed and developing countries. Applicants from all over the world are welcome, also from regions that do not (yet) belong to URSI. All successful applicants are expected to participate fully in the scientific activities of the General Assembly. They will receive free registration, and financial support for board and lodging at the General Assembly. A basic accommodation is provided by the assembly organizers permitting the Young Scientists from around the world to collaborate and interact. Young scientists may arrange alternative accommodation, but such arrangements are entirely at their own expense. Limited funds will also be available as a contribution to the travel costs of young scientists from developing countries.

All Young Scientists should apply via the web-based form which will appear when they check "Young Scientist paper" at the time they submit their paper. All Young Scientists must submit their paper(s) and this application together with a CV and a list of publications in PDF format to the GA submission Web site.

Applications will be assessed by the URSI Young Scientist Committee taking account of the national ranking of the application and the technical evaluation of the abstract by the relevant URSI Commission. Awards will be announced on the URSI Web site in April 2008.

For more information about URSI, the General Assembly and the activities of URSI Commissions, please look at the URSI Web site at: http://www.ursi.org. If the information you are looking for is not on this site, please contact:

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APPLICATION FOR AN URSI YOUNG SCIENTIST AWARD

I wish to apply for an award to attend the XXIXth General Assembly of the International Union of Radio Science in Chicago, Illinois, USA, on 9-16 August 2008.

Name: Prof./Dr./Mr./Mrs./Ms. ....

Family Name First Name Middle Initials

Sex: male / female

Nationality: ....

Studying/Employed at: ....

Institution ....

Department...

Mailing address: Please send all correspondence to my ☐ business / ☐ home address, i.e.

Street ....

City and postal code ....

Province/State .... Country ....

Fax .... E-mail ....

Academic qualifications, with date(s) obtained: ....

....

Title of abstract submitted: ....

....

Type of session preferred: ☐ in an oral session ☐ in a poster session

The subject of the paper is relevant to URSI Commission ……….session (leave blank if uncertain).

I hereby certify that I will be less than 35 years old on September 1, 2008.

Date:............................ Signed: ....

For applicants from developing countries only:
I estimate the cheapest return fare to the URSI meeting is EURO...

Radio-Frequency Interference Mitigation in Radio Astronomy

M. Kesteven

Abstract

Radio-frequency interference (RFI) is an increasing problem for radio astronomy, given the ever-expanding use of the radio spectrum by both the communications industry (transmitting) and the radio astronomers (receiving). Regulation can protect a few windows in the radio spectrum, but many experiments now need to access parts of the spectrum outside the reserved regions. For example, spectral lines may be significantly Doppler shifted, and therefore require an observation window far from their rest frequencies.

A variety of RFI-mitigation techniques has been developed in recent years. Most of these have analogs in other disciplines, but the specifics of the radio astronomers' experiments allow for some interesting refinements. As a rule, the astronomer is not interested in recovering a symbol stream in the data, seeking instead a more general description of the statistics. In this context, a number of post-correlation techniques become valuable and computationally viable.

Introduction

The radio astronomer's spectral domain for investigating the cosmos extends from a few MHz to a few THz. Much of this region is shared with the communications industry, with the multiplicity of transmissions critical to modern society. What is signal to a consumer may be interference to the radio astronomer. Every use of the radio-frequency spectrum – broadcast radio and TV, cell phones, communication satellites, navigation satellites, as well as all the wireless control and monitoring systems – has the potential to affect a radio-astronomical observation. It is the radio astronomical equivalent of light pollution, which is a problem for optical astronomers: the background against which the radio astronomer makes observations is no longer dark.

The basic radio telescope is a large-diameter steerable antenna equipped with very sensitive, low-noise receivers. The 100 m GBT [1] and the Parkes 64 m [2] are among the best examples at the present time. Their task is to map and monitor faint sources of radiation. To give an indication of the signal strengths in question, consider the unit of the field flux density: one jansky is 10^{-26} watts/m^2/Hz in magnitude. (This unit honors Karl Guthe Jansky, the father of radio astronomy. He was an engineer with Bell Labs who discovered radio frequency radiation from the Milky Way in 1931, while investigating interference that affected radio-telephone services.)

A number of observatories operate synthesis radio telescopes. These consist of a number of antennas operating in a phased-mode array: the conversion chains in all the antennas are locked to a common frequency standard, and the data-transmission paths from the antenna to the central site are carefully calibrated for delay. A synthesis telescope is an imaging device: it measures the correlation properties of the wavefront from a distant astronomical target, and derives the image after a data transformation. Sensitivities down to the mJy level are now a routine expectation.

The next generation of radio telescopes now in the planning stages (for example, SKA [3]) will have large collecting areas and wide bandwidths. Unless adequate mitigation strategies can be implemented, they will suffer from radio-frequency interference.

The days of interference-free observations in radio astronomy are long gone. Increasingly, experiments such as the search for Doppler-shifted spectral lines will need to be made outside the bands allocated to radio astronomy. There are also substantial pressures from commercial, defense, and other interests for greater access to the radio-frequency spectrum. This means that radio astronomers can no longer rely on the regulatory authorities for an environment free from interference, and must look seriously at mitigation strategies.

RFI mitigation is a well established discipline in other areas (see, for example, Ghose [4]), but it is relatively recent in radio astronomy. This paper presents an overview of some recent developments in RFI mitigation designed for the radio astronomer.

Michael Kesteven is with the Australia Telescope National Facility, CSIRO; E-mail: michael.kesteven@csiro.au.

This is one of the invited *Reviews of Radio Science* from Commission J.

2. Why has Mitigation Become Necessary?

Astronomers now have to take RFI mitigation seriously because of a conjunction of a number of factors:

1. Telescopes are becoming ever more sensitive. Their threshold for detecting unwanted signals is also moving to fainter levels, exposing the telescopes to greater numbers of RFI sources.
2. More-sensitive telescopes create the challenge that every field of view of the telescope will contain more detectable objects, putting pressure on the image quality. If the dynamic range in the imaging is compromised by RFI, then the faint objects will be blurred, confused, or missed.
3. Better, more-sensitive telescopes mean that astronomers' experiments become more challenging, exploring a wider range of the spectrum with wider instantaneous bandwidths.
4. The commercial use of the spectrum is increasing as well, causing more RFI.

3. The Impact of RFI on the Radio Astronomer

Most modern radio telescopes consist of arrays of antennas (VLA [5], ATCA [6], SKA [3], LOFAR [7]). These are imaging arrays that exploit the van Cittert-Zernicke theorem to synthesize apertures comparable to the array's extent. For each antenna pair, the astronomer measures the correlation function:

$$C_{i,j}(t)=\frac{1}{T}\int_{t-T/2}^{t+T/2} V_i(\tau)V_j^*(\tau)\,d\tau ,$$

where $V_i(t)$ is the receiver voltage output. Each data point has a coordinate **u**, defined by the geometry of the observation (the direction to the target, and the location of antennas *i* and *j*).

At each integration, an array consisting of N antennas will measure $N(N-1)/2$ different samples of this correlation function. As the Earth rotates, the array's orientation to the astronomical target will change, providing a steady stream of fresh samples. At the end of the observation, the astronomer will have collected a large number of samples of the correlation function, $C(\mathbf{u})$.

The van Cittert-Zernicke theorem relates the image (the brightness distribution on the sky) to the correlation function, $C(\mathbf{u})$:

$$B(\xi)=\int_{-\infty}^{\infty} C(\mathbf{u})e^{-2\pi(\mathbf{u}\xi)}d\mathbf{u} .$$

The quality of the image reconstruction is set by the quality of the sampling: ideally, it should be closely and evenly distributed over as large an area as possible.

RFI corrupts this process in several ways:

- RFI that is coherent over parts of the array can generate statistically significant visibilities that lead to artifacts in the image when processed by the imaging machinery.
- Most observations include a regular sequence of calibration observations. These are critical to the quality of the imaging, and it is probably here that RFI-mitigation is most important: each calibration observation is of short duration, so that a burst of RFI could compromise the calibration, compromising all the data that depends on that calibration.
- Strong local RFI that is not coherent over the array may still play an unwelcome role. Antennas subject to the RFI have, in effect, a high system noise, which reduces the signal-to-noise of astronomy data.

3.1 Some Intrinsic Mitigating Factors

Signal-processing and astronomical communities both deal with weak signals, but they differ in their requirements. The communication world expects to recover the underlying symbol stream, whereas the astronomer is searching for a statistical characterization of the data: the spectral power density, for example. A communications engineer could reduce the bit rate, could employ error-correcting codes, or could exploit correlation techniques to extract feeble signals in a noisy environment. There is indeed a powerful armory of techniques available, but in general these are not workable in the astronomer's world.

The nature of the data, and the data processing algorithms used in radio astronomy are such that there are a number of options available to the radio astronomer that would probably not be suitable elsewhere. To give one simple example, in some cases, it is not out of the question to blank the receiving system when the RFI exceeds a given threshold. The outcome will not be as good as in the RFI-free case, because there could be a reduction in signal-to-noise ratio, and possibly a reduction in the imaging fidelity, but the science goals could still be achievable.

A synthesis array does have some built-in immunity to RFI that relates to the way it operates. During an observation, the signal paths from the antennas to the central site are continuously adjusted in phase and delay, so that a wavefront from the astronomical target is coherent at the correlator: the IF voltages are aligned in phase over the received bandwidth, and the signal-to-noise ratio of the co-added signal is maximized. The delay and phase settings are set by the array geometry and the direction to the target. Signals from a direction that differs from the astronomical target will not be phase aligned, and their co-added sum will be reduced. This will reduce the impact of the RFI. The reduction increases with the number of antennas in the array, and with the length of the observation (see Thompson [8]). Future antenna arrays have an advantage here, with greater numbers of antennas, and with longer baselines.

In addition, in modern telescope arrays that tend to be spread out over large distances, the RFI is likely to be local to just a subset of the array's antennas.

3.2 Single-Antenna Radio Telescopes

Large-aperture antennas, such as the GBT [1], still have an important role to play in radio astronomy. These telescopes are more at risk from RFI (compared to the telescope arrays), as they have fewer natural defenses. Any RFI within the observing pass band is a problem, as it is in direct competition with the radio-astronomical signals of interest.

4. Mitigation Strategies

A wide range of strategies is available to the astronomer:

- Avoidance: The astronomer could look for bands free from RFI; the astronomer could timeshare with the RFI if the RFI is not continuous.
- Regulation and legislation: The astronomer could appeal to the authorities to provide spectral bands or geographical regions that are free from RFI.
- The astronomer could take steps to remove the RFI from the data: with blanking (deleting contaminated data), or canceling (removing the RFI, while leaving the astronomical data unaffected). Substantial progress has been made in recent times in both refining the techniques as well as in understanding the strengths and limitations of these techniques. Reviews of the techniques include Fridman and Baan [9], Briggs and Kocz [10], and Ellingson [11].

5. Proactive Mitigation Strategies

Proactive strategies provide the best defense of all, keeping the spectrum clean by removing the sources of RFI.

5.1 Regulation

Through the International Telecommunication Union (ITU-R), the international community has made substantial efforts to balance the needs of the community for all forms of wireless communication with the requests of the radio astronomers for reserved spectral bands. The ITU-R Recommendation ITU-R RA-769 [12] outlines the protection criteria and defines the harmful limits. The CRAF *Handbook for Radio Astronomy* (Cohen [13]) provides an excellent discussion of the details. See also the ITU *Handbook on Radio Astronomy* [14].

5.2 Radio Quiet Zones

A number of observatories are located in radio quiet regions, where local topography provides some protection from RFI. The NRAO Green Bank Observatory is in a shielded valley in West Virginia, USA; the DRAO Penticton observatory is in a protected valley in British Columbia, Canada.

Further protection has been provided by some national licensing authorities, who have declared "Radio Quiet Zones" around specific observatories. The National Radio Quiet Zone was established in 1958 for the Green Bank Observatory (see NRQZ [15]). The Australian government has taken similar steps to protect the Radio Astronomy Park set up by the state government of Western Australia.

This strategy can provide no protection from satellite downlinks, nor from airborne radar.

5.3 The Observatory Environment

Bitter experience has shown that observatories themselves are responsible for a significant fraction of the RFI. Sources include modern computers and high-speed electronics within observatory receiver systems. Remedies include eternal vigilance and aggressive monitoring of all new equipment for sound design and RFI-containment practices. For example, the correlators at the Parkes observatory are housed in RFI-tight cabinets with a high RFI-attenuation rating (≥ 95 dB). The main control complex at Green Bank has extensive RFI shielding. The Penticton observatory has RFI shielding around the entire main office; further, most of the computers are housed in a screened room within the main building.

5.4 Summary

Many observatories still operate satisfactorily with these proactive strategies: they can find satisfactorily clean spectral bands for their observations, and they can find suitable quiet times. Few observatories have found it necessary to provide online RFI-cancellation procedures.

There is mounting evidence that the conditions are changing for the worse: there is more RFI; experiments are more challenging, with less tolerance to RFI; and telescopes are becoming ever more sensitive. Some low-frequency cosmological experiments can already only be performed in the newly defined radio quiet zones: for example, see the discussion in Chippendale [16].

6. Reactive Mitigation Strategies

In *reactive* RFI mitigation, we identify the RFI in the data stream and remove it, so that the subsequent processing machinery is presented with RFI-free data. This ideal is rarely achieved, but substantial progress has been made.

6.1 Robust Receivers

In everything that follows, there is an underlying assumption that the receiver's response is linear. This puts a requirement on the receiver designers to provide adequate reserve against overloading [17-19].

6.2 Notation and Definitions

Let $V(t)$ be the signal from a radio telescope. It is confined to a bandwidth, B, centered on a frequency f_c.

$$V(t) = V_{sys}(t) + V_{ast}(t) + V_{rfi}(t),$$

where $V_{sys}(t)$ is the noise contribution from the receiving system, $V_{ast}(t)$ is the astronomy signal of interest, and $V_{rfi}(t)$ is the RFI.

One class of RFI mitigation operates by determining the RFI-free condition. It then becomes possible to identify the times when RFI is present, and to take remedial action: blanking, for example. This may have an astronomical cost: a reduction in the number of independent samples available for processing will reduce the sensitivity, and it may also reduce the image quality.

An alternative approach is to target the RFI explicitly and cancel it, removing just the $V_{rfi}(t)$ from the data stream. In principle, this is the preferred path, as there should be no reduction in the number of astronomical data points.

6.3 RFI Blanking in Time or Frequency

The technical demands are substantial: astronomers inevitably wish to use as much bandwidth as the processing electronics can support. Bandwidths of several hundred MHz are common in the centimeter-class bands, where RFI is most likely to occur. As a result, the processor will need to operate on digitized data streams with several hundred Msamples/sec.

The process does compromise the astronomical data, since we blank V_{sys} and V_{ast} as well as V_{rfi}, so it is important to examine the balance sheet:

- Impulsive RFI is handled well. Large excursions are removed at a modest cost in the number of affected samples. This can be very cost effective, since the signal-to-noise ratio (SNR) is proportional to the square root of the integration time (i.e., the number of useful samples retained for processing).
- It would be a waste of time to attempt to blank continuous broadband RFI.
- Strong narrowband RFI may have an impact right across the spectrum if there are nonlinearities in the system, or if the processing results in frequency aliasing. Blanking in frequency is therefore of questionable value, unless care is taken with the processing that occurs ahead of the blanking: it requires a linear system, a digitizer with adequate sampling bits, and a spectrometer with well-defined spectral channels.

This is a two-stage procedure:

1. Characterize the statistical properties of the RFI-free data ($V_{sys} + V_{ast}$).
2. Samples that are inconsistent with these are assumed to be RFI and are blanked.

With modern digital processing, it is now possible to perform quite sophisticated blanking. The incoming data stream could be processed in blocks of samples, so that the noise characteristics could be derived on the fly; further, the blanking window could be tailored to remove low-level RFI that is known to accompany bursts of RFI (see, for example, Niamsuwan [20] and Ellingson [21]).

Of course, blanking can be applied to the telescopes in a radio telescope array. In this case, there is the further possibility of identifying the RFI that is coherent between antennas, thereby refining the process of identifying the RFI. Baan, Fridman and Millenaar [22] have described an impressive RFI mitigation machine installed on the Westerbork Array.

The effectiveness of this process is set by the interference-to-noise ratio (INR): that is, by the extent to which the RFI dominates the system noise. Since low-level RFI is in general not an issue, a graceful cutout at low INR is acceptable. However, some experiments require long integrations in order to detect weak objects, and it is here that low-level RFI could be a problem: it is too weak to excise, and it only shows up at the end of the experiment. The post-correlation techniques to be described in Section 6.8 address this question.

6.4 Blanking Post-Correlation Data: Flagging

Flagging is the traditional RFI-excision strategy, operating on the post-correlation data. Traditionally, it is also fearfully labor intensive [23]. It will be effective to the extent that the RFI is impulsive, so that useful RFI-free times can be identified. Algorithms have now been devised the can largely automate the procedure [24].

6.5 RFI Excision

A powerful set of cancellation schemes is available if the RFI signal ($V_{rfi}(t)$) can be identified. The identification key could be its location or its trajectory, its statistical properties, or its detailed properties.

A number of successful strategies operate in the post-correlation domain: in essence, within the imaging machinery. The substantial reduction in the computer load when compared to mitigation strategies operating on the raw data streams makes these very attractive options. In addition, they extend the effectiveness of the RFI mitigation to much lower ranges of INR [25].

6.6 Null Steering

Any phased array will have sidelobes and nulls in its reception pattern. This property has long been exploited (outside radio astronomy) to position the nulls on known sources of interference. Under some circumstances (anti-jamming, for example), with arrays explicitly designed to exploit this technique (regular antenna spacing), this can produce spectacular automatic adaptively adjusted nulling. The adaptive algorithms require high interference-to-noise ratios, and they work best if the array is set up to track a small number of specific target directions (in a beamforming mode).

Only one astronomical array (to date) has explored this technique: the Allen Telescope [26]. In order to avoid interference from satellites known to transmit in the observing band, the complex weights used in the beamformer will be adjusted to provide a null covering the RFI band in the direction of the satellite, while maintaining high gain in the direction of the target [27]. This null steering is critically dependent on an accurate calibration of the array (the receiver gains, delays, and phases), as the steering is done in "open-loop" mode.

Most modern radio telescope arrays operate in imaging mode, in which there is no beamformer; this precludes null steering in its standard mode. Nonetheless, recent work with adaptive filters has brought null-forming back: the filters cancel all the signals from the RFI direction, so the array is insensitive in that direction. The procedures described in the next sections demonstrate that the null steering is as broadband as the RFI, and is generally achieved without compromising the imaging properties of the main beam.

6.7 The Adaptive Filter

The canonical adaptive filter [28] is a powerful tool for removing RFI. It was introduced to the radio-astronomical community in 1998 [29]. The filter is able to remove RFI from a corrupted data channel once it is given an independent copy of the RFI. The filter will reduce the RFI in the astronomy IF (V^{RFI}) by a factor $\frac{1}{1+INR}$, where *INR* is the interference-to-noise ratio in the reference channel. In addition, a fraction of the reference channel's receiver noise will be added to the filter output. This will be equal in magnitude to $\frac{V^{RFI}}{\sqrt{1+INR}}$. To the astronomer, this will appear as a spectral echo of the RFI: it will have the same spectral distribution as the RFI, although it will be quite uncorrelated with the RFI. A long integration, the traditional method of improving the detectability of weak signals, will not remove the echo: it will simply reduce the noise in the baseline and in the echo. This class of filter can also play a role in telescope arrays, with the filter operating on the IF output from individual antennas. In this case, the spectral echo will not be a problem, because it will contain receiver noise that will not be coherent between antennas.

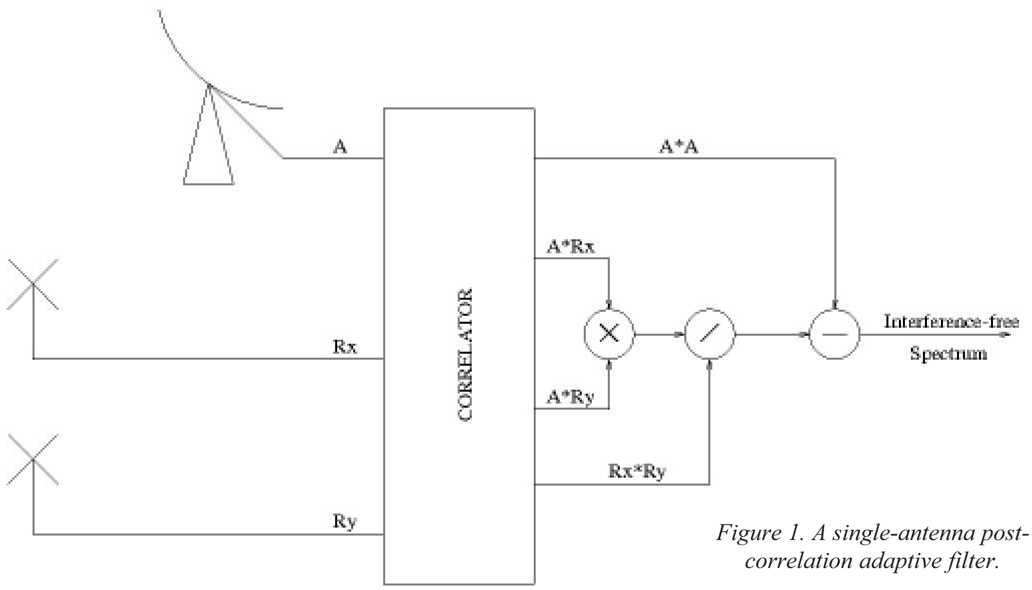

Figure 1. A single-antenna post-correlation adaptive filter.

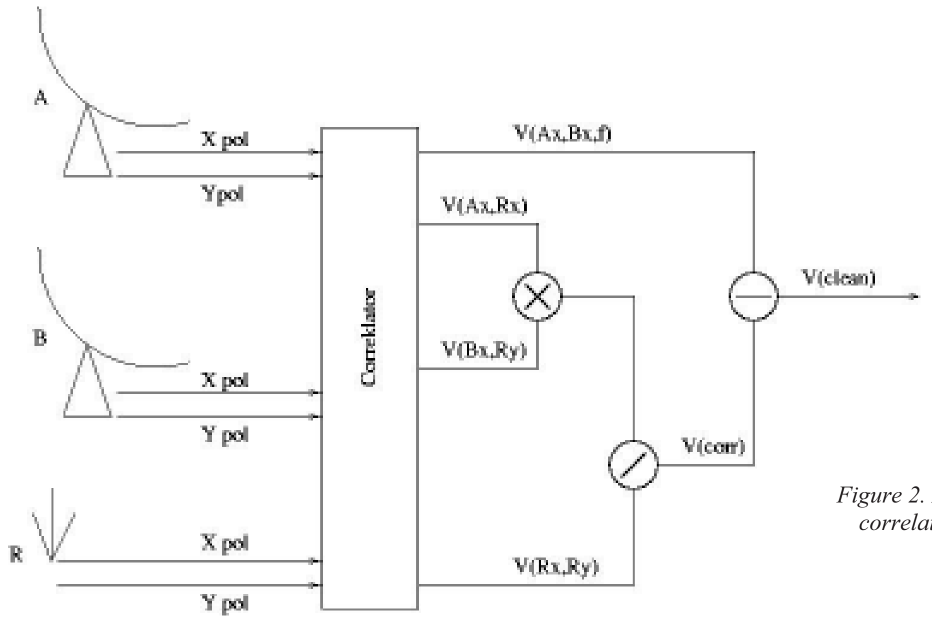

Figure 2. An array-based post-correlation adaptive filter.

The adaptive filter also has a valuable role to play in areas where the spectral distribution is not an issue: for example, in pulsar astronomy the filter is able to reduce the RFI's impact on the SNR, provided only that the RFI has no periodicities commensurate with the pulsar [30].

6.8 The Post-Correlation Adaptive Filter

An alternative design, the post-correlation adaptive filter [31], is shown in Figure 1. To the left of the correlator are three IF data streams. The top signal (*A*) is from the radio telescope. Under normal circumstances, this would be the signal sent to the astronomer's spectrometer. The signals *Rx* and *Ry* come from the reference antenna directed towards the source of interference. In the experiment described below, the interference came from a TV tower installed on a mountain about 50 km to the east of the observatory.

For each pair of signals, the correlator computes the spectral cross-correlation:

$$C_{i,j}(f) = \frac{1}{T}\int V_i(t,f)V_j^*(t,f)\,dt = \left\langle V_i(f)V_j^*(f)\right\rangle,$$

where *T* is the correlator integration time. The algorithm is outlined in Figure 1. The frequency resolution should be matched to the RFI: the channel width should be comparable to the independent spectral components of the RFI.

From the three cross spectra that contain a reference signal, we can estimate the contribution that the RFI makes to the observed spectrum:

$$C_{corr}(f) = \frac{\left\langle V_A V_{Rx}^*\right\rangle \left\langle V_{Ry} V_A^*\right\rangle}{\left\langle V_{Ry} V_{Rx}^*\right\rangle}.$$

The filter, in common with the hardware version, processes each spectral channel in isolation. This means that the filter can accommodate a number of different RFI sources, provided they have no frequency overlap.

There several assumptions underlying this scheme:

1. Only the RFI is common to both the reference antenna and the radio telescope. If the antennas also have some astronomy signals in common, then some level of astronomical cancellation will occur.

2. The algorithm is essentially neutral to changes in the power at the transmitter. It is not neutral to rapid changes in the level ratio $\frac{|V_A|}{|V_{Rx}|}$. The adaptive filter will follow changes as sidelobes of the radio telescope sweep over the source of the RFI, but the time scale of these changes should be long compared to the correlator integration time.

The estimate (C_{corr}) is statistically zero-mean, providing a distinct advantage over the hardware adaptive filter: cancellation with noise but no bias, as opposed to attenuation with noise. The two reference channels, *Rx* and *Ry*, provide copies of the RFI with independent receiver noise. This ensures that the cancellation has no bias. A single-channel model would require the receiver bandpass to be stable and known (calibrated) to high precision.

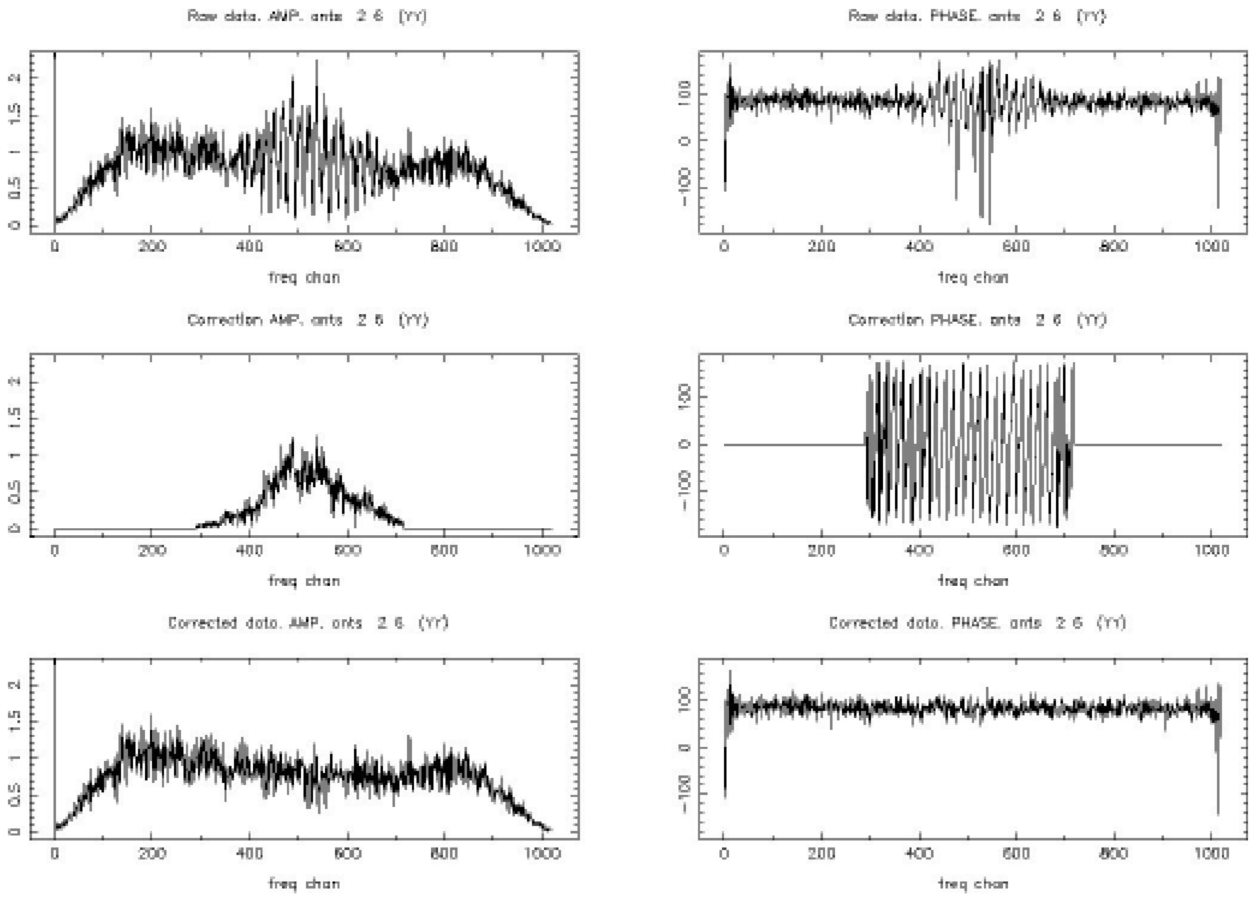

Figure 3. The filter in action on one baseline. The top row shows the raw data, amplitude and phase. The middle row shows the adaptive filter's estimate of the RFI for this baseline. The bottom row shows the baseline with RFI excised.

Furthermore, the filter continues to work well at low-INR levels. The real-time adaptive filter will cease to be effective when the INR approaches one, while the post-correlation filter can work to a level of –20 dB: because the operation takes place after the correlation and integration stage, a $\sqrt{(B\tau)}$ noise reduction takes place, and so the low-level RFI can be measured with some precision. The limiting factor is the integration time (τ). Although the time scale for antenna sidelobes to drift past the RFI is likely to be long, the real time scale is much smaller, as it is set by the propagation effects and changing multipath.

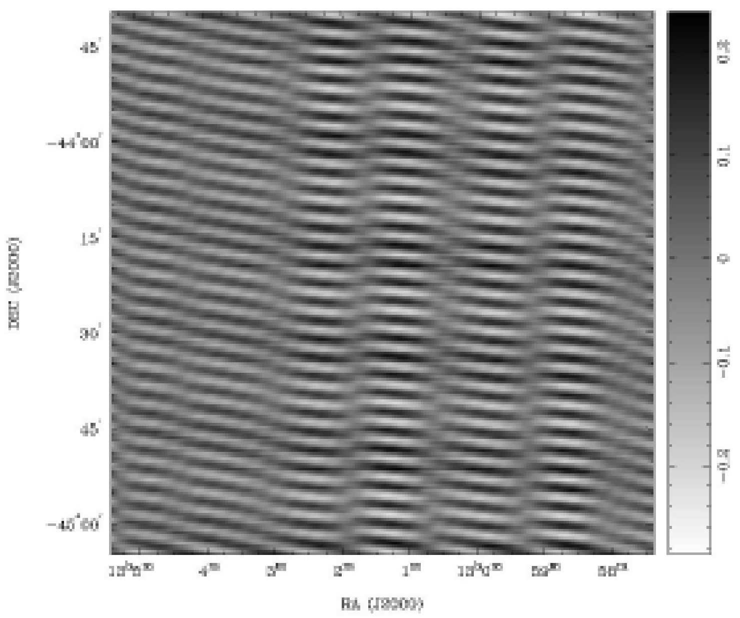

Figure 4. The image based on the raw, unfiltered data.

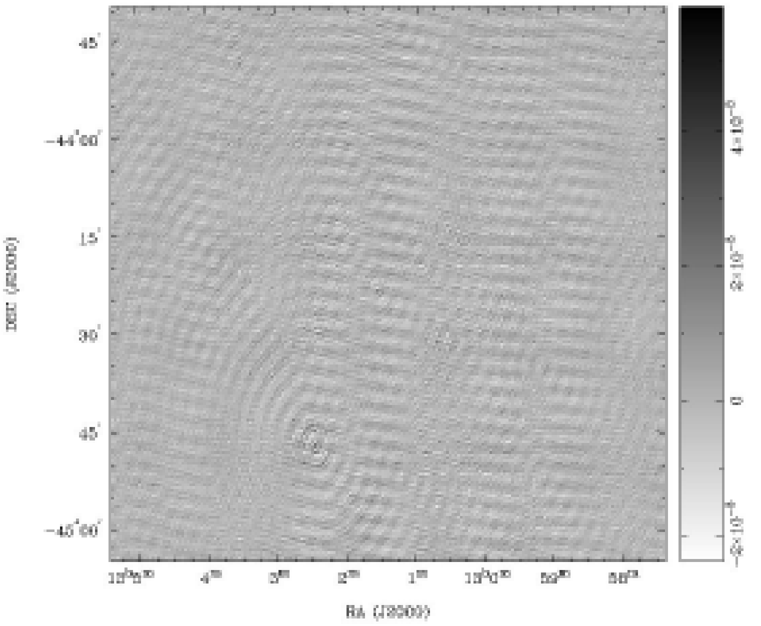

Figure 5. The image based on the filtered data.

This filter can be generalized to provide RFI mitigation in an array. The scheme is shown in Figure 2. Each antenna pair (baseline) is processed separately, and the "RFI-free" ensemble is passed to the calibration/imaging machinery. Figure 3 shows an example of the scheme in operation on one baseline.

A field trial of the technique used the six-antenna array of the ATCA at a frequency of 2.4 GHz and a bandwidth of 128 MHz. The data with their RFI contamination were collected over a 12-hour period. The target field was an almost blank patch of sky, containing just a few weak (mJy) sources. Figure 4 shows the result of imaging the raw data. The RFI overwhelmed the system. In effect, we "mapped" the RFI. The gray-scale wedge on the right shows that the system sensitivity was at best still several hundreds of times worse than needed to detect the known objects.

Figure 5 has the image from the filtered data. The field was essentially empty, but three or four weak sources can be seen. (Genuine point sources show the signature of the relatively sparse sampling in the **u** plane: a set of concentric circles). The rms noise in the image (the RFI) was reduced by two orders of magnitude.

This scheme works well, allowing imaging in the presence of severe RFI. Its main limitation is that it requires the location of the RFI to be known a priori so that the reference antenna(s) can be optimally directed to the source of the RFI. The RFI filtering requires only modest additional correlator resources, equivalent to adding one antenna to the array. The fractional increase for an array of N antennas amounts to $(N+1)/(N-1)$. It may have serious implications for the data rates, however: the time-varying delays inserted at each antenna to keep the astronomy signals fully coherent at the correlator are not the delays suitable for a stationary source of RFI. A long integration cycle in the correlator will attenuate the RFI (which is good), but will also prevent the adaptive filter from working effectively. The correlator integration time has to be smaller than the RFI decorrelation time. This is generally not a serious constraint at the frequencies most affected by RFI. Arrays operating at frequencies above 10 GHz, where the correlator integration times would be unacceptably small, are fortunately generally free of RFI.

6.9 RFI Mitigation in the Image Domain

Several groups have demonstrated that RFI can be identified and removed within the image-processing operation [32, 33]. The advantage is that there is then no need for a separate reference antenna that would provide the clean copy of the RFI. The distinguishing feature that identifies the RFI is the known movement of the RFI relative to the imaged sky. (In the VLA case [33], the target was stationary with respect to the array. A moving RFI source – a satellite, for example – could be accommodated in this formulation, provided that the trajectory were known with some precision).

6.10 Generalized Spatial Filtering

In the previous section, the RFI was identified by a spatial signature established at the imaging stage. A more general and elegant scheme has been described by Leshem et al. [34]. The basic idea is to exploit the fact that if the RFI is a problem, it must stand out. Noise from a receiver is generally white, uncorrelated from one sample to the next, and quite uncorrelated from one receiver to the next. RFI has a variety of correlations, in time and between antennas. Astronomy signals share these types of correlation, but at a lower level. Spatial filtering attempts to categorize the samples via the correlation properties, and to then discard the RFI.

Given an array of N antennas, we form the correlation matrix **R** over all $N(N+1)/2$ antenna combinations over some time interval τ . **R** describes the array's response to the astronomy within the field of view, to the RFI, and, along the diagonal, to the receiver noise. To the extent that the RFI is stronger than the astronomy component, an eigen decomposition will recover the RFI vector, so that a projection operation could remove the RFI.

RFI excision exacts a computing penalty, because the array's response to a point source varies over the field of view. However, the benefits of the better-defined procedure for identifying the RFI make this an attractive option.

7. RFI Mitigation for the Next Generation of Telescope Arrays (SKA)

It is clear that the SKA (the Square Kilometer Array [3]), an array of very many antennas, will present a substantial challenge to the software groups involved in calibration, imaging, and analysis. RFI mitigation is in danger of swamping that endeavor.

It is probable that with the next generation of telescope arrays, we will see a substantial paradigm shift in the handling of telescope data. To date, it has been possible to archive the raw data for subsequent processing (and reprocessing). For example, it has been possible to form optimal calibration solutions to the entire dataset, to identify and remove poor quality data, and to remove RFI, long after the data were obtained. This mode of operation will not be possible with the next generation of arrays, as the flood of data would overwhelm the archive system [35]. The next generation of large arrays (ASKAP [36] and meerKAT [37]) propose to adopt a one-pass, online pipeline, with the data processed on-the-fly. There is no possibility of revisiting the data: once it has been processed, it evaporates. This means that the RFI mitigation must also be done on-the-fly. The adaptive filters discussed earlier fit well to this model.

The array will consist of a number of "stations," each containing a number of antennas the signals form which will be combined in a small number of beamformers. The stations are distributed over large distances, so much of the ground-based RFI will be confined to one or two stations. This suggests that the RFI mitigation should parallel this architecture:

- A station-level mitigation to provide a RFI-cleaned output from the beamformer. This could involve wideband array nulling. A station-level correlator will be needed to provide the calibration needed for the beamformer, so much of the required machinery will already be in place. Recent work at the Allen telescope [27] suggests that this may entail substantial processing effort. Adaptive filtering within the beamformer output is another option.
- Post-correlation RFI filtering in the final processing stage will have to operate on the data as it floods past in the pipeline. The luxury of building up a model of the RFI is excluded.

The bottom line seems to be that RFI mitigation will be difficult. Without a doubt, the best strategy is to find a site that is free from RFI.

8. Conclusion

RFI mitigation is still in its infancy in radio astronomy. However, recent developments suggest that it will soon be installed online, and will become part of an observatory's standard routine. The computing effort is significant, but less daunting than other software components of a modern telescope array.

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Propagation of Current Waves Along Quasi-Periodic Thin-Wire Structures: Taking Radiation Losses into Account

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S.V. Tkachenko

Abstract

By applying Full-Wave Transmission-Line Theory [1-3], the problem of current propagation along a thin, nonuniform wire near to the ground can be reduced to a Schrödinger-like second-order differential equation. This type of equation has a "potential" that is dependent on both the geometry of the wire and the frequency. The "potential" is a complex-valued quantity that corresponds to either radiation losses in the framework of electrodynamics, or to the absorption of particles in the framework of quantum mechanics. If the wire structure is quasi-periodic, i.e., if it consists of a finite number of identical sections, the "potential" can be approximately represented as a set of periodically arranged identical potentials. We can then use the formalism of transfer matrices to find an analytical expression for the transmission coefficient that also contains the scattering data of one nonuniform section. The result obtained allows us to investigate the frequency zones, both forbidden and allowed, that are a typical feature of periodic structures.

1. Introduction

An analysis of the propagation of current waves along periodic structures in different radio-technical and electro-technical applications has become necessary. These periodic structures show non-trivial electrodynamic properties, and can sometimes be used to build filters, antennas, and HPM (high-power microwave) sources. Moreover, because of the simplicity of building periodic thin-wire structures, they can serve as elements for the design of metamaterials.

Periodic infinite structures have been studied in a number of papers [4, 5] from an electrodynamic point of view. However, in real life one deals with quasi-periodic systems: systems that consist of a finite number of identical sections.

In previous papers [6, 7], we investigated the propagation of current waves along a wire without any losses (radiation, ohmic, dielectric, etc.). We transformed the equations of nonuniform transmission-line theory (with coordinate-dependent inductance and capacitance per unit length) to a second-order differential equation for some auxiliary function, which was simply connected with the current. The equation looked like a typical one-dimensional Schrödinger equation in quantum mechanics, with a potential that could be calculated using the per-unit-length transmission-line parameters. The "potential" decayed to zero at plus and minus infinity, and the "energy" of the "particle" was positive (see Section 3). Thus, we dealt with a one-dimensional quantum-mechanical scattering problem [8], and could apply powerful and well-developed mathematical methods to investigate such problems. A quasi-periodic wiring system also has a quasi-periodic "potential." Using the formalism of the transfer matrix [9], we find an analytical expression for the transmission coefficient of the finite number of periodically located non-uniformities that also contains the scattering data for one non-uniformity. The absolute value of the transmission coefficient oscillates, depending on the frequency. This corresponds to forbidden and allowed frequency zones, which are typical for periodic structures [10].

However, the wiring systems that are usually used can have different kinds of losses: radiation losses, ohmic losses, and dielectric losses. In the present paper, we generalize the formalism [6, 7] for such systems. We consider quasi-periodic structures, which consist of a wire with finite conductivity coated by lossy dielectric insulation. For this type of system, radiation losses can become substantial at high frequencies, but the simple approach to a nonuniform transmission line as was used in [6] is not

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applicable. Instead, we have to apply a general Full-Wave Transmission-Line theory (FWTL) [1, 2, 3], which has to be modified for the case of dielectric and ohmic losses. In the second section, we start from the mixed-potential integral equations (MPIE) for the dielectrically coated wire with finite conductivity [11]. We use this mixed-potential integral equation and general techniques described in [12] to derive simple analytical expressions for the global parameters of the FWTL. Using the global parameters, the FWTL equations are reduced to a Schrödinger-like second-order differential equation in a simple way.

Section 2 partially provides already published material, and thereby serves to facilitate access to formulations of subsequent sections. In contrast to cases without radiation, dielectric, or ohmic losses, the "potential" in this Schrödinger-like equation is a complex-value. The explicit connection between the losses and the imaginary component of the potential is established at the beginning of the third section. Thereafter, we generalize the formalism of the transfer matrix for lossy systems, and derive an analytical expression for the transmission coefficient of the finite number of periodically located lossy non-uniformities. Then, the connection between the transformation parameters of quasi-periodic systems and parameters of corresponding periodic systems (quasi-pulse) is established.

In the fourth section, we consider a numerical example of the quasi-periodic line with radiation losses. It will be shown that the zone structure that exists in the lossless case also holds for the lossy case. Again, depending on the frequency, the absolute value of the total propagation coefficient through the chain oscillates. It corresponds to forbidden and allowed frequency zones. However, the radiation losses essentially attenuate the propagation coefficient through the chain for the allowed frequency zones.

In conclusion, we formulate some further problems for future investigations.

2. Full-Wave Transmission-Line (FWTL) Equations for the Wiring System with Losses: Iteration Approach for the Global Parameters

We consider a thin, dielectrically coated, finitely conducting wire of arbitrary geometric form, $\vec{r}(l)$, (where l is the coordinate along the wire's axis), near the perfectly conducting ground. The wire is excited by an external electromagnetic field, $\vec{E}^e(\vec{r})$. The current, $I(l)$, and the potential, $\varphi(l)$, on the boundary of the wire (we use the Lorenz gauge) can be described by the Mixed-Potential Integral Equations (MPIE) [11]:

$$\begin{cases} \frac{\partial \varphi(l)}{\partial l} + j\omega \frac{\mu_0}{4\pi} \int_0^L g_I^L(l,l') I(l') dl' + Z'_w I(l) = E_l^e(l) \\ \int_0^L g_I^C(l,l') \frac{\partial I(l')}{\partial l'} dl' - \frac{4\pi\varepsilon_0}{\tilde{C}'} \frac{\partial I(l)}{\partial l} + 4\pi\varepsilon_0 j\omega\varphi(l) = 0 \end{cases} \tag{1a,b}$$

Here, $L = 1/2 \oint dl'$ is half of the length of the complete closed loop. The functions $g_I^C(l,l')$ and $g_I^L(l,l')$ are the Green's functions along the curved line for the scalar potential and for the tangential component of the vector potential, respectively, which take into account the reflection of the ground plane:

$$g_I^C(l,l') = \frac{e^{-jk\sqrt{[\vec{r}(l)-\vec{r}(l')]^2+a^2}}}{\sqrt{[\vec{r}(l)-\vec{r}(l')]^2+a^2}} - \frac{e^{-jk\sqrt{[\vec{r}(l)-\tilde{\vec{r}}(l')]^2+a^2}}}{\sqrt{[\vec{r}(l)-\tilde{\vec{r}}(l')]^2+a^2}}, \tag{2}$$

$$g_I^L(l,l') = \vec{e}_l(l) \bullet \vec{e}_l(l') \frac{e^{-jk\sqrt{[\vec{r}(l)-\vec{r}(l')]^2+a^2}}}{\sqrt{[\vec{r}(l)-\vec{r}(l')]^2+a^2}} - \vec{e}_l(l) \bullet \tilde{\vec{e}}_l(l') \frac{e^{-jk\sqrt{[\vec{r}(l)-\tilde{\vec{r}}(l')]^2+a^2}}}{\sqrt{[\vec{r}(l)-\tilde{\vec{r}}(l')]^2+a^2}}. \tag{3}$$

The unit tangential vector, $\vec{e}_l(l) = \partial\vec{r}(l)/\partial l$, of the curve is taken along the wire axis; $\tilde{\vec{r}}(l)$ is the radius vector mirrored by the ground plane; and $\tilde{\vec{e}}_l(l) = \partial\tilde{\vec{r}}(l)/\partial l$ is the corresponding unit tangential vector.

Equation (1a) takes into account the boundary condition for the total tangential electric field on the surface of the wire. There, $Z'_w(j\omega)$ is the per-unit-length impedance of the wire [13] with radius a and electrical conductivity σ_w:

$$Z'_w(j\omega) = -\frac{1}{2\pi a}\sqrt{\frac{j\omega\mu_0}{\sigma_w}} \frac{I_0\left(a\sqrt{j\omega\mu_0\sigma_w}\right)}{I_1\left(a\sqrt{j\omega\mu_0\sigma_w}\right)}. \tag{4}$$

Here, the functions $I_0(x)$ and $I_1(x)$ are modified Bessel functions.

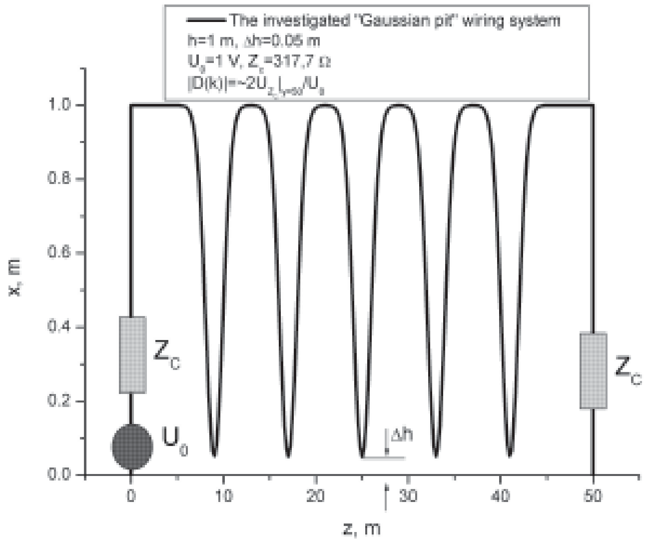

Figure 1. The geometry of the quasi-periodic wiring structure: $h = 1$ *m,* $b = 0.75$ *m,* $k_0 = 0.75\,m^{-1}$*,* $a = 0.01$ *m,* $L = 8$ *m,* $N = 5$.

Equation (1b) is just the definition of the scalar potential on the boundary of the coated wire. To obtain this equation, an auxiliary electrostatic problem for the straight cylindrical coated wire was solved [11], and the continuity equation connecting the charge per unit length and the current in the wire was used. The quantity $\tilde{C}'$ is some auxiliary capacitance, connected with the external radius of the coating, b, and the dielectric permittivity of the coating material, ε:

$$\tilde{C}' = \frac{2\pi\varepsilon_0\varepsilon}{\varepsilon - 1}\frac{1}{\ln\left(b/a\right)}. \qquad (5)$$

The mixed-potential integral equation equations, Equations (1a, 1b), are the basis for our further consideration.

There are several methods to solve the system of Equation (1) with an arbitrary type of excitation. For arbitrary frequencies, one can use full-wave numerical methods, as, for example, the Method of Moments (MoM) [14-16] or the Partial Element Equivalent Circuit (PEEC) method [17], leading to SPICE-like equations for the characterization of bundled transmission lines. The stability of PEEC time-domain solutions was improved in [18], and in [19], the PEEC method was extended to wires near complex structures.

For low frequencies (when the characteristic wavelength is larger than the height of the line, and the quasi-static approximation can be used in the transverse direction), one can use a classical transmission-line (TL) approximation [20] (references of recent papers can be found in the review article [21]). The transmission-line approximation reduces the integral-differential equations of Equation (1) to the simpler system of non-homogeneous differential equations (the integral terms in Equations (1a, 1b) approximately reduce to a multiplication), which can be solved by different standard analytical or numerical methods. This approximation can be used for the system analysis and characterization of transmission lines close to more general structures (not just ground planes) [22]. However, for higher frequencies, the transmission-line approximation is not valid. A solution of Equation (1) by an iteration approach [23] then allows us to calculate radiation corrections to the transmission-line results.

Frequently, sources (loads) are placed at the ends of wiring systems (see Figure 1). In this case, one can re-write the system of Equations (1a,b) as a system of the first-order differential equations in the transmission-line-like form. However, the corresponding parameter matrix (global parameters) is complex-valued, is length and frequency dependent, and is also different from the classical transmission line: it has diagonal terms. This transformation forms the basis equation of the Full-Wave Transmission-Line theory (FWTL). Below, we will shortly outline its derivation, referring the reader for more information to [12, 24, 25].

To define the global generalized transmission-line parameters, we consider an excitation of the transmission line by point sources with arbitrary dimensionless amplitudes U_1 and U_2, located at the beginning and the end of the line. This corresponds to the tangential component of the exciting electrical field:

$$E_l^i\left(l\right) = \left[U_1\delta\left(l-\Delta\right) + U_2\delta\left(l - L + \Delta\right)\right]1\text{V}, \qquad (6)$$

with

$$\Delta \to 0.$$

One can show that the excitation field for the loaded line can be formally reduced to a similar equation [12, 24, 25]. For example, when the system is loaded by the impedance Z_2 at one end, then the corresponding constant is

$$U_2 = -I(L)Z_2/1\text{V} \cdot \quad (7)$$

Now, let the functions $I_1(l)$, $I_2(l)$, and $\varphi_1(l)$, $\varphi_2(l)$ be solutions of the system of Equations (1a, 1b) for the current and the potential with sources of amplitude 1 V: $\delta(l-\Delta)$, $\delta(l-L+\Delta)$ located at the points Δ and $L-\Delta$, correspondingly. Due to the linearity of the problem considered, we can write the solution for the total induced current as

$$I(l) = U_1 I_1(l) + U_2 I_2(l) \cdot \quad (8)$$

For the potential, $\varphi(l)$, along the wire, we find an analog equation:

$$\varphi(l) = U_1 \varphi_1(l) + U_2 \varphi_2(l) \cdot \quad (9)$$

Now, we assume that the potential and current outside the source region satisfy a Transmission-Line Theory-like system, Equation (10) (full Transmission-Line equations, FWTL), introducing a corresponding parameter matrix, $[P(l)]$:

$$\begin{cases} \dfrac{d\varphi(l)}{dl} + j\omega P_{11}(l) I(l) + j\omega P_{12}(l)\varphi(l) = 0 \\ \dfrac{dI(l)}{dl} + j\omega P_{21}(l)\varphi(l) + j\omega P_{22}(l) I(l) = 0 \end{cases} \quad (10)$$

In a matrix notation, the type of solution can be generalized for the multiconductor case. We introduce a column vector, $\underset{\downarrow}{x}$, the components of which are potential and current, for both the partial and general solutions:

$$\underset{\downarrow}{x_1} := \begin{bmatrix} \varphi_1(l) \\ I_1(l) \end{bmatrix},$$

$$\underset{\downarrow}{x_2} := \begin{bmatrix} \varphi_2(l) \\ I_2(l) \end{bmatrix}, \quad (11)$$

$$\underset{\downarrow}{x} := \begin{bmatrix} \varphi(l) \\ I(l) \end{bmatrix}.$$

Equations (8) and (9) now are written as

$$\underset{\downarrow}{x} = U_1 \underset{\downarrow}{x_1} + U_2 \underset{\downarrow}{x_2}, \quad (12)$$

and, instead of Equation (10), we have

$$\frac{d}{dl}\underset{\downarrow}{x} + j\omega[P]\underset{\downarrow}{x} = 0, \quad (13a)$$

where

$$[P(j\omega,l)] = \begin{bmatrix} P_{11}(j\omega,l) & P_{12}(j\omega,l) \\ P_{21}(j\omega,l) & P_{22}(j\omega,l) \end{bmatrix}, \quad (13b)$$

Equations (13a) and (12) imply that

$$U_1\left\{\frac{d}{dl}\underset{\downarrow}{x_1} + j\omega[P]\underset{\downarrow}{x_1}\right\} + U_2\left\{\frac{d}{dl}\underset{\downarrow}{x_2} + j\omega[P]\underset{\downarrow}{x_2}\right\} = 0. \quad (14)$$

Since the constants U_1 and U_2 have arbitrary values in Equation (14), we derive

$$\frac{d}{dl}\underset{\downarrow}{x_1} + j\omega[P]\underset{\downarrow}{x_1} = 0, \quad (15a)$$

$$\frac{d}{dl}\underset{\downarrow}{x_2} + j\omega[P]\underset{\downarrow}{x_2} = 0. \quad (15b)$$

After the introduction of a matrix notation for the fundamental solutions,

$$[X] := \left[\underset{\downarrow}{x_1}, \underset{\downarrow}{x_2}\right] = \begin{bmatrix} \varphi_1(l) & \varphi_2(l) \\ I_1(l) & I_2(l) \end{bmatrix}, \quad (16)$$

Equations (15a,b) can be written as

$$\frac{d}{dl}[X] + j\omega[P][X] = 0 \quad (17)$$

If the matrix of the fundamental solutions, $\hat{x}$, is non-degenerate, i.e.,

$$\det[X] = \varphi_1(l)I_2(l) - \varphi_2(l)I_1(l) := -\Delta_{I,\varphi} \neq 0, \quad (18)$$

then the solution for the matrix $[P]$ can be written in the following form:

$$\left[P(l)\right] = -\frac{1}{j\omega}\frac{d[X]}{dl}[X]^{-1}. \tag{19}$$

The matrix [P] is invariant to transformations of the following kind (with constant matrix $[\alpha]$):

$$\left[\tilde{X}\right] = [X][\alpha], \text{ where } \det[\alpha] \neq 0, \tag{20}$$

$$\left[\tilde{P}(l)\right] = -\frac{1}{j\omega}\frac{d\left([X]\cdot[\alpha]\right)}{dl}\left([X][\alpha]\right)^{-1}$$

$$= -\frac{1}{j\omega}\frac{d[X]}{dl}[\alpha][\alpha]^{-1}[X]^{-1}$$

$$= -\frac{1}{j\omega}\frac{d[X]}{dl}[X]^{-1}$$

$$= [P(l)]. \tag{21}$$

Thus, we have shown that the solution of the mixed-potential integral equation system of Equation (1) with sources as in Equation (6) is defined by two independent constants, and it can be explicitly reduced to the differential equations of Equations (10), (13a) with parameters of Equation (19). These parameters are either global parameters in the FWTL or the parameters of "Maxwellian circuits." The parameters are complex valued, and they also describe the radiation of the system [12]. They are dependent on the geometry of the system, and therefore on the local parameter, l, along the line. This fact was established earlier in [1-3] with the method of the product integral, and (up to notation) in [26], by calculating the numerical solution for the current and potential with the Method of Moments.

The solution of the system in Equation (10) yields the current and voltage distributions along the line for given values of the terminal sources and/or loads. This system uses parameter matrix $\hat{P}(l)$ as shown in Equation (19), and the boundary conditions typically used for the currents and voltages (differences of potentials for the small Δ) at the points $l = \Delta$ and $l = L - \Delta$. The procedure is convenient when the exact values of the functions $I_1(l)$, $I_2(l)$, $\varphi_1(l)$, $\varphi_2(l)$ are known from analytical [12, 25] or numerical [26] solutions.

Another way to obtain the matrix of global parameters is to organize some iteration procedure for this matrix. Generally, at the zeroth step, the approximate solution of the system in Equation (10) is defined. This solution is then used to find the corresponding parameters, etc. In [1-3], the static distributions for the current and potential were used for the zeroth iteration, and the first iteration for the parameters was obtained after a numerical procedure.

Another approach, which is based on the thickness of the wire, was proposed in [12]. Here, at the zeroth step the mixed-potential integral equation, Equation (1) (within the logarithmic accuracy), was reduced to the classical transmission-line system with constant parameters. The solution of this system with sources from Equation (6) yields the current of the first iteration, $I_1(l)$ and $I_2(l)$, the linear combination of which (up to a constant factor) can be represented as forward and backward propagating waves:

$$I_1^{(1)}(l) = \exp(-jkl),$$
$$I_2^{(1)}(l) = \exp(jkl). \tag{22}$$

However, for the scalar potential in the first iteration and for its derivative, the exact equations, Equations (1a,b), are used. After some straightforward calculations, we obtain the global parameter matrix in the first-order approximation:

$$P_{11}^{(1)}(l) = c\frac{L'_+(l) - L'_-(l)}{\frac{1}{C'_+(l)} + \frac{1}{C'_-(l)} - \frac{2}{\tilde{C}'}}, \tag{23a}$$

$$P_{12}^{(1)}(l) = \frac{\left[L'_+(l) + \frac{Z'_w}{j\omega}\right]\left(\frac{1}{C'_-(l)} - \frac{1}{\tilde{C}'}\right)}{\frac{1}{C'_+(l)} + \frac{1}{C'_-(l)} - \frac{2}{\tilde{C}'}} + \frac{\left(L'_-(l) + \frac{Z'_w}{j\omega}\right)\left(\frac{1}{C'_+(l)} - \frac{1}{\tilde{C}'}\right)}{\frac{1}{C'_+(l)} + \frac{1}{C'_-(l)} - \frac{2}{\tilde{C}'}} \tag{23b}$$

$$P_{21}^{(1)}(l) = \frac{2}{\frac{1}{C'_+(l)} + \frac{1}{C'_-(l)} - \frac{2}{\tilde{C}'}}, \tag{23c}$$

$$P_{22}^{(1)}(l) = -\frac{1}{c}\frac{\frac{1}{C'_+(l)} - \frac{1}{C'_-(l)}}{\frac{1}{C'_+(l)} + \frac{1}{C'_-(l)} - \frac{2}{\tilde{C}'}}. \tag{23d}$$

In Equations (23), we used the following expressions for the "forward" and "backward" inductance and capacitance of the first order, respectively:

$$L'_{\pm}(l) = \frac{\mu_0}{4\pi}\int_0^L g_I^L(l,l')\exp\left[\mp jk(l'-l)\right]dl', \quad (24)$$

$$C'_{\pm}(l) = \frac{4\pi\varepsilon_0}{\int_0^L g_I^C(l,l')\exp\left[\mp jk(l'-l)\right]dl'}. \quad (25)$$

For the low-frequency case ($k \to 0$) , we find

$$L'_{+}(l) = L'_{-}(l) = L'_0(l) :=$$

$$\frac{\mu_0}{4\pi}\int_0^L \left\{ \frac{\vec{e}_l(l)\bullet\vec{e}_l(l')}{\sqrt{\left[\vec{r}(l)-\vec{r}(l')\right]^2+a^2}} - \frac{\vec{e}_l(l)\bullet\vec{\tilde{e}}_l(l')}{\sqrt{\left[\vec{r}(l)-\vec{\tilde{r}}(l')\right]^2+a^2}} \right\} dl' \quad (26)$$

$$C'_{+}(l) = C'_{-}(l) = C'_0(l) :=$$

$$\frac{4\pi\varepsilon_0}{\int_0^L \left\{ \frac{1}{\sqrt{\left[\vec{r}(l)-\vec{\tilde{r}}(l')\right]^2+a^2}} - \frac{1}{\sqrt{\left[\vec{r}(l)-\vec{\tilde{r}}(l')\right]^2+a^2}} \right\} dl'} \quad (27)$$

The quantities $L'_0(l)$ and $C'_0(l)$ constitute the real, low-frequency length-dependent inductance and capacitance per unit length for the lossless uncoated transmission line [2]. Then, using Equation (45) for our case, we obtain the parameter matrix in the classical anti-diagonal form for the coated wire with losses:

$$\left[P^{(1)}(l)\right] \underset{k\to 0}{=} \begin{bmatrix} 0 & L'_0(l)+Z'_w/j\omega \\ C'_{0\varepsilon} & 0 \end{bmatrix}, \quad (28a)$$

$$C'_{0\varepsilon} = \frac{1}{\frac{1}{C'_0(l)} - \frac{1}{\tilde{C}'}}, \quad (28b)$$

where we introduced the per-unit-length capacitance for the coated wire, $C'_{0,\varepsilon}$.

3. Propagation of Current Waves Along Quasi-Periodic Wiring Structures

3.1 FWTL and Second-Order Equations

We consider a long lossless, thin, nonuniform conductor above a perfectly conducting ground, with the non-uniformities located along the central part of the conductor. We assume that the sources are at the left end of the wire (at minus infinity) and that there is no reflection on the right end of the wire (plus infinity) (see the structure in Figure 1 with infinitely continued horizontal parts). As shown in Section 2, the current and potential along the line are described by the FWTL, Equation (10), with the matrix of global parameters $\left[P(l)\right]$. We use the Lorenz gauge for the potential, but any another gauge could also be used, for example, the Coulomb gauge. However, for the current we obtain a gauge-independent differential equation of the second order [26, 12]:

$$I''(l) + U_M(l)I'(l) + T_M(l)I(l) = 0. \quad (29)$$

Here, $U_M(l)$ is the complex damping function, and $T_M(l)$ corresponds to the square of the propagation constant. These parameters are connected with the global parameters of the FWTL [11], and they also depend on the frequency and geometry of the system.

$$U_M(l) = -\frac{d}{dl}\ln(P_{21}) + j\omega(P_{11}+P_{22}), \quad (30a)$$

$$T_M(l) = j\omega P_{21}\frac{d}{dl}\left(\frac{P_{22}}{P_{21}}\right) - \omega^2\det[P] \quad (30b)$$

In order to reduce Equation (29) to a convenient form for further analysis, we eliminate the first derivative by introducing a new unknown function, $\psi(l)$:

$$I(l) = f(l)\psi(l), \quad (31)$$

$$f(l) = \exp\left[-\frac{1}{2}\int_{-\infty}^{l} U_M(l')dl'\right]$$

$$= \sqrt{\frac{P_{21}(l)}{P_{21}(-\infty)}}\exp\left\{-\frac{j\omega}{2}\int_{-\infty}^{l}\left[P_{11}(l)+P_{22}(l)\right]dl\right\} \quad (32)$$

The function $\psi(l)$ satisfies the differential equation of the second order:

$$\psi''(l)+k^2(l)\psi(l)=0, \tag{33}$$

with

$$k^2(l):=T_M(l)-\frac{1}{2}\frac{dU_M(l)}{dl}-\frac{U_M^2(l)}{4}, \tag{34a}$$

$$\lim_{l\to\pm\infty}\left[k^2(l)\right]=k^2=\frac{\omega^2}{c^2}>0. \tag{34b}$$

To consider the wiring structure at the uniform ends, we introduce function $u(l)$ as follows:

$$u(l)=k^2-k^2(l), \tag{35a}$$

$$\lim_{l\to\pm\infty}\left[u(l)\right]=0. \tag{35b}$$

$$\psi''+\left[k^2-u(l)\right]\psi(l)=0. \tag{36}$$

Equation (36) looks like a Schrödinger equation in non-relativistic quantum mechanics with a "potential" $u(l)$, which describes the one-dimensional scattering of quantum-mechanical particles [8]. The parameters $T_M(l)$ and $U_M(l)$ and the function $u(l)$ all depend on the geometry of the wire and on frequency. For low frequencies, $kh \ll 1$, (where h is the height of the wire at $l=\pm\infty$), using Equations (26)-(28) and (30), (34a), and (35a), the function $u(l)$ can be expressed as

$$u(l)=\frac{\omega^2}{c^2}-\omega^2\left[L_0'(l)+Z_w'/j\omega\right]C_{0\varepsilon}'(l)$$

$$-\frac{1}{2}\frac{1}{C_{0\varepsilon}'(l)}\frac{d^2C_{0\varepsilon}'(l)}{dl^2}+\frac{3}{4}\frac{1}{\left[C_{0\varepsilon}'(l)\right]^2}\left[\frac{dC_{0\varepsilon}'(l)}{dl}\right]^2$$

$$=\frac{\omega^2}{c^2}-\omega^2\left[L_0'(l)+Z_w'/j\omega\right]C_{0\varepsilon}'(l)$$

$$+\sqrt{C_{0\varepsilon}'(l)}\frac{d^2}{dl^2}\left(\frac{1}{\sqrt{C_{0\varepsilon}'(l)}}\right) \tag{37}$$

From Equation (37) it is obvious that the function $u(l)$ is real for the lossless line.

For the general frequency case, we have to use the results of Equations (23) in Equations (30) and (34a), (35a). The function $u(l)$ for this case then becomes

$$u(l)=k^2-j\omega P_{21}\frac{d}{dl}\left(\frac{P_{22}}{P_{21}}\right)+\omega^2\det\left[\hat{P}\right]-\frac{1}{2}\frac{d^2\ln\left(P_{21}\right)}{dl^2}$$

$$+j\omega\frac{d}{dl}\left(P_{11}+P_{22}\right)+\frac{1}{4}\left[j\omega\left(P_{11}+P_{22}\right)-\frac{d}{dl}\ln\left(P_{21}\right)\right]^2 \tag{38}$$

Now, the function $u(l)$ is a complex-valued quantity that includes radiation losses in the electrodynamics problem. This is also true for the low-frequency case with ohmic or dielectric losses. (The complex aspect of the potential $u(l)$ corresponds to particle absorption in the quantum-mechanical analogy.)

In conclusion, we add two remarks. First, the system of first-order differential equations in Equation (10) is more convenient for a numerical solution than the second-order differential equation of Equation (36), the parameter $u(l)$ of which is obtained after two differentiations of the parameter matrix $\left[P(l)\right]$. However, a number of sophisticated methods have been developed for the qualitative analysis and analytical solution of this equation. Some of these methods will be used in the next sections. Second, one of the most interesting properties of the Schrödinger equation is the allowance of bound states, when the particle is localized in a finite space region. In our case of a "potential" with an imaginary part, these states are quasi-stationary, i.e., they decay after some time. For the current waves, these states correspond to evanescent modes. This interesting problem requires further investigation. In order to study the propagation of current waves through wiring structures, we will next examine the states of the continuous spectrum, i.e., in the one-dimensional scattering problem.

3.2 One-Dimensional Scattering Problem: Reflection and Transmission Coefficients for Lossy Systems

In the previous subsection, we showed that the homogeneous electrodynamic problem is equivalent to the one-dimensional scattering problem: the wave comes from minus infinity, scatters at the non-uniformity, is partially absorbed in the region of the non-uniformity, propagates partially through the non-uniformity, and also is partially reflected by the non-uniformity. The complex amplitudes of these processes are described by the complex coefficients for reflection, R, and transmission, D (see Figure 2):

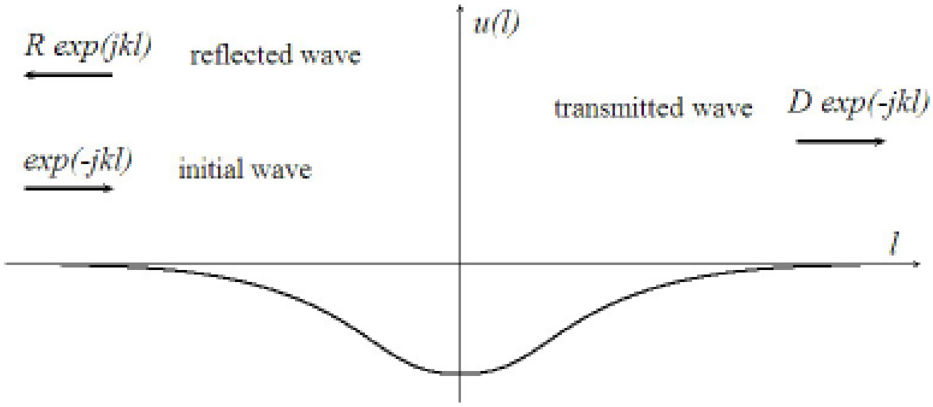

Figure 2: One-dimensional scattering problem

$$\psi(l) = \begin{cases} \exp(-jkl) + R\exp(jkl) & \text{for } l \to -\infty \\ D\exp(-jkl) & \text{for } l \to \infty \end{cases} \quad (39)$$

Due to the importance of these two coefficients in this article, we will now describe their properties in more detail.

For a symmetrically scattering non-uniformity, $u(-l) = u(l)$, these coefficients are the same for both the left and right scattering problem.

One can show that for the low-frequency and lossless case (where the function $u(l)$ is real), these coefficients satisfy the following equations [8]:

$$|R|^2 + |D|^2 = 1 \quad (40a)$$

$$\operatorname{Re}\left\{RD^*\right\} = 0 . \quad (40b)$$

However, for the complex function $u(l)$ corresponding to radiation and/or ohmic and dielectric losses, Equations (40a,b) are not valid. The imaginary part of $u(l)$ is now responsible for the losses. Let us establish this dependence.

If we have a uniform line with current waves propagating in both directions (and the electromagnetic field around the wire is a TEM wave),

$$I(l) = I_1 \exp(-jkl) + I_2 \exp(jkl), \quad (41)$$

the time-averaged power propagating along the uniform line in the positive direction can be written as

$$W = \frac{Z_C}{2}\left(|I_1|^2 - |I_2|^2\right). \quad (42)$$

Equation (42) can be represented as

$$W(l) = \frac{Z_c}{4jk}\left\{I(l)\frac{\partial I^*(l)}{\partial l} - I^*(l)\frac{\partial I(l)}{\partial l}\right\}, \quad (43)$$

$$Z_c = \frac{\eta_0}{2\pi}\ln\left(\frac{2h}{a}\right).$$

Let us now define the value $W(l)$ in Equation (43), not only for the two asymptotic regions $(l \to \pm\infty)$, but also for the intermediate region (the region of interaction). We can then express the energy losses of the current during the scattering process (caused by radiation, ohmic, or dielectric losses) using the law of energy conservation:

$$W_{loss} = -\left[W(\infty) - W(-\infty)\right]. \quad (44)$$

Taking the representation of the current through the ψ function, Equations (31) and (32), we can write, for the quantity $W(l)$,

$$W(l) = \frac{Z_C}{4jk}\exp\left\{\operatorname{Re}\int_{-\infty}^{l} U_M(l')dl'\right\}$$

$$\left\{\psi(l)\frac{\partial\psi^*(l)}{\partial l} - \psi^*(l)\frac{\partial\psi(l)}{\partial l} + \operatorname{Im}\left[U_M(l)\right]|\psi(l)|^2\right\} \quad (45)$$

For a symmetrical wiring system – for example, a wire with vertical coordinate $x(l)$ and horizontal coordinate $z(l)$, which are given by the relations

$$\vec{r}(l) = [x(l), 0, z(l)], \quad (46a)$$

$$\vec{r}(-l) = [x(l), 0, -z(l)], \quad (46b)$$

we find, after some cumbersome calculations with the aid of the technique from Section 2, the following symmetry properties for the global FWTL parameters:

$$P_{11}(-l) = -P_{11}(l), \quad (47a)$$

$$P_{12}(-l) = P_{12}(l), \quad (47b)$$

$$P_{21}(-l) = P_{21}(l), \quad (47c)$$

$$P_{22}(-l) = -P_{22}(l). \quad (47d)$$

Now, using the definition of the parameter $U_M(l)$, Equations (30a) and Equation (47), we derive

$$U_M(-\infty) = U_M(\infty) = 0, \quad (48a)$$

$$\int_{-\infty}^{\infty} U_M(l')\,dl' = 0. \quad (48b)$$

Equation (45) then gives

$$W(l) \underset{l\to\pm\infty}{=} \frac{Z_C}{4jk}\left\{\psi(l)\frac{\partial\psi^*(l)}{\partial l} - \psi^*(l)\frac{\partial\psi(l)}{\partial l}\right\}, \quad (49)$$

and, consequently,

$$W_{loss} = \frac{Z_C}{2}|I_0|^2\left(1 - |R|^2 - |D|^2\right). \quad (50)$$

For the lossless case, we obtain the obvious answer: $W_{loss} = 0$. For the lossy case, some standard manipulations can be made on the second-order equation of Equation (36) in order to obtain the term in the bracket of Equation (49).

We start with second-order Equations (51) for the function $\psi(l)$ and for the complex-conjugate function ψ^*. Multiplying the resulting equations by ψ^* and by ψ, respectively, and then subtracting them,

$$\psi^*(l)\left\{d^2\psi(l)/dl^2 + \left[k^2 - u(l)\right]\psi(l) = 0\right\}$$

$$-\psi(l)\left\{d^2\psi^*(l)/dl^2 + \left(k^2 - u^*(l)\right)\psi^*(l) = 0\right\}$$

(51a,b)

one gets as a result

$$0 = \psi^*(l)\frac{d^2\psi(l)}{dl^2} - \psi(l)\frac{d^2\psi^*(l)}{dl^2}$$

$$-u(l)\psi(l)\psi^*(l) + u^*(l)\psi^*(l)\psi(l)$$

$$= \frac{d}{dl}\left\{\psi^*(l)\frac{d\psi(l)}{dl} - \psi(l)\frac{d\psi^*(l)}{dl}\right\}$$

$$-2j\,\mathrm{Im}\left[u(l)\right]|\psi(l)|^2. \quad (52)$$

The integration of Equation (52) from $-\infty$ to ∞ and the use of Equation (39) yields

$$\left\{\psi^*(l)\frac{d\psi(l)}{dl} - \psi(l)\frac{d\psi^*(l)}{dl}\right\}\Bigg|_{-\infty}^{\infty}$$

$$= 2j\int_{-\infty}^{\infty}\mathrm{Im}\left[u(l')\right]|\psi(l')|^2\,dl'$$

$$= 2jk\left(1 - |R|^2 - |D|^2\right). \quad (53)$$

Taking Equations (53) and (50) into account, we finally have

$$W_{loss} = \frac{Z_C}{2}|I_0|^2\left(1 - |R|^2 - |D|^2\right)$$

$$= \frac{Z_C}{2}|I_0|^2\frac{1}{k}\int_{-\infty}^{\infty}|\psi(l)|^2\,\mathrm{Im}\left[u(l)\right]dl. \quad (54)$$

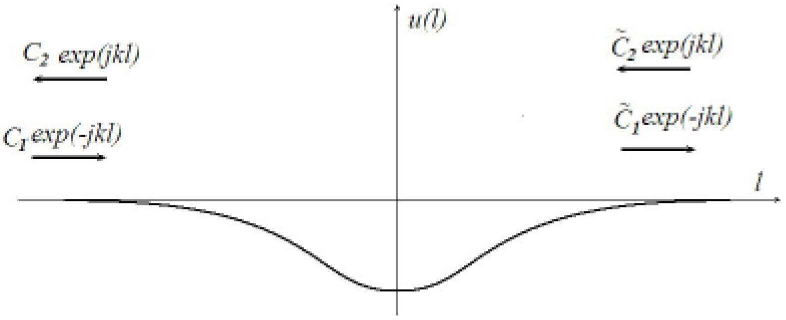

Figure 3. An illustration used in the definition of the transfer matrix, $\hat{S}$.

Equation (54) gives the desired connection between the imaginary part of the function $u(l)$ and the losses in the wire.

Note that in the low-frequency limit, $\omega \to 0$, the calculation for the reflection and transmission coefficients (using the integral representation of the second-order Schrödinger equation [27]) yields the obvious results $R = 0$ and $D = 1$.

3.3 Transfer Matrices for the One-Dimensional Scattering Problem

Here we consider another, more-general approach to describe one-dimensional scattering. We apply the method of the transfer matrix [9]. In this method, one considers waves propagating in positive and negative directions with different amplitudes, both from the left and right sides of the function $u(l)$ (see Figure 3):

$$\psi(l) = \begin{cases} C_1 \exp(-jkl) + C_2 \exp(jkl) & \text{for } l \to -\infty \\ \tilde{C}_1 \exp(-jkl) + \tilde{C}_2 \exp(jkl) & \text{for } l \to \infty \end{cases} \quad (55)$$

Since the problem considered is linear, a linear connection exists between the asymptotic amplitudes C_1, C_2, and $\tilde{C}_1$, $\tilde{C}_2$. This connection is given by the 2×2 transfer matrix

$$\hat{S} = \begin{pmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{pmatrix}, \quad (56)$$

which links the column vectors of the wave amplitudes:

$$\underset{\downarrow}{\tilde{C}} := \begin{pmatrix} \tilde{C}_1 \\ \tilde{C}_2 \end{pmatrix} = \hat{S} \begin{pmatrix} C_1 \\ C_2 \end{pmatrix} =: \hat{S} \underset{\downarrow}{C}. \quad (57)$$

The transfer matrix can be expressed in terms of reflection and transmission coefficients, R and D:

$$\hat{S} = \begin{pmatrix} \frac{D^2 - R^2}{D} & \frac{R}{D} \\ -\frac{R}{D} & \frac{1}{D} \end{pmatrix}. \quad (58)$$

One can easily check that the determinant of $\hat{S}$ becomes

$$\det \hat{S} = 1. \quad (59)$$

For a real "potential" function $u(l)$, which corresponds to a lossless system, we use the properties of the reflection and transmission coefficients, Equations (40a,b) to show that [6,7]

$$\hat{S} = \begin{pmatrix} \frac{1}{D^*} & \frac{R}{D} \\ \frac{R^*}{D^*} & \frac{1}{D} \end{pmatrix}$$

$$= \begin{pmatrix} \frac{e^{j\varphi_D}}{|D|} & j(-1)^n \frac{\sqrt{1-|D|^2}}{|D|} \\ -j(-1)^n \frac{\sqrt{1-|D|^2}}{|D|} & \frac{e^{-j\varphi_D}}{|D|} \end{pmatrix}, \quad (60)$$

where $D = |D| e^{j\varphi_D}$, and the numbers $n = 0, 1, 2, \ldots$ correspond to the number of bounded energy states in the "potential," Equation (35a).

Also, for the lossless system,

$$\hat{S}^* = \hat{S}^{-1}. \quad (61)$$

This matrix keeps the value

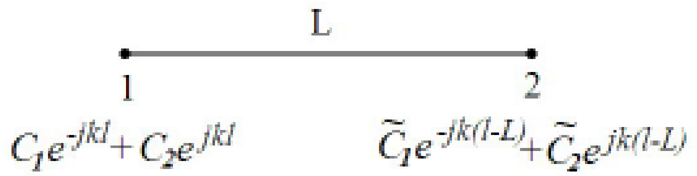

Figure 4: Free propagation of the current wave

$$|C_1|^2-|C_2|^2=|\tilde{C}_1|^2-|\tilde{C}_2|^2\sim W=const \tag{62}$$

constant, which physically corresponds to power conservation along the line.

We can also introduce the transfer matrix for the current wave, propagation without any scattering (a free "particle" in the quantum-mechanical analogy). In this case, the translation leads to a change of the coordinate l. To see this, we consider the free propagation of waves at two coordinate origins, l_1 and l_2 (see Figure 4):

$$C_1e^{-jk(l-l_1)}+C_2e^{jk(l-l_1)}$$

$$=\underbrace{C_1e^{-jk(l_2-l_1)}}_{\tilde{C}_1}e^{-jk(l-l_2)}+\underbrace{C_2e^{jk(l_2-l_1)}}_{\tilde{C}_2}e^{jk(l-l_2)} \tag{63}$$

The transfer matrix for the free propagation becomes

$$\begin{pmatrix}\tilde{C}_1\\ \tilde{C}_2\end{pmatrix}=\begin{pmatrix}e^{-jk(l_2-l_1)} & 0\\ 0 & e^{jk(l_2-l_1)}\end{pmatrix}\begin{pmatrix}C_1\\ C_2\end{pmatrix}=:\hat{T}(l_2,l_1)\begin{pmatrix}C_1\\ C_2\end{pmatrix} \tag{64}$$

3.4 Transfer-Matrix Formalism for the Quasi-Periodic System with Losses

The quasi-periodic wiring structure is formed by a finite number of identical sub-elements (see also Section 4). We assume that the corresponding total function $u_t(l)$ in the second-order Equation (36) can be represented as a set of periodically arranged identical functions $u_s(l)$. (One can show that this assumption better satisfies the case of low frequencies. However, for high frequencies, when radiation does not dominate, this assumption is approximately valid. Moreover, the greater the number of sub-elements that are considered, the better this assumption is satisfied.)

Consider propagation through a chain consisting of N scatterers $u_s(l)$, separated by asymptotic regions, where the total function $u_t(l)$ is approximately zero (see Figure 5). We assume that the column vector on the left-hand side of the quasi-periodic system is $\underset{\downarrow}{C}$, and that the origin of the coordinates is in the center of the first scatterer $u_s(l)$. After the first scattering, the column vector becomes $S_1\underset{\downarrow}{C}$. Changing the coordinate origin by the free propagation transfer matrix, $\hat{T}_{21}:=\hat{T}(l_2,l_1)$, on the left-hand side of the second scatterer $u_s(l)$ gives us a column-vector $T_{21}S_1\underset{\downarrow}{C}$. Repeating this process up to the last scatterer, we can write the total transfer matrix, with the origin of coordinates in the center of the last function $u_s(l)$, as

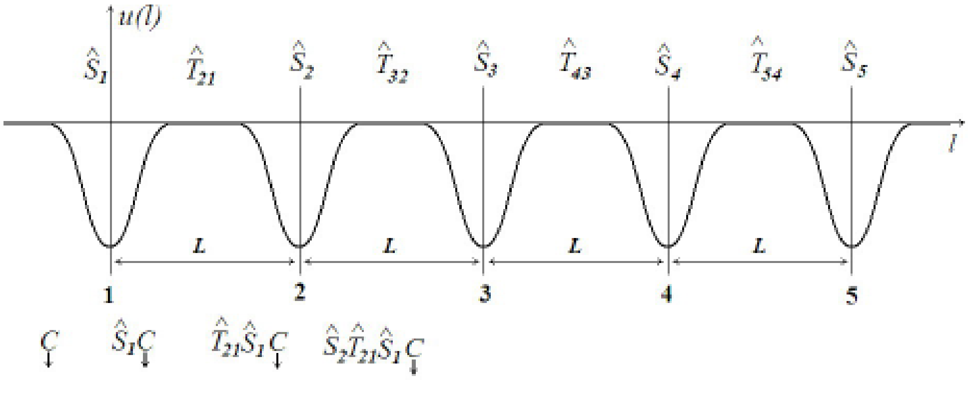

Figure 5. Propagation through the quasi-periodic chain of scatterers, $N=5$.

$$\hat{T}^t(l_N,l_1) := \hat{T}(l_N,l_{N+1})\prod_{n=1}^{N}\hat{T}(l_{n+1},l_n)\hat{S}_n . \quad (65)$$

After the origin of the coordinates returns to the center of the first scatterer, we have the corresponding transfer matrix

$$\hat{S}_{\Sigma(N)} = \hat{T}(l_1,l_{N+1})\prod_{n=1}^{N}\hat{T}(l_{n+1},l_n)\hat{S}_n . \quad (66)$$

(When the regions of interaction are separated by the regions where $u_t(l)=0$, the matrix of Equation (65) is connected with an explicit form of the product integral [2] (which yields the solution of the second-order differential equation, Equation (36))).

For the case of periodically arranged identical scatterers, Equation (66) can be rewritten in the following form:

$$\hat{S}_{\Sigma(N)} = \hat{T}(0,NL)\left[\hat{T}(L,0)\hat{S}\right]^N . \quad (67)$$

Now, it is more convenient to move the coordinate origin to the center of the quasi-periodic system. This can be done if the corresponding total function, $u_t(l)$, is symmetrical, and left and right reflection and transmission coefficients are the same. In this case, Equation (67) can be rewritten as

$$\hat{S}_{\Sigma(N)}$$

$$= \hat{T}\left[0,(N+1)L/2\right]\left[\hat{T}(L,0)\hat{S}\right]^N \hat{T}\left[-(N-1)L/2,0\right] \quad (68)$$

or, using Equations (56) and (58),

$$\hat{S}_{\Sigma(N)} = \begin{pmatrix} \dfrac{D^2_{\Sigma(N)} - R^2_{\Sigma(N)}}{D_{\Sigma(N)}} & \dfrac{R_{\Sigma(N)}}{D_{\Sigma(N)}} \\ -\dfrac{R_{\Sigma(N)}}{D_{\Sigma(N)}} & \dfrac{1}{D_{\Sigma(N)}} \end{pmatrix} . \quad (69)$$

Once the entire transfer matrix is known, we may obtain an equation for the entire transmission coefficient in explicit form, expressed by the scattering data for only one scatterer.

The solution to this problem is known (see the review in [28]). The solution is important in quantum mechanics (as a self-significant theoretical problem, and for the study of super lattices) and in optics (penetration through the set of dielectric layers with periodically changing permittivity).The entire transfer matrix for the periodic system can be obtained in two different ways.

The first way is to apply the Cayley-Hamilton Theorem to establish a relation between $\left(\hat{T}^t\right)^2$ and $\hat{T}^t$ [28], and to use the standard method to diagonalize matrices [22] (for matrices with unit determinant [9]). The second way is to take into account the recurrence relations for reflection and transmission coefficients [30].

With each of these methods, it is possible to deal with general lossy cases, i.e., cases with a complex potential function $u(l)$. However, only lossless cases – which are more familiar in quantum mechanics – have been investigated in the literature. The investigation of the propagation of high-frequency current waves along the wire, which accounts for radiation, ohmic, and dielectric losses, is connected with the imaginary part of the function $u(l)$.

We present the closed-form results for the general lossy case. The results for the entire transfer matrix and the reflection and transmission coefficient are found using properties of the internal symmetry of the scattering system [11]. This method relies on the basic ideas described in [9], and has some connection with the recent paper [31].

To obtain the entire transfer matrix, we calculate a simple analytical expression for the *N*th power in Equation (68). For this purpose, it is sufficient to find an exponential representation of the matrix $\hat{T}(L,0)\hat{S}$ with some additive parameters.

We look for the representation of the matrix $\hat{T}(L,0)\hat{S}$ in the form of a matrix for finite rotation [8], namely

$$\hat{T}(L,0)\hat{S} = \exp\left(j\varphi\vec{n}\vec{\hat{\sigma}}\right) = \hat{I}\cos(\varphi) + j\vec{n}\vec{\hat{\sigma}}\sin(\varphi) \quad (70)$$

(The second equality in Equation (70) for the unit vector $\vec{n}$ can be obtained using the anti-commutation properties of the Pauli matrices, $\hat{\sigma}_i\hat{\sigma}_j + \hat{\sigma}_j\hat{\sigma}_i = \delta_{i,j}$, and the definition of the matrix exponent from the series representation [8].) Here, φ is the "angle of rotation" around the unit "vector" $\vec{n}$, and is a complex additive parameter whereby $\vec{n}$ has complex components and $\vec{n}^2 = 1$. (Here we used the parameter φ instead of the standard value $\varphi/2$ [8] for convenience.) The quantity $\vec{\hat{\sigma}}$ is the vector of the Pauli matrices, which, together with the unit matrix $\hat{I}$, form a basis for 2×2 matrices

$$\hat{I} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}, \quad (71a)$$

$$\hat{\sigma}_x = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}, \quad (71b)$$

$$\hat{\sigma}_y = \begin{pmatrix} 0 & -j \\ j & 0 \end{pmatrix}, \quad (71c)$$

$$\hat{\sigma}_z = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}. \quad (71d)$$

Then, we try to extract the parameters φ and n_x, n_y, n_z from Equation (70).

The left-hand side of Equation (70) is

$$\hat{T}(L,0)\hat{S} := \begin{bmatrix} \hat{T}_{11}^t(L,0) & \hat{T}_{12}^t(L,0) \\ \hat{T}_{21}^t(L,0) & \hat{T}_{22}^t(L,0) \end{bmatrix}$$

$$= \begin{bmatrix} e^{-jkL}\dfrac{\left(D^2 - R^2\right)}{D} & e^{-jkL}\dfrac{R}{D} \\ -e^{jkL}\dfrac{R}{D} & e^{jkL}\dfrac{1}{D} \end{bmatrix} \quad (72)$$

The right-hand side of Equation (70) can be written as

$$\exp\left(j\varphi\vec{n}\hat{\vec{\sigma}}\right) = \hat{I}\cos(\varphi) + j\vec{n}\hat{\vec{\sigma}}\sin(\varphi)$$

$$= \hat{I}\cos(\varphi) + jn_x\hat{\sigma}_x\sin(\varphi) + jn_y\hat{\sigma}_y\sin(\varphi) + jn_z\hat{\sigma}_z\sin(\varphi)$$

$$= \begin{bmatrix} \cos\varphi + jn_z\sin\varphi & \left(jn_x + n_y\right)\sin\varphi \\ \left(jn_x - n_y\right)\sin\varphi & \cos\varphi - jn_z\sin\varphi \end{bmatrix}. \quad (73)$$

The parameters of the exponential representation can be found by comparing Equations (72) and (73). The additive parameter φ can be found by taking the sum of the diagonal elements:

$$\cos\varphi = \frac{1}{2}\left[T_{11}^t(L,0) + T_{22}^t(L,0)\right]$$

$$= \frac{1}{2D}\left[e^{-jkL}\left(D^2 - R^2\right) + e^{jkL}\right] := \alpha\,. \quad (74)$$

The components n_x and n_y are obtained by summation and subtraction of the non-diagonal elements, correspondingly:

$$j\,n_x\sin\varphi = \frac{1}{2}\left[T_{12}^t(L,0) + T_{21}^t(L,0)\right]$$

$$= -j\frac{R}{D}\sin kL$$

or

$$n_x = -\frac{R}{D}\frac{\sin kL}{\sin\varphi}, \quad (75)$$

$$n_y\sin\varphi = \frac{1}{2}\left[T_{12}^t(L,0) - T_{21}^t(L,0)\right]$$

$$= \frac{R}{D}\cos kL$$

or

$$n_y = \frac{R}{D}\frac{\cos kL}{\sin\varphi}. \quad (76)$$

The z component of the "vector" $\vec{n}$ can be obtained by subtraction of the diagonal elements:

$$j\,n_z\sin\varphi = \frac{1}{2}\left[T_{11}^t(L,0) - T_{22}^t(L,0)\right]$$

$$= \frac{e^{-jkL}\left(D^2 - R^2\right) - e^{jkL}}{2D}$$

$$n_z = \frac{e^{-jkL}(D^2 - R^2) - e^{jkL}}{2jD\sin\varphi}. \quad (77)$$

Note that as opposed to the lossless case (where the parameter φ is either real or purely imaginary), in the lossy case this parameter is complex (see also Section 3.5).

The vector $\vec{n}$ is complex-valued, and its squared value becomes one, as we assumed:

$$\vec{n}^2 = 1. \quad (78)$$

(The complex nature of the components of the unit vector $\vec{n}$, in contrast to the real unit vector for the operation of finite rotation [8], is caused by the fact that the transfer matrix, $\hat{T}^t(L,0)$, now is not Hermitian).

Now, having the matrix $\hat{T}(L,0)\hat{S}$ in exponential form, we can easily write the following for the *N*th power of it:

$$\left[\hat{T}(L,0)\hat{S}\right]^N = \left\{\exp\left(j\varphi\vec{n}\vec{\sigma}\right)\right\}^N$$

$$= \exp(jN\varphi\vec{n}\vec{\sigma})$$

$$= \begin{bmatrix} \cos N\varphi + jn_z \sin N\varphi & \left(jn_x + n_y\right)\sin N\varphi \\ \left(jn_x - n_y\right)\sin N\varphi & \cos N\varphi - jn_z \sin N\varphi \end{bmatrix}$$

$$= \begin{pmatrix} \cos N\varphi + \beta\dfrac{\sin N\varphi}{\sin\varphi} & e^{-jkL}\dfrac{R}{D}\dfrac{\sin N\varphi}{\sin\varphi} \\ -e^{jkL}\dfrac{R}{D}\dfrac{\sin N\varphi}{\sin\varphi} & \cos N\varphi - \beta\dfrac{\sin N\varphi}{\sin\varphi} \end{pmatrix} \quad (79)$$

Here, we have introduced the notation

$$\beta := \frac{1}{2}\left[T_{11}^t(L,0) - T_{22}^t(L,0)\right]$$

$$= \frac{1}{2D}\left[e^{-jkL}\left(D^2 - R^2\right) - e^{jkL}\right] \quad (80)$$

After simple matrix multiplications, we have for the transfer matrix of Equation (68),

$$\hat{S}_{\Sigma(N)}$$

$$= \hat{T}\left[0,(N+1)L/2\right]\left[\hat{T}(L,0)\hat{S}\right]^N \hat{T}\left[-(N-1)/2,0\right]$$

$$= \begin{bmatrix} e^{jkLN}\left(\cos N\varphi + jn_z \sin N\varphi\right) & e^{jkL}\left(jn_x + n_y\right)\sin N\varphi \\ e^{-jkL}\left(jn_x - n_y\right)\sin N\varphi & e^{-jkLN}\left(\cos N\varphi - jn_z \sin N\varphi\right) \end{bmatrix}$$

$$= \begin{bmatrix} e^{jkLN}\left(\cos N\varphi + \beta\dfrac{\sin N\varphi}{\sin\varphi}\right) & \dfrac{R}{D}\dfrac{\sin N\varphi}{\sin\varphi} \\ -\dfrac{R}{D}\dfrac{\sin N\varphi}{\sin\varphi} & e^{-jkLN}\left(\cos N\varphi - \beta\dfrac{\sin N\varphi}{\sin\varphi}\right) \end{bmatrix} \quad (81)$$

Comparing Equation (81) with the equation for the entire transfer matrix, expressed through the total reflection and transmission coefficients in Equation (69), we can find for these coefficients,

$$R_{\Sigma(N)} = \frac{R}{D}\frac{\sin N\varphi}{\sin\varphi}\frac{e^{jkLN}}{\cos N\varphi - \beta\dfrac{\sin N\varphi}{\sin\varphi}}, \quad (82a)$$

$$D_{\Sigma(N)} = \frac{e^{jkLN}}{\cos N\varphi - \beta\dfrac{\sin N\varphi}{\sin\varphi}}. \quad (82b)$$

Equations (82) can be rewritten into another form using the definition of Chebyshev polynomials of the first kind, $T_N(x)$, and second kind, $U_N(x)$ [32]:

$$\cos N\varphi = \cos\left[N \arccos(\alpha)\right]$$
$$= T_N(\alpha), \quad (83a)$$

$$\sin N\varphi = \sin\left[N \arccos(\alpha)\right]$$

$$= \left(1-\alpha^2\right)U_{N-1}(a) \quad (83b)$$

$$= \sin\varphi U_{N-1}(\alpha),$$

$$R_{\Sigma(N)} = \frac{R}{D}\frac{e^{jkLN}U_{N-1}(\alpha)}{T_N(\alpha) - \beta U_{N-1}(\alpha)}, \quad (84a)$$

$$D_{\Sigma(N)} = \frac{e^{jkLN}}{T_N(\alpha) - \beta U_{N-1}(\alpha)}. \quad (84b)$$

Using the definitions of α, Equation (74), and β, Equation (80), we can rewrite the equations for the total reflection and transmission coefficients of the periodic chain of one-dimensional scatterers in the explicit form

These two equations are an important result of this paper.

$$R_{\Sigma(N)} = \frac{R}{D}\frac{e^{jkLN}U_{N-1}\left[\frac{e^{-jkL}\left(D^2-R^2\right)+e^{jkL}}{2D}\right]}{T_N\left[\frac{e^{-jkL}\left(D^2-R^2\right)+e^{jkL}}{2D}\right]-\frac{e^{-jkL}\left(D^2-R^2\right)-e^{jkL}}{2D}U_{N-1}\left[\frac{e^{-jkL}\left(D^2-R^2\right)+e^{jkL}}{2D}\right]} \quad (85)$$

$$D_{\Sigma(N)} = \frac{e^{jkLN}}{T_N\left[\frac{e^{-jkL}\left(D^2-R^2\right)+e^{jkL}}{2D}\right]-\frac{e^{-jkL}\left(D^2-R^2\right)-e^{jkL}}{2D}U_{N-1}\left[\frac{e^{-jkL}\left(D^2-R^2\right)+e^{jkL}}{2D}\right]} \quad (86)$$

Let us now briefly investigate some special cases of Equations (85) and (86).

For the case of a lossless line (real function $u(l)$), using Equations (40a,b) we can write

$$\alpha = \cos(\varphi) = \mathrm{Re}\left(\frac{e^{jkL}}{D}\right), \quad (87a)$$

$$\beta = -\mathrm{Im}\left(\frac{e^{jkL}}{D}\right), \quad (87b)$$

and, hereafter, Equations (85) and (86) are reduced to the result [6, 7]

$$R_{\Sigma(N)} = \frac{R}{D}\frac{e^{jkLN}U_{N-1}\left[\mathrm{Re}\left(\frac{e^{jkL}}{D}\right)\right]}{T_N\left[\mathrm{Re}\left(\frac{e^{jkL}}{D}\right)\right]+j\,\mathrm{Im}\left(\frac{e^{jkL}}{D}\right)U_{N-1}\left[\mathrm{Re}\left(\frac{e^{jkL}}{D}\right)\right]} \quad (88)$$

$$D_{\Sigma(N)} = \frac{e^{jkLN}}{T_N\left[\mathrm{Re}\left(\frac{e^{jkL}}{D}\right)\right]+j\,\mathrm{Im}\left(\frac{e^{jkL}}{D}\right)U_{N-1}\left[\mathrm{Re}\left(\frac{e^{jkL}}{D}\right)\right]} \quad (89)$$

The reflection and transmission coefficients, Equations (88) and (89), coincide with corresponding results [30] for the finite chain of symmetric scatterers (after changing there $i \to -j$, using the relationship between Chebyshev polynomials of the first and second kind, and an appropriate origin). The transfer matrix with these coefficients also coincides with the corresponding equation in [28].

For the case of one scatterer, $N = 1$ (where the function $u(l)$ has a general form), we use the Chebyshev polynomials $T_1(x) = x$ and $U_0(x) = 1$, and find from Equations (85) and (86) the obvious result

$$D_{\Sigma(1)} = D, \quad (90a)$$

$$R_{\Sigma(1)} = R. \quad (90b)$$

For two scatterers ($N = 2$), we find, with the Chebyshev polynomials $T_2(x) = 2x^2 - 1$ and $U_1(x) = 2x$,

$$D_{\Sigma(2)} = \frac{D^2}{1 - R^2 e^{-2jkL}}, \quad (91a)$$

$$R_{\Sigma(2)} = Re^{jkL} + \frac{RD^2 e^{-jkL}}{1 - R^2 e^{-2jkL}}. \quad (91b)$$

If for one single non-uniformity we have $|R| \approx 1$, $|D| \ll 1$, then resonant scattering is present for the chain of non-uniformities. To make a short qualitative investigation of this phenomenon, we consider Equation (91a), and notice that the single-potential reflection and transmission coefficients, D and R, have a slow frequency dependence compared to that of the exponential function $\exp(-2jkL)$. For the transmission coefficient $D_{\Sigma(2)}$, the main frequency region is $|2kL - 2\varphi_R - 2\pi n| \sim 1$ (φ_R is the phase of the reflection coefficient R, $n = 1,2,3..$). The denominator in

Equation (91a) is of the order of magnitude of one, and therefore penetration through the two-scatterer chain is small: $|D_{\Sigma(2)}| \sim |D^2| \ll 1$. However, in narrow frequency bands, when $|2kL - 2\varphi_R - 2\pi n| \ll 1$, one can observe a resonant scattering. If we detune the nth resonance, then for the frequency dependence of the transmission coefficient in the neighborhood of this resonance ($\Delta k_n L = 2kL - 2\varphi_R - 2\pi n$), we can write

$$D_{\Sigma(2)} \approx \frac{D^2}{1 - |R|^2 + 2j\Delta k_n L |R|^2}. \quad (92)$$

Equation (92) describes a typical resonance-frequency curve. For zero detuning, the propagation coefficient strongly increases to

$$\left[D_{\Sigma(2)}\right]_{res} \approx \frac{D^2}{1 - |R|^2}. \quad (93)$$

For the case of lossless scattering, $\left[D_{\Sigma(2)}\right]_{res} \approx D^2 / |D|^2$, and its absolute value is one.

One can show ([33]) that in the case of resonance scattering, the wave is "jammed" between these scatterers and has multiple re-reflections. It spends a long time inside the chain of scatterers. This leads to the increase of the ψ function's amplitude inside the chain. In other words, during resonant scattering the current amplitude between two scatterers increases. If we deal with lossy systems, the losses of any nature (ohmic, radiation, etc.) will increase. This can become important for the intensity of the system's radiation and for the resistance of the system with respect to ohmic heating.

3.5 Allowed and Forbidden Frequency Zones: Connection of the Parameters of Quasi-Periodic and Periodic Systems

In the present section, we use the results obtained to investigate the transmission coefficients and to establish a connection between parameters of quasi-periodic and periodic systems.

First, consider the lossless case. For such systems, the equation of the "rotation angle" φ (main branch) can be written, Equation (87a), for different magnitudes of the value α as

$$\varphi = \begin{cases} j\,\mathrm{arccosh}\left(\mathrm{Re}(e^{jkL}D^{-1})\right), & \mathrm{Re}(e^{jkL}D^{-1}) \geq 1 \\ \arccos\left(\mathrm{Re}(e^{jkL}D^{-1})\right), & -1 \leq \mathrm{Re}(e^{jkL}D^{-1}) \leq 1 \\ \pi - j\,\mathrm{arccosh}\left(\mathrm{Re}(e^{jkL}D^{-1})\right), & \mathrm{Re}(e^{jkL}D^{-1}) \leq -1 \end{cases} \quad (94)$$

If the wave number/frequency is such that the parameter $-1 \leq \cos\varphi = \mathrm{Re}\left(e^{jkL}D^{-1}\right) \leq 1$, then there are oscillating functions in the denominator of Equation (82b), and the total propagation coefficient is of the order of magnitude one. For the cases $\mathrm{Re}\left(e^{jkL}D^{-1}\right) \geq 1$ or $\mathrm{Re}\left(e^{jkL}D^{-1}\right) \leq -1$, there is a hyperbolic function in the denominator, and the propagation coefficient is exponentially damped: $\left|D_{\Sigma(N)}\right| \sim \exp(-N\varphi)$ (for $N \gg 1$). The reflection coefficient is approximately one. Thus, we have shown that allowed and forbidden zones appear for the finite chain of scatterers. These frequency zones are called "allowed" and "forbidden" correspondingly because in the allowed zone (for $N \to \infty$), the wave can propagate inside the infinite chain. In the forbidden zone, it can not. The existence of the allowed and forbidden zones is well known in solid-state physics and quantum mechanics for infinite [10] and finite [28] periodic potentials. Good penetration through the finite chain of scatterers for the allowed zone can be physically explained as a resonant scattering on the quasi-stationary energy levels of the chain of scattering potentials. These appear because of the splitting of the quasi-stationary energy levels in the system of several potential pits, or barriers (for the case of two pits (barriers), see the end of the previous section). In this case, again one has $|R| \approx 1$, $|D| \ll 1$. The wave is "jammed" between these potential pits (barriers) and has multiple re-reflections. Again, the wave function (current amplitude) strongly increases. For the chain, the increase can be much stronger in comparison to the case of two scatterers. This phenomenon was numerically investigated in [6], and can serve as the basis for constructing radiating devices, as well as for investigating the resistance of a periodic system with respect to ohmic heating.

The inclusion of radiation losses reduces the penetration in the allowed zones (see Section 4 of the present paper), but the structure of the allowed and forbidden zones remains conserved.

We now derive the connection between the parameters of the wave propagation through the infinite chain and the parameters of the exponential representation for the one-center scattering transfer matrix [28].

If the particle propagates through the infinite chain of scatterers with period L, we have

$$u(l+L) = u(l). \quad (95)$$

The ψ function can be represented as [10] (Floquet theorem)

$$\psi(l) = \exp(-jKl)\Psi(l), \quad (96)$$

$$\Psi(l+L) = \Psi(l). \quad (97)$$

The parameter K, called the quasi-pulse (or more precisely, the quasi-wave number), characterizes the translation properties of the ø function, and may be positive or negative.

$$\psi(l+L) = \exp\left[-jK(l+L)\right]\Psi(l+L) \qquad (98)$$

$$= \exp(-jKL)\psi(l) \cdot$$

Remember that in our case of periodic scatterers separated by asymptotic regions, the wave function can be represented in the asymptotic region as

$$\psi(l) = C_1 \exp(-jkl) + C_2 \exp(jkl) \cdot \qquad (99)$$

The transfer matrix, $\widehat{T}^t(L,0)$, for the column vector $\underset{\downarrow}{C}$ for a one-period translation is given by Equation (72). On the other hand, Equation (98) yields the following expression for the one-period transfer matrix:

$$\widehat{T}^t(L,0) = \exp(-jKL)\widehat{I} \cdot \qquad (100)$$

Equalizing the transfer matrices in Equations (72) and (100) leads to a homogeneous linear system for the column vectors:

$$\begin{bmatrix} e^{-jkL}\dfrac{\left(D^2-R^2\right)}{D} & e^{-jkL}\dfrac{R}{D} \\ -e^{jkL}\dfrac{R}{D}, & e^{jkL}\dfrac{1}{D} \end{bmatrix}\begin{pmatrix} C_1 \\ C_2 \end{pmatrix} = e^{-jKL}\widehat{I}\begin{pmatrix} C_1 \\ C_2 \end{pmatrix} \qquad (101)$$

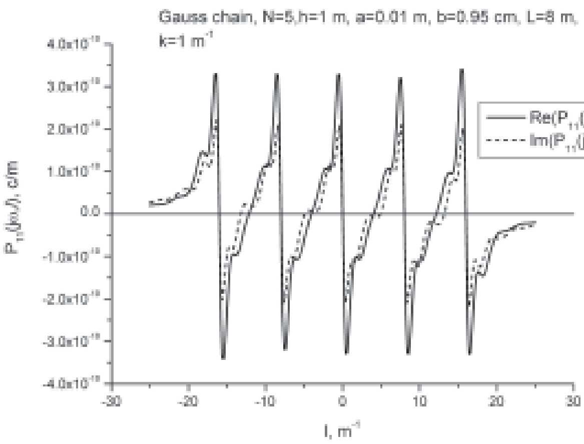

Figure 6a. The matrix of the global parameters for the Gaussian-chain wiring structure: $P_{11}(j\omega,l)$.

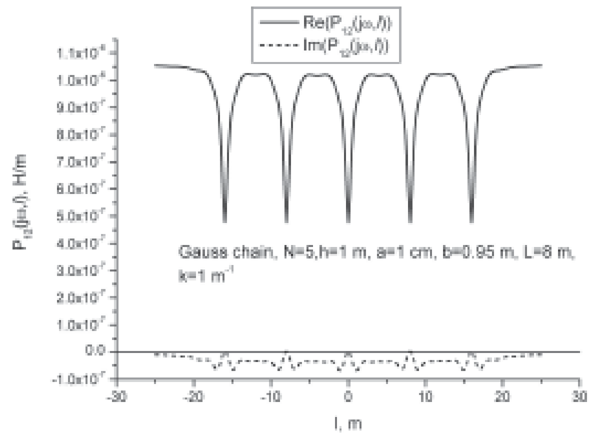

Figure 6b. The matrix of the global parameters for the Gaussian-chain wiring structure: $P_{12}(j\omega,l)$.

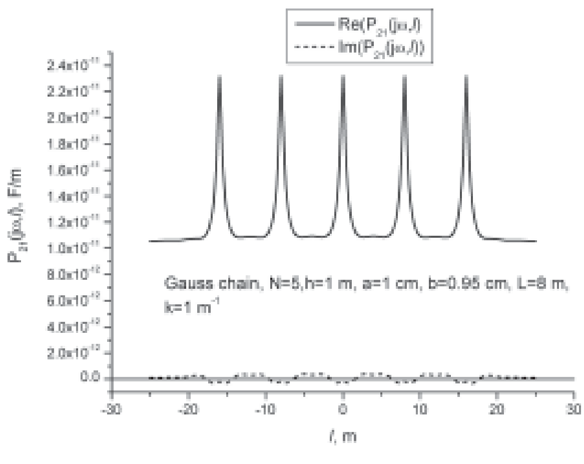

Figure 6c. The matrix of the global parameters for the Gaussian-chain wiring structure: $P_{21}(j\omega,l)$.

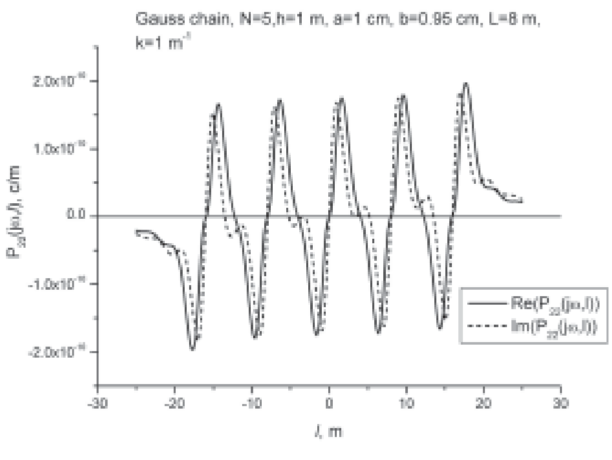

Figure 6d. The matrix of the global parameters for the Gaussian-chain wiring structure: $P_{22}(j\omega,l)$.

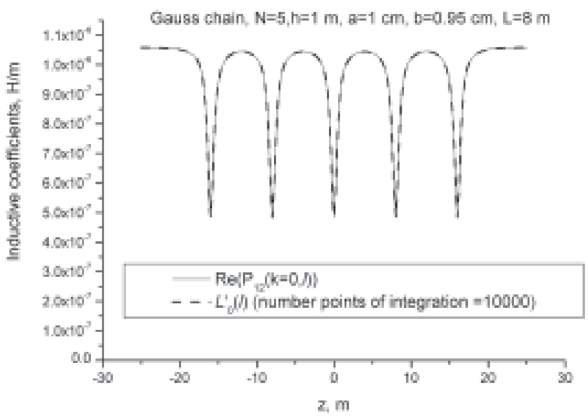

Figure 7a. A comparison of the inductive and capacitive coefficients for $k = 0$ with static inductance and capacitance for the quasi-periodic wire structure: $P_{12}(k=0,l)$ *and* $L_0'(l)$.

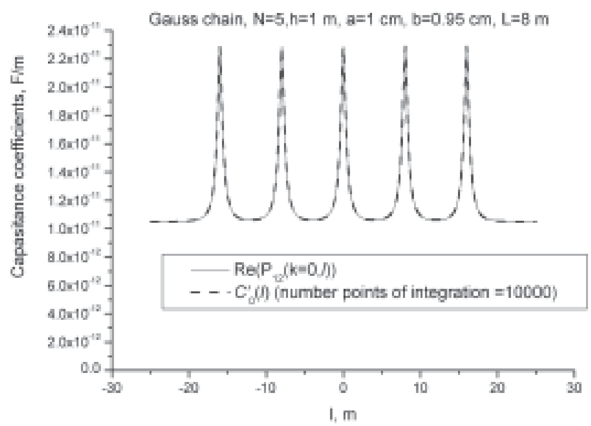

Figure 7b. A comparison of the inductive and capacitive coefficients for $k = 0$ with static inductance and capacitance for the quasi-periodic wire structure: $P_{21}(k=0,l)$ *and* $C_0'(l)$.

which is solvable if

$$\det\begin{bmatrix} e^{-jkL}\dfrac{\left(D^2-R^2\right)}{D}-e^{-jKL} & e^{-jkL}\dfrac{R}{D} \\ -e^{jkL}\dfrac{R}{D} & e^{jkL}\dfrac{1}{D}-e^{-jKL} \end{bmatrix}=0 \quad (102)$$

From this equation, we derive the dispersion relation [10] for the quasi-pulse:

$$\cos(KL)=\frac{e^{-jkL}\left(D^2-R^2\right)+e^{jkL}}{2D}=\cos(\varphi). \quad (103)$$

Equation (103) establishes the connection between the quasi-pulse (quasi-wave number), K, and the usual wave number, $k=\omega/c$.

From Equations (103) and (94), one can observe that for the allowed zones, the quasi-pulse is real (for the lossless system) and the wave can propagate along the infinite chain. For the forbidden zones, the quasi-pulse is imaginary and there is no propagation. In the case of a lossy system, the imaginary part of the propagation constant weakens the wave propagation through the allowed zones.

Here, we would like to add a few words about the propagation of energy in the infinite periodic system. Using the formulae from Section 3.2, one can obtain the following equation (in the asymptotic regions) for the averaged power propagating along the line:

$$W=\frac{Z_C\left|I_0\right|^2}{2}\left(\left|C_1\right|^2-\left|C_2\right|^2\right). \quad (104)$$

We can then use the connection of the coefficients C_1 and C_2 from Equation (101). Omitting the cumbersome calculations, we formulate the final results here. For even-numbered allowed zones, the direction of the phase propagation has the sign of Equation (104). The sign of the quasi-pulse K coincides with the direction of the propagation of the energy. For odd-numbered allowed zones, these directions are opposite. It seems that this fact is connected with the experimentally established [34] connection of the phase and group velocity of periodically loaded transmission lines, where for some frequency bands, they have opposite directions.

4. Numerical Example

In this section, we present a specific example and apply the method developed. We consider a wire of radius $a=1$ cm, coming from minus infinity at a height of $h=1$ m, performing several oscillations and running to plus infinity. The non-homogeneous part of the wire consists of five identical sections of a Gaussian form (see also Figure 1 without vertical risers):

$$x(z)=h-b\sum_{n=-2}^{2}\exp\left[-k_0\left(z-nL\right)^2\right]. \quad (105)$$

We consider a perfectly conducting uncoated wire, where only radiation losses are possible. The elements of the matrix of the corresponding global parameters $\left[P(k,l)\right]$ of the FWTL can be calculated using our perturbation theory (Equations (23)-(25)). These parameters are complex-valued and coordinate-dependent (see

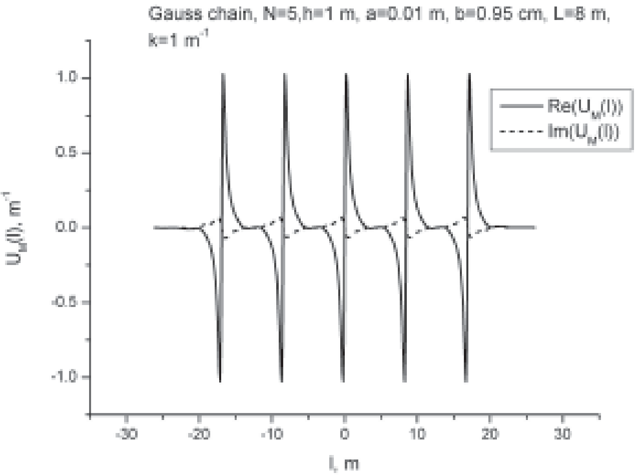

Figure 8a. Global parameters for the periodic wiring structure: $U_M(j\omega,l)$.

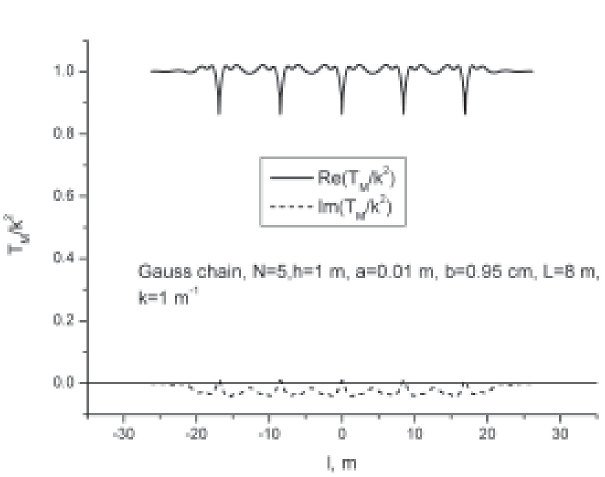

Figure 8b. Global parameters for the periodic wiring structure: $T_M(j\omega,l)/k^2$.

Figures 6a-6d). To check our calculation, we compared the results for $k=0$ with the static results for $P_{12}(k,l) \underset{k\to0}{=} L_0'(l)$ and $P_{21}(k,l) \underset{k\to0}{=} C_0'(l)$ obtained from Equations (26)-(27) (see Figures 7a and 7b). Since the wire system considered is symmetrical around the origin of coordinates, one can observe that the diagonal parameters are symmetrical and the anti-diagonal parameters are anti-symmetrical around the origin of the coordinates (see Equation (47)).

We then calculated the parameters $U_M(l)$ and $T_M(l)$ in the second-order differential Equation (29) (see Figures 8a and 8b). Note that for the symmetrical wire, $U_M(l)$ is an anti-symmetrical function of l ($U_M(-l)=-U_M(l)$) and the integral $\int_{-\infty}^{\infty} U_M(l)\,dl = 0$, which confirms the reasoning at the end of Section 3.2 (Equation (48)).

The total function $u(k,l)$ for the quasi-periodic wiring system, which is calculated with the aid of the global parameters $\left[P(k,l)\right]$, is presented in Figure 9. Note that the imaginary part of the function is not exactly periodic. The real part of the function $u(k,l)$ does not depend on frequency (at least for $0 \le k \le 1.5$ m-1) (see Figure 10a). However, the imaginary part, which defines radiation, is frequency dependent (see Figure 10b). The frequency dependency can be roughly approximated by a quadratic frequency function, $\mathrm{Im}\left[u(k,l)\right] \sim k^2$. This approximation is displayed for different points (the central maximum point of the real part of $u(k,l)$, and a relative-minimum point of the real part of this function) in Figure 11. It is interesting that the imaginary part of the function $u(k,l)$ has positive and negative signs. In our opinion, the explanation is that this complex wiring structure radiates energy at some points and absorbs energy at others.

Now, with the knowledge of the function $u(k,l)$, we can obtain the total transfer matrix of the system and, after that, we can obtain the transmission coefficient of the current wave through the system. Simple numerical methods have been developed to do that [11]. The method consists of breaking down the function $u(k,l)$ into N ($N \gg 1$) rectangular step potentials, and applying the modified method of transfer matrices.

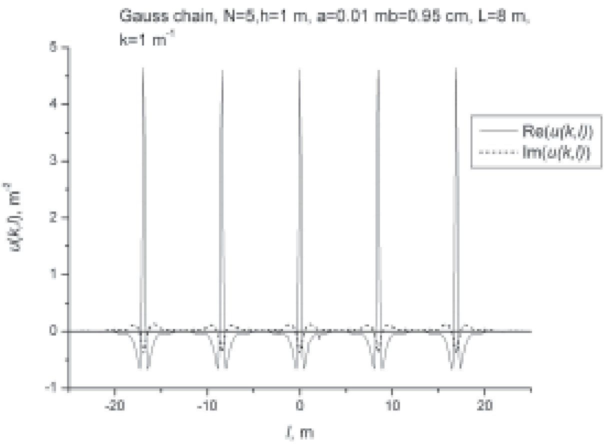

Figure 9a. The real and imaginary parts of the "potential" function $u(k,l)$ for the periodic wiring structure.

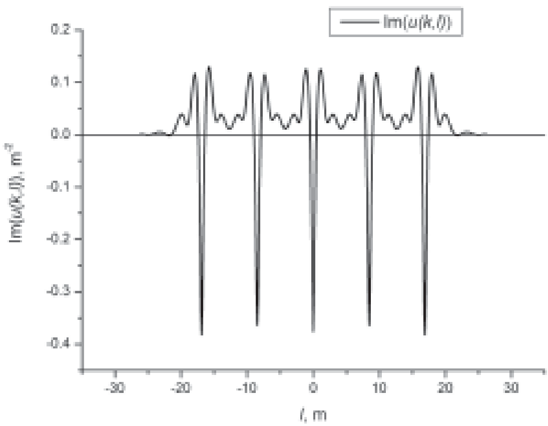

Figure 9b. The imaginary part of the "potential" function $u(k,l)$ for the periodic wiring structure.

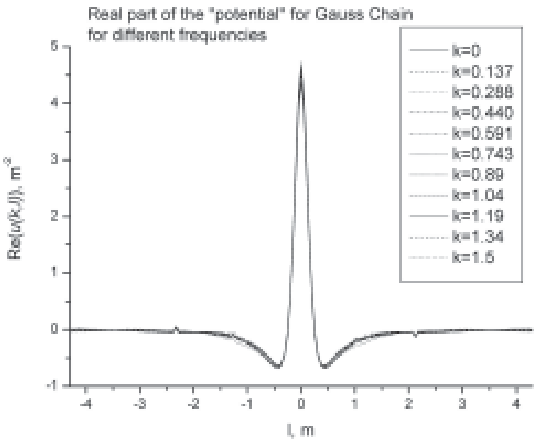

Figure 10a. The spatial dependence of the real part of the partial "potential" function $u(k,l)$ for the quasi-periodic Gauss system (the central period, $n=0$, $-4 \le z \le 4$) for different frequencies.

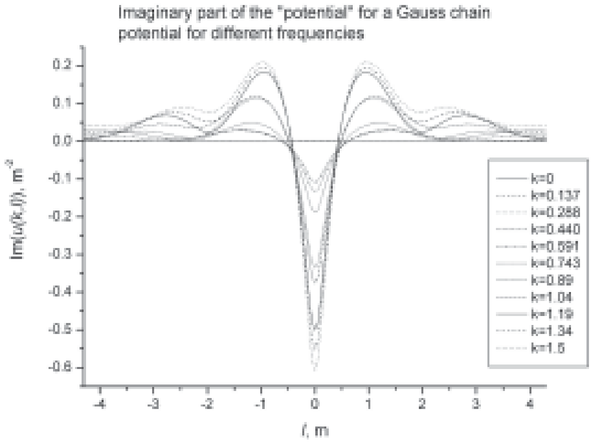

Figure 10b. The spatial dependence of the imaginary part of the partial "potential" function $u(k,l)$ for the quasi-periodic Gauss system (the central period, $n=0$, $-4 \le z \le 4$) for different frequencies.

To check our calculation, we used the MoM code *CONCEPT* [16]. The configuration of the finite wire structure that was used to model the infinite quasi-periodic structure is shown in Figure 1. The quasi-periodic system was terminated at some distance from the periodic part, and was supplemented by the vertical risers loaded by the characteristic impedance of the line: $Z_C = \eta/2\pi \ln(2h/a) \approx 317.7\ \Omega$. The system was excited by the unit voltage source $U_0 = 1\,\mathrm{V}$ at the left terminal. Under such conditions, one can show that the voltage on the right load was connected with the value of the transfer function. Of course, this connection was valid if the transmission-line approximation can be applied to the asymptotic and near-terminal regions of the line.

We display interesting results in Figure 14. The solid-line curve presents the result of the *CONCEPT* code calculation of the configuration of Figure 1, when the doubled voltage on the matched load (with unit voltage excitation) was approximately the transmission coefficient of the current wave through the system. We can recognize the allowed and forbidden zones on this curve. However, in contrast to results of previous modeling with a real function $u(k,l)$ (the dashed-line curve) [6, 7], we can see the attenuation of the transmission coefficient, which is caused by radiation. The dotted-line curve is the result of a calculation with the function $u(k,l)$ from Figure 9 by the matrix method. Quite good agreement with *CONCEPT* is observed (up to the fourth allowed zone). However, because we had to calculate the function at each frequency point (which is different from the low-frequency case), the calculation time was very long, and we had to use a quite rough division of the interval. (We divided the 50 m distance interval into 1000 subintervals and used 100 frequency points. Moreover, for this rough approximation, the calculation time with *CONCEPT* was about 30 hours!).

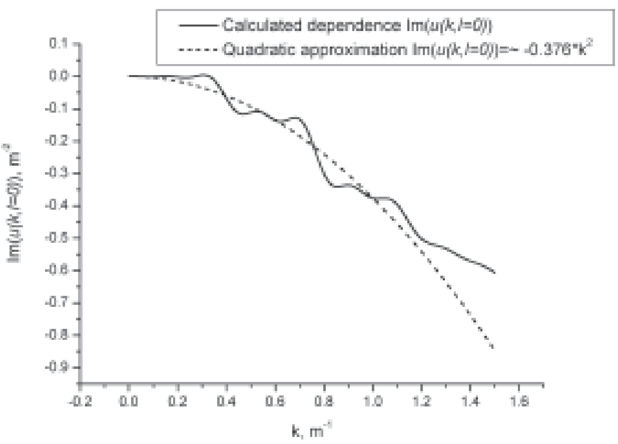

Figure 11a. The frequency dependency (exact and approximation) of the imaginary part of the partial "potential" function $u(k,l)$ for the quasi-periodic Gaussian system (the central period, $n=0$) for different spatial points: a - $l=0$.

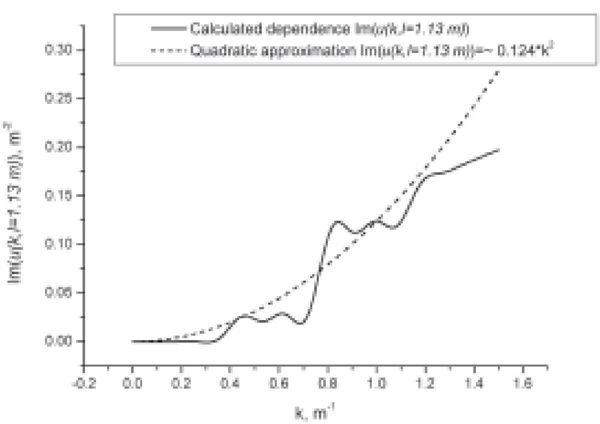

Figure 11b. The frequency dependency (exact and approximation) of the imaginary part of the partial "potential" function $u(k,l)$ for the quasi-periodic Gaussian system (the central period, $n=0$) for different spatial points: b - $l=1.13$ m.

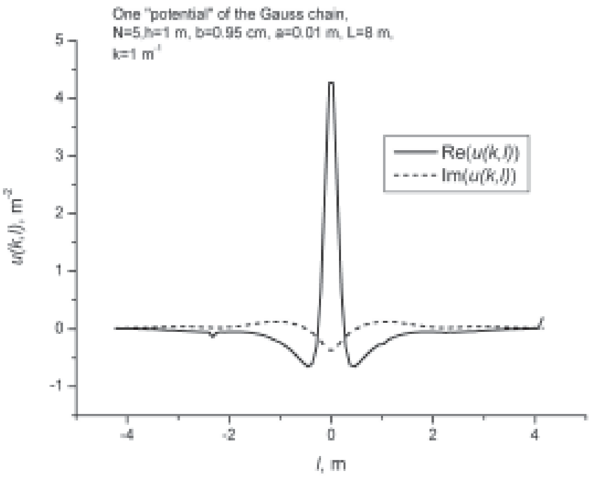

Figure 12. One singe "potential" function $u(k,l)$ (central) of the Gaussian wiring chain ($-4 \le z \le 4$).

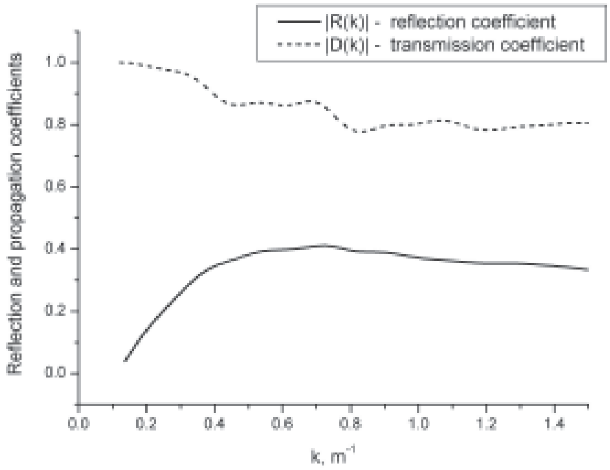

Figure 13. The reflection and transmission coefficients for the one partial "potential" function $u(k,l)$ (central) of the Gaussian wiring chain.

The difference of the two methods can be explained by the strong radiation near the vertical conductor parts (for high frequencies).

On the other hand, we used our analytical formula for the propagation coefficient of the chain. We first used the matrix method to define the reflection and transmission coefficients (see Figure 13) through one single (central) function $u(k,l)$ of the Gaussian chain (see Figure 12). This calculation was five times faster than the transfer-matrix calculations for the total system. We then used our analytical formula with Chebyshev polynomials. The result is presented in the dashed-dotted curve. The agreement with the previous curve is quite good. The difference can again be explained by two reasons: In reality, the function $u(k,l)$ was not periodic along the entire conductor, and the division was quite rough.

We also investigated the influence of ohmic losses and a dielectric coating on the propagation of current waves through the quasi-periodic wiring structure [11]. We observed that the influence of ohmic and dielectric coating losses was quite small in comparison with radiation losses.

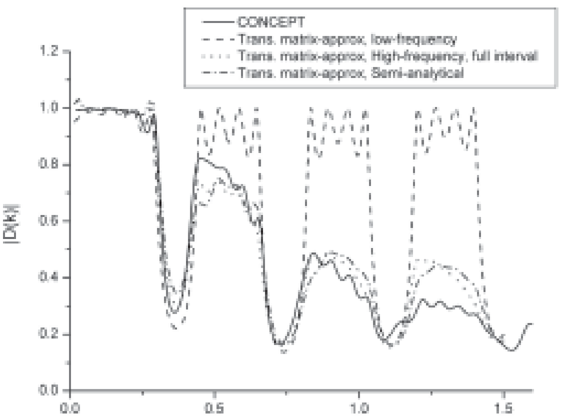

Figure 14. The transmission coefficient for the periodical structure considered, calculated by different methods.

5. Conclusion

In an exact way, we reduced a homogeneous electrodynamic problem for current waves propagating along nonuniform coated wires with finite conductivity to a transmission-line-like system of differential equations of first order (Full-Wave Transmission-Line equations – FWTL) with global parameters. We applied a simple perturbation theory to define these parameters, which was based only on the thickness of the wire. In turn, these FWTL equations could be reduced to a second-order Schrödinger-like equation with complex "potential" function, the imaginary part of which defines radiation, ohmic, and/or dielectric losses.

Using the Schrödinger-like equation we obtained, the propagation of current waves along quasi-periodic thin-wire structures was considered. Under the hypothesis that the quasi-periodic wiring system corresponds to the quasi-periodic "potential," we applied the method of transfer matrices – which was generalized to the case of complex "potentials" – and obtained an explicit form for the reflection and transmission coefficient through such a chain of potentials. The analysis of the formulae obtained showed that for some frequencies, the penetration through the chain practically happens without damping, while for other frequencies, it is suppressed. A connection between the frequency regions with allowed and forbidden zones was established. These zones are well known from quantum mechanics and solid-state physics. Taking losses into account led to decreasing propagation in the allowed zones, but the effect did not disappear.

Two other effects were noted that are connected with the penetration of the current wave through a quasi-periodic chain. The first effect appears if the "potential" function (which corresponds to one separate non-uniformity) is not easy to penetrate. In this case, for allowed zones, the current strongly increases inside the structure. This can be a cause of strong radiation or heating inside the structure. The second effect appears for the infinite periodic chain. Here, it is possible to have opposite directions of phase penetration (direction of the quasi-pulse) and power penetration.

In the future, we intend to use group-theoretical analogies [11] to investigate propagation problems. We also plan to consider the current propagation along multiconductor periodic wire structures using one of the methods described in this paper for the one-wire case: he transfer-matrix method or the standard matrix-theory method. Moreover, we will try to apply the method considered to a stochastically installed wire.

Finally, we note that the mathematical apparatus developed can be applied to other physical and engineering problems. For example, it can be applied to the penetration of electromagnetic waves through composite materials with lossy sandwiched components.

6. Acknowledgments

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Radio-Frequency Radiation Safety and Health

James C. Lin

Exposure of Dairy Cattle to Fields Associated with 735 kV AC Transmission Lines

The biological effects and potential health hazards from exposure to extremely-low-frequency (ELF) electromagnetic fields (EMF), in the 50/60 Hz range, have been the subject of world-wide attention by both the scientific community and the general public for quite a number of years. These topics occupied a significant portion of the effort of the World Health Organization's (WHO's) International EMF Project since 1996. A major concern has been that exposure to the power-frequency EMF could lead to an increased incidence of cancer in children and to other adverse health effects. The strongest scientific data supporting these concerns comes from residential epidemiological studies. These data suggest that children exposed to 50/60 Hz magnetic fields are associated with an increased risk of leukemia [1, 2].

This column has avoided all of this for the simple and obvious reason that the frequency is well below that commonly employed for telecommunications. However, a recent research article in the *Bioelectromagnetics* journal caught my interest. The article is about exposure of pregnant dairy heifers to 60 Hz magnetic fields associated with 735 kV AC transmission lines [3].

The suggestion that ELF fields may represent a health hazard to mammals has been a strong incentive for research efforts aimed toward a better understanding of the biological effects of ELF fields associated with electric power transmission. Reports of studies in the bovine species include farm surveys, retrospective examinations, and prospective analyses. The most recent study reports the results of one in a series of studies designed to evaluate the effect of ELF exposure on the bovine species to uniform 60 Hz EMF (10 kV/m; 30 μT), similar to the fields generated by 735 kV power transmission lines carrying 2000 A of current.

The previous studies have shown that dairy cattle exposed to the maximum EMF found directly under 735 kV lines had modest effects of EMF on some physiological variables. These included the cattle's feed consumption, milk yield, progesterone concentrations in blood plasma, and estrous cycle length [4-6]. The length of the estrous cycle is related to the progesterone profile across the estrous cycle. It is possible that the ELF field inhibited the nocturnal secretion of melatonin, an antigonadotrophic hormone, which had helped to maintain the plasma progesterone levels for a longer time.

The experiments provided some evidence that ELF exposure may modify the response of dairy cows to photoperiod. Dairy cows exposed to ELF EMF intensities comparable to those found under 735 kV power transmission lines and maintained under short-day photoperiods (8 h of light) showed responses analogous to those expected under long photoperiods (16 h of light), that is, a decrease in circulating or plasma melatonin and an increase in circulating prolactin. Melatonin is known to act on the pituitary gland to affect the photoperiod-induced pattern of change of prolactin secretion. Both lactating pregnant and non-lactating non-pregnant dairy cows exposed to EMF showed a decreasing tendency in melatonin concentrations during the light period, but not during the dark period. However, the plasma prolactin increased in the EMF-exposed lactating pregnant dairy cows. In the non-lactating non-pregnant group, the overall plasma prolactin concentrations were lower, while the mean plasma prolactin concentration was not affected [7].

Thyroid hormones (e.g., thyroxine) are known to play fundamental roles in developing and adult animals, among them, growth, metabolism, reproduction, and somatic differentiation. Mild variations in plasma thyroxine [8] in lactating pregnant dairy cows exposed to EMF were also found.

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Investigation of the levels of neurotransmitter metabolites, such as biogenic amine metabolites, quinolenic acid, and beta-endorphin, in the cerebrospinal fluid in dairy cows showed that there was a significant increase in quinolinic acid, and a trend towards an increase in tryptophan, suggesting a weakening of the blood-brain barrier due to exposure to the EMF [9]. Moreover, exposure to EMF has been associated with changes in the concentrations of macro and trace elements in blood plasma [10]. In particular, exposure resulted in decreased concentrations of Mg in blood plasma and in increased concentrations of Ca and P and decreased concentrations of Fe and Mn in cerebrospinal fluid.

Thus, these associations appear to establish a relationship between the exposure to ELF EMF comparable to those found under 735 kV power transmission lines and changes in a variety of production and physiological variables in dairy cattle. An attempt has been made to assess whether the EMF effects are associated with the 10 kV/m ELF electric field (EF) or the 30 μT magnetic field (MF): worst-case exposure scenarios encountered underneath 735 kV AC high-voltage transmission lines. The most recent article [3] reports experiments investigating whether the effects observed with dairy cows may be attributable to the magnetic field component alone. Indeed, the research in exposing pregnant dairy cattle to a 10 kV/m ELF electric field alone – the same strength used for ELF EMF exposures – did not show any effect on melatonin, prolactin, progesterone, or insulin-like growth factor I (IGF-I) [11].

Let us now turn to the most recent article on whether effects observed with ELF EMF exposure may be attributable to the magnetic field alone. The study included 32 pregnant Holstein heifers, weighing approximately 500 kg, at 3.1 mo of gestation and 21 mo of age [3]. The animals were subjected to artificial light with a cycle of 12 h of light followed by 12 h of darkness. During the study, lights in the chamber were turned on and off at 04:00 and 16:00 h, respectively, on each day. The animals were confined to wooden metabolism cages in control and exposure chambers for the duration of the experiment. The control chamber had the same design as the magnetic-field exposure chamber, without the coil to generate the magnetic field [12]. These chambers were designed and constructed to resemble commercial tie stall barns prevailing in Québec, Canada. During the experiment, the temperature and humidity in the control and exposure rooms were similar.

The intensity of the magnetic field (30 μT) mimicked the exposure encountered by animals standing continuously under a 60 Hz 735 kV power transmission line carrying 2000 A of current. Specifically, the control and exposure groups were exposed to horizontal magnetic fields of 0.58 μT and 30 μT, respectively, for an average of 20 hours per day.

The study was carried out in two cohorts. The first and second cohorts were conducted between October and December, 2001 (16 animals), and between February and March, 2004 (16 animals), respectively. Each cohort was divided into two groups of eight animals, one group becoming the non-exposed group and the second group being the exposed group. The animals were subjected continuously to the treatments for four weeks, except during the time required for cleaning, feeding, and sampling. After four weeks of treatment, the animals switched rooms: the non-exposed group was moved to the magnetic-field exposure chamber and the exposed group was moved to the control chamber. During this time the magnetic fields were deactivated, and for another week without treatment. Four additional weeks of exposure then followed.

The results indicated that in the present experiment, exposure of pregnant heifers to magnetic fields similar to those encountered underneath a 735 kV high-voltage transmission line for 20 hours per day during a period of four weeks produced a statistically significant higher body weight (1.2%), higher weekly body weight gain (30%), and decreased the concentration of prolactin (15%) and insulin-like growth factor 1 – IGF-1 (4%) in blood serum. Also, a residual IGF-1 effect was evident from the magnetic-field exposure. However, the serum concentrations of progesterone and melatonin were not affected by the magnetic-field exposure. Thus, some moderate effects are associated with the magnetic-field exposure of pregnant Holstein heifers.

However, the present study fell short in clarifying the question of whether the effects of 10 kV/m and 30 μT ELF EMF exposure are associated with the 10 kV/m ELF electric field (EF) or the 30 μT magnetic field (MF), the worst-case exposure field levels encountered underneath 735 kV AC high-voltage transmission lines. The observed effects of electric fields and magnetic fields were not consistent or uniform. For example, while electric-field exposure did not affect prolactin and IGF-1 concentrations, exposure to EMF resulted in elevations in prolactin and IGF-1, but a decrease under only magnetic-fields exposure. The progesterone results from both electric fields and magnetic fields were similar, but they did not agree with those obtained in similar experiments with EMF, where progesterone was elevated in pregnant lactating dairy cows. Also, exposures of pregnant dairy heifers to either electric fields or magnetic fields alone did not affect diurnal melatonin, but exposure to EMF decreased diurnal melatonin concentration in blood plasma. These confounding results may have been confounded by differences with respect to the age, production status, and reproduction condition of the cattle used, and various light regimes employed in different experiments.

It is interesting to note that exposure to 10 kV/m electric fields did not cause any change in body weight or weekly weight gain [11]. In the present experiment, the animals increased in body weight and weekly body weight gain when compared to control animals. In a similar experiment with lactating pregnant cows, EMF exposure also resulted in a greater body weight, compared to control animals [4, 13]. The consistency between body weight gains of magnetic-field- and EMF-exposed cattle suggests a possible causal relationship between the magnetic-field exposure and the animal's weight gain.

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CONFERENCE REPORTS

4th GRSS/ISPRS Joint Workshop on "Remote Sensing and Data Fusion over Urban Areas (URBAN 2007) and 6th International Symposium on Remote Sensing of Urban Areas (URS 2007)

Paris, France, 11 - 13 April 2007

According to the schedule agreed, the 4th GRSS/ISPRS Joint Workshop on "Remote sensing and data fusion over urban areas" and the 6th International Symposium on "Remote sensing of urban areas" were jointly held in Paris on April 11-13, 2007. The meeting was named "2007 Joint Urban remote Sensing Event", and set a very high the standard for future conferences of the same series. As a matter of fact, after the first attempt in March 2005, this year the two major urban conferences were supposed to provide a real joint meeting, fully exploiting the possibilities offered by the different points of views and background of their respective participants.

After the end of the conference we can actually say that the challenge was hard, but the organizing committee succeeded in putting together a really excellent sequence of presentations, paired with very good interactive sessions. Moreover, the wonderful location of the conference in Paris and the extraordinary hospitality of the local team truly concurred to make this event something to be remembered for a long time. It is therefore mandatory, at the start of this report, to thank all the people who worked hard to obtain such an outstanding result, and especially Florence Tupin and Michel Roux, Co-Chairs of the event, and the whole team of people at the Ecole Nationale Superieure des Telecommunications (ENST).

The conference was technically co-sponsored by a number of societies representing all the different scientific actors in the urban remote sensing research field: the Geoscience and Remote Sensing Society of the IEEE, four ISPRS Working Groups, ASPRS, EARSeL and URSI Commission F.

As for the technical program, the spirit of the two joint conference was captured more than in the 2005 edition by a mix of parallel and joint sessions, totaling nearly 120 papers. Parallel sessions were designed to let the peculiar aspects of urban remote sensing be discussed by those really familiar to them. General sessions were instead managed to provide insights to research areas that might be of interest to everyone, but with different perspectives. Moreover, the URBAN Technical Committee promoted 5 Special Sessions with invited talks, whose organization was instrumental to promoting the quality of the meeting. Two keynotes, by Chris Elvidge (NOAA) and George Hepner (Univ. of Utah) completed the program,

Oral and interactive sessions were equally distributed during the morning and the afternoon of a full three days' program. They were attended by more than 150 registered participants, from 26 different nations. Among the oral sessions assembled from general submissions, special interest deserved the session on change detection and urban monitoring. Well attended were also the more specific sessions on morphological processing, a really growing branch of spatial analysis for remotely sensed data in urban areas, and the session on interferometric SAR applications, with excellent papers on this rather innovative topic.

An interesting addition to the 2007 conference with respect to the past was the organization of two panel discussions, with invited guest providing their views about urban remote sensing, and interacting with the audience. Although somehow "compressed" between technical sessions, these panels offered to the participants the needs of social scientists with respect to urban remote sensing, and the current as well as future plans for data providers to the scientist working on human settlements. The panels were interesting and successful, but for the future a more adequate time period should be schedule to improve interaction and make these parts of the program even more fruitful.

Finally, a special word has to be said with respect to the social events. It was rather unusual but really exciting to have a charming and pleasant conference dinner on a small boat (the world famous "Bateaux Mouche") on the river Seine. The possibility to look at some of the most famous views of the world while enjoying the best French cooking is something that will remain for long time in the participants' mind. However, no one will also forget the delicious "Wine & Cheese buffet" during the Icebreaker party, coupling two among the most renewed French specialties with the friendly atmosphere due to the long time familiarity among many of the researchers at the meeting.

So far for the report of this successful meeting. In 2009 the joint event will move to China, a growing country with many applications for urban remote sensing and a really high appetite for research results in this field. The three applications that were received by the Search Committee for the 2009 event were indeed in two cases coming from China. The final choice was Shanghai, and the event will be organized by SAST, the Shanghai Association for Science and Technology, whose delegation was in Paris

this year and discussed with the organizers how to make next event at least as good as the one we just concluded. Everyone is invited to Shanghai for 2009: stay tuned and you'll find more information looking at the 2007 event web site http://tlc.unipv.it/urban-remote-sensing-2007/

A really important step before the 2009 event, however, is the Special Issue of the IEEE Transactions on Geoscience and Remote Sensing on "Remote sensing of human settlements: status and challenges", whose call is open. The deadline for paper submission is October 31st, and many papers from authors presenting their work at the conference are expected, as well as open submissions. Topics of interest are: land cover/land use mapping using HR and VHR data in urban areas, monitoring land use/cover and environmental changes in urban areas, feature extraction and combination for urban scene interpretation, and population and informal settlement monitoring using remotely sensed data.

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6th COSPAR Capacity Building Workshop Solar-Terrestrial Interactions: Instrumentation and Techniques (STIINTE)

Sinaia, Romania, 4 - 16 June 2007

The Committee for Space Research (COSPAR) initiated in 2001 a series of Capacity-Building Workshops with the objective to develop the scientific skills of a small group of young scientists from developing countries by a well-targeted and high level course on space data processing. The sixth workshop of this series took place in Sinaia (Romania, June 4-16, 2007), and was dedicated to the analysis of data from multisatellite space missions such as Cluster.

This workshop was attended by 24 very motivated PhD and post-doc students coming from Central and Eastern Europe: Romania, Hungary, Bulgaria, Czech Republic, Poland, Ukraine, Russia, Armenia, and Georgia. The scientific programme focused on various aspects of multisatellite missions, ranging from data analysis and instrument design to kinetic modelling, the analysis of boundaries, and the analysis of auroral processes. What the students learned during the morning lectures was directly put into practice in the afternoon, using hands-on multilevel computer sessions. Thanks to an excellent network of computers, the students had the opportunity to try out some the public data archives, to process wave-field and particle data, to carry out conjugate observations of auroral signatures, and much more.

After a first and already quite intensive week, the work culminated in the preparation of scientific projects by five teams. Each team had to address a specific problem in magnetospheric physics, gather the appropriate data or carry out the proper simulations, and get results. This led to very intensive team-work (24hrs a day), and provided an excellent opportunity for the students to interact, put together their competences and apply what had been learnt. On the last day of the school, each team defended its project to a panel of senior scientists who were participating at the simultaneous STIMM-2 (Solar Terrestrial Interactions from Microscales to global Models) meeting.

The lecture material of this workshop, together with the computer programmes and the data files are now available in a single repository, which will remain accessible; see the address below.

The lectures and computer sessions at this workshop were given by : Uli Auster (Braunschweig), Thierry Dudok de Wit (Orléans), Marius Echim (Bruxelles and Bucharest-Magurele), Edita Georgescu (Garching), Stein Haaland (Bergen and Garching), Tomas Karlsson (Stockholm), Berndt Klecker (Garching), Joseph Lemaire (Bruxelles), Octav Marghitu (Bucharest-Magurele and Garching), Götz Paschmann (Garching), Ondrej Santolik (Prague), and Joachim Vogt (Bremen). Most of the lecturers also acted as tutors for the project teams. Adrian Blagau (Garching and Bucharest-Magurele) and Dragos Constantinescu (Braunschweig and Bucharest-Magurele) joined as tutors during the second half of the school.

Getting to interact so intensively with the students will certainly be a lasting experience. This school also revealed the need for a follow-up. Missions such as Cluster, FAST, and THEMIS have provided a wealth of high-quality data that are particularly appropriate for collaborative research, and could help young scientists from Central and Eastern Europe to interact more strongly with their colleagues from other countries. The STIINTE school has confirmed the need for this and hopefully will lead to a more regular series of such events.

Two participants of STIINTE were supported by a grant from URSI commission H. The other sponsors and supporters of STIINTE were : COSPAR (host), the Romanian Space Agency (ROSA), the Romanian Authority for Scientific Research (ANCS), ESA, UNESCO, the United Nations Office for Outer Space Affairs (UNOOSA), ICSU, ITT Visual Information Solutions, the Mathworks Inc., and the Phoenix Business computer company. Satellite data were generously provided by PI and CoI institutions involved in the Cluster, FAST, and THEMIS missions.

Finally, we would like to express our deepest gratitude to the members of the local organizing committee, to the Space Plasma and Magnetometry Group from the Institute for Space Sciences, Bucharest, for the preparation of this school, for their hospitality, and for highly appreciated social events. For sure we will not forget soon the thunderstorms and the close encounters with the bears !

For more information about the school and to access the school material, see http://www.faculty.jacobs-university.de/jvogt/cospar/cbw6/ or http://iss30.nipne.ro/cbw6/

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ETTC'07: European Test and Telemetry Conference

Toulouse, France, 12 - 14 June 2007

For more than twenty years, test and evaluation professionals have gathered each year, once in Europe (in France in the odd years, in Germany in the even years), and once in the USA. June 12-14, 2007 the conference took place in Toulouse, France. It was organized jointly by the AAAF (Association Aéronautique et Astronautique de France) and the SEE (Société de l'Electricité de l'Electronique).

Topics

- Test ranges, test methods, measurement devices,
- Test data acquisition and recording,
- Test data processing and analysis,
- Test tools and simulation,
- Electromagnetic compatibility,
- Telemetry systems,
- Propagation and antennas.

Moreover, the conference included a session on "Telemetry Frequency," led by ICTS (International Consortium for Telemetry Spectrum). ICTS is an international group of telemetry practitioners, committed to promoting the benefits of the electromagnetic spectrum for telemetering applications. A number of studies, including the global usage of the telemetry spectrum, more efficient transmission techniques, and future spectrum requirements and associated technology challenges, are promulgated via the ICTS. ICTS members participate in national and international meetings for the preparation of the World Radio Conference (WRC 2007, Geneva, October-November), in particular to accompany the decision-making process on Agenda Item 1.5 "Additional spectrum for aeronautical wideband telemetry."

The opening speech of ETTC'07, "Tests Cost Reduction and European Co-Operation in French DGA," by Lieutenant General Engineer Pierre Bascary, Director of Test and Evaluation (Figure 1), was followed by the four speeches of the plenary session. These gave a general view of the importance of adequate aeronautical telemetry spectrum, the economic aspects of which were underlined by Ms. Carolyn A. Kahn, Mitre Corp., in her paper "The Economic Importance of Adequate Aeronautical Telemetry Spectrum – Why Countries Should Care."

Among the 50 selected papers, and to show the diversity of presentations, the following papers can be mentioned:

- "Testing of Flight Display for Unmanned Air Vehicles to be Used for Geophysical Survey Mission" by Michael Harris (University of South Australia): The paper reported on the test method and results of a test program specifically developed for UAVs (unmanned air vehicles) to be used in airborne geological surveying. This involved continual flying at altitudes below 400 ft, where turbulence, ground-obstacle clearance, and line-of-sight telemetry required the UAV to be semi-automated.

The Electromagnetic Compatibility (EMC) session was very rich, both in the number of papers and the variety of subjects:

- "High Power Antenna Specifically Designed for Reverberation Chamber Use," by Sergio Fernandez et al. (INTA, Spain): The paper described a high-power antenna for use in reverberation chambers during radiated susceptibility tests. The measurements of the most important parameters of the antenna were presented.
- "Sensors for Monitoring and Logging Electromagnetic Field Strength for Personal Safety and Cohort (Epidemiological) Studies," by Franck Leferink (THALES & University of Twente, The Netherlands) underlined the fact that during health studies, it appears that the actual field-strength levels are often unknown. A relationship between health and the distance to an antenna mast was made, but correlation with the actual field strength failed. So, a need exists for logging and quantifying the exposure to fields by a system to be used for widespread deployment. The same author gave an original paper on "In-Situ High Field Testing Using a Transportable Reverberation Chamber." This gave him the opportunity to describe the advantages and limitations of the various types of reverberation chambers.

Due to the ever-increasing number of test points and data flow during evaluation tests (for large aircraft, 15000 hours of simulator tests and around 2500 flight hours are necessary to achieve the final integration and to demonstrate the final compliance), several authors pointed to the vital subjects of frequency bands and synchronization among multiple units acquiring data on the vehicle (data flows are around 40 Mbps average and 80 Mbps peak). The latter has become particularly important, given the trend towards commercial buses, especially Ethernet, for system interconnection. The above matter was the subject of the two papers, "IEEE 1588 – A Solution for Synchronization of Networked Data Acquisition Systems," by Dave Heyes (ACRA Control, Ireland), and "Current Task Within the US-RCC Telemetry Group," by Tim Chalfant (Air Force Flight Test Center, USA).

Figure 1. The opening speech, by Lieutenant General Engineer Pierre Bascary from the French Ministry of Defense, addressed European cooperation for test and evaluation.

There is no doubt that propagation and antennas are key elements in the telemetry chain. We listened to several valuable papers. Among them was "Modeling Results for Multipath Interference in Aeronautical Telemetry Over Water," by Dr. Michael Rice et al. (Brigham Young University, USA). This presented results from over-water channel-sounding experiments, conducted in the Pacific ocean near Point Mugu (California). After a brief history of telemetry, the author also presented and compared the performance of cross-correlated trellis-coded Q-modulation (XTCQM) and SOQPSK modulation and space-time coding using tier-1 modulation for solving the two-antenna problem.

Serge Villers (Astrium, France), in "A Global Conformal Antenna (ACG) for Localisation (GPS & Radar Responder) Telemetry and Neutralisation Telecontrol Transmission on a Flight Test Missile," described the properties of an antenna used for the transmission of the localization, telemetry, and neutralization telecontrol signals between the missile and satellites or/and ground stations. The ACG is a conformal antenna, on which one finds patch elements with thermal protection.

In "Integration of Antennas On Board Vehicles by Computation," André Barka (ONERA, France) first reminded the audience that the modeling of real antennas mounted on an aircraft requires a model built by the

Figure 2. At Cité de l'Espace, where the gala dinner took place, the participants could enjoy an impressive collection of mock-ups.

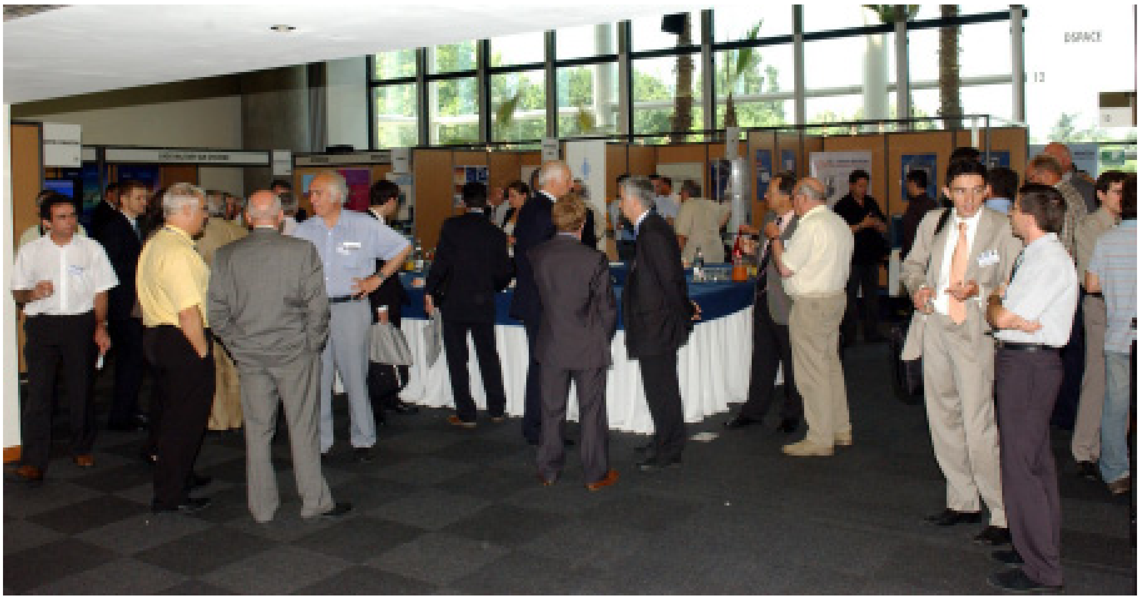

Figure 3. A view of part of the industrial exhibition associated with the conference.

company manufacturing the antenna and the company building the aircraft. Usually, the antenna placement process requires several iterations for optimizing both radiation performance and antenna position. The author's main contribution was the description as well as the results of the Domain Decomposition Method (DDM) for calculating the radiation characteristics of antennas mounted on large structures. Reducing the duration of conception and preserving the proprietary savoir faire of the antenna manufacturer were two noticeable advantages.

From ETTC'07, we can say that several subjects of research will have to be worked out in the coming years. These include efficient use of the transmission channel and dynamic allocation of frequencies to the transmission channel, including the minimization of noise generated in the neighboring channels, and the reduction of signal distortion due to multipath effects. New modulation and coding schemes will have to be implemented. In the case of a partial move of telemetry into upper bands, even more studies will be necessary.

A gala dinner took place at the Cité de l'Espace (Figure 2).

Despite the large array of subjects dealt with at the conference, there were relatively few papers on space telemetry. The latter could be an interesting subject for the next conference.

Heartfelt thanks are given to all organizers of the conference, namely Pierre Bascary, Chair of the International Program Committee; Guy Destarac, Chair of the Organizing Committee; and Jean-Claude Ghnassia, in charge of the exhibition (Figure 3).

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The 6th International Kharkov Symposium on Physics and Engineering of Microwaves, Millimeter and Sub-Millimeter Waves (MSMW'07) and Workshop on Teraherz Technology (TERATECH'07)

Kharkov, Ukraine, 25 - 30 June 2007

Abstract

The MSMW'07 Symposium took place at the V. Karazin Kharkov National University, Ukraine on June 25-30, 2007. It was organized by the Scientific Council of the National Academy of Sciences of Ukraine (NASU) on Radio-Physics and Microwave Electronics, in co-operation with the following organizations: the A. Usikov Institute of Radio-Physics and Electronics of NASU (IRE NASU), the Institute of Radio Astronomy of NASU (IRA NASU), the V. Karazin Kharkov National University (KhNU), Kharkov National University of Radio Electronics (KhNURE), the Institute of Magnetism of NASU and Ministry of Education

Science of Ukraine (MESU) (IM NASU&MESU), the Institute of Ionosphere of NASU and MESU (II NASU&MESU), IEEE AP/MTT/ED/AES/GRS/NPS/EMB Societies East Ukraine Joint Chapter, IEEE MTT/ED/COM/CPMT/SSC Societies Central Ukraine Joint Chapter, IEEE MTT/ED/AP/CPMT/SSC Societies West Ukraine Joint Chapter and the National URSI Committee of Ukraine.

This Symposium was possible thanks to the support of sponsors: URSI (Commissions D and F), IEEE ED and MTT Societies, the US Army International Technology Center-Atlantic, Research Division, the European Office of Aerospace Research and Development, AEOSR, AFRL and has also been made possible thanks to the efforts of the traditional founders and organizers of MSMW and new co-organizing establishments - IM and II NASU&MESU. The European Microwave Association (EuMA) has donated a special grant for the funding of the EuMA-MSMW Microwave Prizes awarded to the young scientists who presented outstanding papers during the Symposium.

The working days of the Symposium were June 26 to 29, 2007. Every day the program started with a plenary session of five 35-min of invited lectures in a large auditorium followed by four or three parallel sessions of 15-min of contributed papers. The working language of the Symposium was English. June 26 was filled in with social events. The number of registered participants was 232 including 133 from Kharkov, 30 from the rest of Ukraine, 27 from Russia, 8 from Mexico, 6 from Germany, 4 from Japan and Lithuania, 3 from USA and 2 from Belarus, China, France, Italy, Israel, Turkey, the United Kingdom, Canada, the Czech Republic and India. The total number of papers presented during the Symposium was about 290 (out of 322 included in the Program) including 32 invited ones.

MSMW'07 Proceedings (two-volume,1004 pages) had been published before the Symposium. The Symposium program contains papers submitted by world-known experts in microwaves and shorter wavelength science and technology, that's why participation in the Symposium has become a unique experience to Ukrainian participants.

This year, upon the initiative of the IM NASU&MESU, a Workshop on Terahertz Technologies (TERATECH'07) was organized in the framework of the MSMW'07 Symposium in the format of a special two-day session. We strongly hope that it will have remarkable impact on the ongoing and future R&D in this novel area. This is fully in line with traditionally strong emphasis placed by the MSMW program on the mm and sub-mm wave physics and technology. The extremely captivating and challenging area of nanophysics and nanoelectronics, considered as the key technology of the current century, has also been included in the agenda of the workshop.

Another important contribution to the success of MSMW'07 (organised by IM NASU&MESU) was a bus tour to the unique experimental research center "Incoherent Scatter Observatory" located in the natural reserve about 50 km southwards from Kharkov on the forested bank of the Seversky Donets River.

June 25, 2007

On June 25, the day of registration, a bus city tour was organized, enabling participants to get acquainted with the history of Kharkiv, the second-largest Ukrainian city. Remarkable historical buildings and monuments, such as the Assumption Cathedral, WW II Memorials, and the "Gosprom" complex built in the 1920s in the constructivism style of the early Soviet period were visited.

June 26, 2007

MSMW'07 started at 9:00 on June 26, 2007 with the opening ceremony at the "Large Chemical" auditorium of the Kharkov National University. The first to address the participants was the MSMW'07 Chairman, Director of IRE NASU and Vice-Chairman of the Ukrainian National URSI Committee, Prof. Vladimir M. Yakovenko. He was followed by the welcome words from other organizations behind MSMW'07: Vice-Director of IRA NASU, Prof. Alexander A. Konovalenko, Vice-Rector of KhNU, Prof. Ilyi I. Zalubovsky, Rector of KhNURE, Prof. Michail F. Bondarenko, and Vice-Director of II NASU&MESU, Dr. Valeriy N. Lysenko. The representative of Administration of the Kharkov region, Dr. Vladlen Vavilov, informed the audience about the most significant achievements of scientists and engineers of Kharkov. The next to make a welcoming speech was MSMW'07 Co-Organizer Prof. Alexander I. Nosich of IRE NASU, who spoke in the name of the IEEE AP/MTT/ED/AES/GRS/NPS/EMB Societies East Ukraine Joint Chapter.

After the opening ceremony, the first plenary session was held, consisting of five invited talks:

- G. Duxbury, N. Langford, Glasgow Quantum Cascade Laser Spectroscopy Trace Gus Analysis to Non-Linear Optics, Glasgow, UK
- V. Parshin, the Precise Microwave Resonator Spectroscopy of Gases and Condensed Media, Nizhny Novgorod, Russia
- T. Idehara, H. Tsuchiya, La Agusu, H. Mori, H. Murase, T. Saito, I. Ogawa, S. Mitsudo, Development of CW THz Gyrotrons in FIR FU, Fukui, Japan
- O. A. Tretyakov, Separation of the instantaneous and Dynamic Polarizations in Studies of Dispersive Dielectrics, Gebze, Turkey
- J. Chandezon, Evolution of C-Method within the Frames of Diffraction grating Theory Development in France, Lasmea, France

After a lunch, the symposium continued with four simultaneous sessions:

- Session W. Workshop on Terahertz Technology
- Session I. Electromagnetic Theory and Numerical Simulation
- Session II. Waves in Semiconductors and Solid State Structures
- Session VIII. Radio Astronomy and Earth's Environment Study

In those sessions, the following invited papers were presented:

- (Session W):
  - G. Annino, T. Kolodiazhnyi, M. Martinelli,Open Resonators for Millimeter-Wave Spectroscopy, Pisa, Italy
  - E. M. Ganapolskii, Z. E. Eremenko, Yu. V. Tarasov, Influence of Random Bulk Inhomogenieties on Quasioptical Cavity Resonator Spectrum, Kharkov, Ukraine
- (Session I):
  - A. Brovenko, P. Melezhik, A. Poyedinchuk, N. Yashina, G. Granet, Periodic Interface with/of Metamaterial: Resonant Absorption, Radiation, and Eigen Regimes, Kharkov, Ukraine, Aubiure, France
  - S. L. Prosvirnin, N. I. Zheludev, Planar Chiral Meta-Materials, Kharkov, Ukraine·
- (Session II):
  - M. Rendon, N. Makarov, F. Izrailev, Square-Gradient Mechanism of Surface Scaterring in Quasi-1D Waveguides with random rough Surfaces, Nice, France, Puebla, Mèxico
  - G. A. Luna-Acosta, J. A. Méndez-Bermùdez, Microwave Chaotic open Cavities. Applications of Dynamical Trapping, Puebla, Mèxico
  - N. M. Makarov, Localization Length for one-dimensional Array of Dielectric Bi-Layers with Correlated Positional Disorder, Puebla, Mèxico
- (Session VIII):
  - E. Serabyn, toward a 25 m Submillimeter Telescope, California, USA

After these sessions, all the participants were invited to enjoy the concert provided by amateur performers of IRE NASU. Later that evening, at 8:00 p.m., on the welcome party at the university restaurant, Ukrainian champagne was served. This event created a perfect atmosphere to relax after long and sometimes tiring journeys that participants had to make to reach MSMW'07.

June 27, 2007

At the plenary session, the following invited papers were presented:

- S. Vitusevich, Low Noise Microwave Devices: ALGAN/GAN High Mobility Transistors and Oscillators, Juelich, Germany
- M. Lankaster, Micromachined Microwave Components for Communications and Radars, Birmingham, UK
- Y. Kulikov, new mobile Ground-Based Microwave Instrument for Research of Stratospheric Ozone (some Results of Observation), Nizhny Novgorod, Russia
- Y. He, H. Li, A. He, S. Li, X. Zhang, C. Li, L. Sun, Q. Zhang, F. Li, Developments of HTS Microwave Filters for Applications in TD-SDMA Base Station, Satellite Receiver and Meteorological Radar, Beijing, China
- N. Pompeo, R. Rogai, S. Sarti, E. Silva, Microwave Properties of Cup Rate Superconductors in External Magnetic Fields, Roma, Italy D.M.

That day regular sessions of contributed papers consisted of:

- Session W: Workshop on Terahertz Technology
- Session III: Microwave Superconductivity
- Session IV: Wave Propagation, Radar, Remote Sensing and Signal Processing
- Session V: Vacuum Electronics

In those sessions, the following invited papers were presented:

- (Session III):
  - V. M. Pan, A. L. Kasatkin, A. A. Kalenyuk, Nonlinear Microwave Properties of High-Temperature Superconducting $YBA_2CU_3O_{7-d}$ Single Crystal thin Films, Kiev, Ukraine
  - J. Wosik, M. R. Kamel, L Xue, L.-M Xie, K Nesteruk, Houston, Superconducting 300 MHZ Phased-Array for Magnetic Resonance Imaging Applications, USA; Warsaw, Poland
- (Session IV):
  - D. M. Vavriv, O. O. Bezvesilniy, V. V. Vynogradov, V. A. Volkov, R. V. Kozhin, High-Accuracy Doppler Signal Processing: Techniques and Applications, Kharkov, Ukraine
  - K. À. Lukin, A. À. Mogyla, P. L. Vyplavin, V. P. Palamarchuk, Î. V. Zemlyaniy, Y. Shiyan, N. Ê. Zaets, V. N. Skresanov, A. I. Shubniy, V. Glamazdin, M..P. Natarov, Î. G. Nechayev, Ka-Band Ground-Based Noise Waveform SAR, Kharkov, Ukrain*e*

June 28, 2007

On the third day, the plenary session looked as follows:

- R. Heidinger, Development of the ECRH Launcher at the Iter upper port, Karlsruhe, Germany
- A. A. Savchenkov, A. B. Matsko, V. S. Ilchenko, N. Yu, L. Maleki, Microwave Photonics Applications of Whispering Gallery Mode Resonators, Pasadena, USA
- J. Wosik, C. Darne, P. Xie, J. Krupka, Resonant and Broadband Microwave Characterization of Single-Walled Carbon Nanotubes, Houston, USA; Warszawa, Poland
- F. Pérez-Rodríguez, F. Díaz-Monge, N. M. Makarov, R. Márquez-Islas, B. Flores-Desirena, Spatial-

Dispersion Effects in one-dimensional Photonic Crystals with Metallic Inclusions, Puebla, Mexico
· R. G. Barrera, A. Reyes-Coronado, A. García-Valenzuela, E. Gutiérrez-Reyes, Insights into the Problem of Reflection from Colloidal Systems: an Effective Medium Approach, Mexico-City, Mexico

Three parallel sessions of regular papers that day went along the following topics:
- Session IX. Radiospectroscopy, Complex Media, Nanophysics
- Session X. Scientific, Industrial and Biomedical Applications
- Session XI. R-Functions, Atomic functions, Wavelets, Fractals

During those sessions the following invited papers were presented:
· (Session IX):
  – K. N. Rozanov, I. T. Iakubov, A. N. Lagarkov, S. A. Maklakov, A. V. Osipov, D. A. Petrov, I. A. Ryzhikov, M. V. Sedova, S. N. Starostenko, Laminates of thin Ferromagnetic Films for Microwave Applications, Moscow, Russia
  – V Krivoruchko, A. Marchenko, A. Mazur, A. Prokhorov, Magnetic Structure and Microwave Properties of $La_{0.7}Sr_{0.3}MnO_3$ Ultrafine Particles, Donetsk, Ukraine
· (Session X):
  – Y. Feldman, A. Puzenko, P. B. Ishai, A. Caduff, A. J. Agranat, the Electromagnetic Response of Human Skin in Submillimeter Frequency Range, Jerusalem, Israel
· (Session XI):
  – V. Ponomaryov, Order Statistics Based Algorithms in Filtering of 2D-3D Images and Objects, Mexico-City, Mexico

That evening, the Symposium banquet was held at the university restaurant. It was a lovely event accompanied with live music, dance and informal speeches. The dominant tone, however, was the joy of meeting old friends and colleagues and making new ones.

June 29, 2007

On the last working day at the morning session, the following invited topics were presented:
Session VI. Solid State Devices
Session VII. Antennas Waveguides and Integrated Circuits

The plenary session consisted of one invited paper:
– G. Granet, Improvement of Fourier Modal Methods by Means of Non Conventional Coordinate Systems, Aubière, France

EuMA-MSMW Prizes

The closing ceremony of MSMW'07 took place in the "Large Chemical" auditorium of KhNU at 15:00. At first, the winners of the Best Young Scientist Paper Contest were announced and awarded with the EuMA-MSMW Prizes. This year the European Microwave Association established a 1000 Euro fund to be awarded to the winners of the Young Scientist Paper Contest. They were divided into 6 prizes: one First Prize (300 Euro), two second prizes (200 Euro), and three third prizes (100 euro). The number of papers considered for the Contest was 54. The International Awards Jury consisted of 9 members: T. Idehara, Fukui, Japan; M. Lancaster, Birmingham, UK; G. Granet, Aubiure, France; A.I. Nosich, Kharkov; Ukraine, S.V. Boriskina, Kharkov; Ukraine, N. T. Cherpak, Kharkov; Ukraine, D.M. Vavriv, Kharkov; Ukraine, F.I. Yanovskiy, Kiev; Ukraine, and B. G. Kutuza, Moscow, Russia.

The First Prize was awarded to
- **O. Kononenko**, Mathematical Model of Ohmic Losses in Coaxial Cavity Gyrotron with a Corrugated Insert, KhNU, Kharkiv, Ukraine

Two Second Prizes were awarded to
- **Aleksey Gubin**, Grazing Incidence Reflectivity of High-TC Superconductors: MM Wave Technique, a new Approach to Study and first results, IRE NASU, Kharkiv, *Ukraine*
- **Stanislav Sekretarov**, Development of A Ka-Band Slotted Antenna Array, IRA NASU, Kharkiv, Ukraine

Three Third Prizes were awarded to
- **Ekaterina Yarko,** using of PSTD-Method and Transmission Matrixes for Research of Light Diffraction by Periodic Nanostructures, KhNU, Kharkiv, Ukraine
- **Olga Polischuk,** Tunable Screening of Inter-Contact Plasmons by a recessed Gate in Field-Effect Transistor with two-dimensional Electron Channel, Institute of Radio Engineering and Electronics RAS, Saratov, Russia
- **Oksana Shramkova,** Nonlinear Effects in the Layered Semiconductor Structures, IRE NASU, Kharkiv, Ukraine

Besides, 3 honorary mentions were made for the "Next to the best papers".
- **Sergey Boruhovich**, Three-Dimensional Chirality Degree Model, IRA NASU, Kharkiv, Ukraine
- **Vitaliy Lomakin**, Phenomena of Resonant Transmission through Perforated Metal Plates, University of California, San Diego, USA
- **Sergey Skripka**, Planar Waveguides and Resonators of mm- and submm Bands, Kiev National University, Kiev

The colorful certificates of the EuMA-MSMW Prize, signed by Prof. R. Sorrentino, President of the European Microwave Association and by Prof. Vladimir M.

Yakovenko, MSMW'04 Chairman, were handed to the winners by Prof. Felix. J. Yanovsky on behalf of EuMA.

Besides the EuMA-MSMW Prizes, another Young Scientist Award was granted by the IEEE East Ukraine Joint Chapter for the best poster paper presented at the symposium. It consisted of a certificate and a 100 USD money prize. This award was given to

- **Aleksandr Barannik,** Whispering-Gallery-Mode Sapphire Resonators in the Forms of Cylindrical Disc and Cone for Millimeter-Wave Resistance Measurements of HTS Films, IRE NASU, Kharkiv, Ukraine

The final closing address was done by Prof. Vladimir M. Yakovenko. He announced that the next Symposium, MSMW'07, will be held again in Kharkov in June, 2010. He thanked the participants and organizers for creating an unprecedented forum for scientific discussions and expressed the hope that the MSMW Symposia series will be continued. He also expressed gratitude to international institutions such as IEEE, URSI, and EuMA for their valuable and timely support.

June 30, 2007

On the weekend after the Symposium, the participants were proposed a social program in order to relax after four days of intensive work and to strengthen the links originated at the Symposium.

On Saturday, June 30, a full-day bus tour was organized from Kharkov to the Experimental Center of the Institute of Ionosphere of NASU&MESU. It is located in a picturesque Ukrainian countryside at the junction of the Mzha and Siverskiy Donets rivers and possesses two radars for the incoherent scattering. The radars of the meter waveband include the biggest in Europe bi-reflector zenith-looking parabolic 100 m in diameter antenna and a full-revolving 25 m in diameter antenna, 3.6 MWt transmitter, high-stability sensitive receiver of 150 K noise temperature and short-wavelength heating test bench. A method of incoherent scattering is based on the scattering of radiowaves by thermal fluctuations of electron density. The method allows one to obtain estimates of electron concentration, ionic and electronic temperatures, plasma drift velocities, ion structure, and collision frequency of ions and electrons with neutral particles. Parameters of ionosphere are determined in the wide range of altitudes from 70 to 1500 km, both below and above the main ionization maximum. After visiting the facilities of the Experimental Center, hosted by the Vice Director of the Institute of Ionosphere of NASU&MESU, Prof. V. Lysenko, and the Center's personnel, a barbecue party was held.

Prof. Vladimir M. Yakovenko
E-mail: yakovenko@ire.kharkov.ua

Workshop on Ionosphere-Modelling, Forcing and Telecommunications (IRI-COST296)

Prague, Czech Republic, 10 - 14 July 2007

The Workshop on Ionosphere-Modelling, Forcing and Telecommunications was held in Prague, Czech Republic, from 10 to 14 July 2007, and was attended by 103 participants from Africa, Asia, Europe, Northern America and Southern America. At the same time, the Management Committee meeting of COST296 and a similar meeting of IRI (International Reference Atmosphere working group of URSI/COSPAR) were held. 67 oral and 50 poster papers were presented. The publication of these papers is foreseen in a special issue of Advances in Space Research (as usual for IRI workshops).

Since scientific interests of IRI and COST296 communities overlap and several scientists are working in both bodies, a joint workshop has been organized. A previous joint workshop was held in Kühlungsborn, Germany, in 1997. Since IRI is a joint Working Group of COSPAR and URSI, URSI co-sponsored the Workshop.

Five invited papers in the first part of the workshop were focused on providing complex information on COST296 to IRI community, and several others treated specific COST296 topics like HF channels, ionospheric scintillations, and ionospheric influence on performance of various GNSS-GPS-based systems (positioning etc). Several other papers dealt with total electron content (TEC) measured using GPS signals, and with GPS-based radio occultation (RO) measurements of electron density profiles regionally as well as globally using low Earth orbiting (LEO) satellites like CHAMP or COSMIC/FORMOSAR-3. Behaviour of the ionosphere during geomagnetic storms derived from ground-based and satellite measurements and studies of variability of the equatorial ionization anomaly were presented in another group of papers. Another topic treated in several papers was modelling and observations of the topside ionosphere with particular attention to IRI and NeQuick models. Several papers were focused on the lower part of the ionosphere, the E and D region. Another group of papers presented new results in forecasting behaviour of the ionosphere, particularly using neural network-based methods. Important part of the workshop were papers testing the IRI model with various measurements, which showed strong as well as weak features of the IRI 2001 version and in a few cases already IRI 2007 version. Lower atmospheric forcing of the ionosphere via atmospheric waves as well as behaviour of electron temperature in the topside ionosphere was mentioned in a couple of papers.

The workshop presented further progress in development of the IRI model and the usefulness of collaboration of IRI and COST296 scientific communities, many members of them being also active in other sub-commissions of COSPAR commission C.

Prof. Reinisch, chairman of IRI and chairman of the Program Committee, was asked to prepare a broader scientific report to be published in Space Research Today and in The Radio Science Bulletin.

Jan Lastovicka
E-mail: jla@ufa.cas.cz

International Symposium on Radio Systems and Space Plasma (ISRSSP'07)

Sofia, Bulgaria, 2 - 5 September 2007

The First International Symposium on Radio Systems and Space Plasma was held in the Park Hotel Vitosha, Sofia, Bulgaria, from September 2 to 5, 2007. The Symposium was organized by the Bulgarian URSI Committee, the Institute of Mathematics and Informatics at Bulgarian Academy of Sciences, the Technical University of Sofia and was supported by International Union of Radio Science (URSI). There were 70 participants from 10 different countries.

The symposium was opened in the morning of September 2, 2007. We have listened to the welcome messages of the Chair of ISRSSP'07, Prof. Blagovest Shishkov, and the URSI President, Prof. François Lefeuvre and addresses of Prof. Nikola Sabotinov, President of the Bulgarian URSI Committee and Prof. Kamen Veselinov, Rector of the Technical University of Sofia.

The Symposium program consisted of 2 plenary lectures, 9 contributed papers, 8 posters and 27 invited papers: Bulgaria (3), Czech Republic (1), France (1), Germany (1), Japan (13), Romania (2), Russia (1), UK (1) and USA (4).

The Symposium provided a scientific forum covering the topics of URSI Commissions C and H (toward space plasma) and Space Solar Power System (SSPS). More exactly it is a three component scientific body event, concerned with the international development and application of the broad range of aspects beginning from the intelligent methods of radio-communication systems and signal processing, through the updated methods for analyzing non-linear interactions of space plasma, up to radio science aspects of SSPS, ranging from microwave power generation and transmission to the effects on humans and the potential interference with communications, remote sensing, and radio astronomy observations. URSI has been recognized as the scientific body to coordinate this research field on an international basis and to open a forum for the debate of the above aspects.

Radio and its application have been one of the key/core technologies during the whole 20th century. It has expanded the horizon of human activity into modern life style and is now an indispensable media to human life. Its main application today is telecommunications, especially mobile communications and radio links among various computers and computer controlled systems. However, radio can be used for other purposes in the light of human welfare. To maintain the human welfare and even to avoid perishing disaster during this century, energy, food and environmental issues should be seriously discussed, steered and controlled. In this regard, power transmission via microwave is one of the new technological frontiers in the scope of the Solar Power Satellite (SPS) which will provide a clean and limitless energy resource from space. Since P. E. Glaser proposed an idea to place a power station in the geosynchronous orbit in space in 1968, the SPS research was booming in the 1970's in the USA. The SPS research, however, entered into the dark era in the early 1980. During this era, however, SPS research has been continued in Japan and other countries.

The conference began with keynote plenary talks over the following areas covered by the scientific program and presented by their distinguished leaders:

- **Maurice BELLANGER**
  CNAM - Electronique et radiocommunications, France
  Spectrum Analysis in Future Multiantenna Radiocommunication Systems
- **Gottfried MANN**
  Astrophysikalisches Institut Potsdam, Germany
  The Radio Sun
- **Kozo HASHIMOTO, Hiroshi MATSUMOTO**
  Research Institute for Sustainable Humanosphere, Kyoto University, Japan
  URSI White Paper on Solar Power Satellite (SPS) Systems and ICWG Report

These areas could be enlarged due to URSI's ten Scientific Commissions covering a broad range of aspects involved in SPS systems.

Our invited, contributed and poster talks presented original contributions in the following (but not limited to) broadly – defined topics: Radio-Communication and Telecommunication Systems; Spectrum and Medium Utilization; Information Theory, Coding, Modulation and

Detection; Signal and Image Processing in the area of radio science; The generation (i.e. plasma instabilities) and propagation of waves in plasmas; The interaction between these, and wave particle interactions; Plasma turbulence and chaos; Spacecraft-plasma interaction; SPS Radio Technologies; Influence and Effects of SPS-Radio Science Aspects; Radio Science Issues for Further Study; URSI White Paper.

In order to provide meaningful impact to scientific and engineering communities, we have created a web page of ISRSSP'07: http://www.math.bas.bg/isrssp/

This symposium has been organized jointly by the International Union of Radio Science (URSI), the Bulgarian URSI Committee, the Institute of Mathematics & Informatics (BAS) and the Technical University of Sofia, who was of great help in organizing the ISRSSP. I would like to express our great thanks to all these organizations for their valuable support in organizing successfully this international scientific event. Last but not least I would like to thank the secretary of ISRSSP, Dr. Canka Shishkova, for her permanent and valuable help.

In addition to scientific sessions, the participants have enjoyed beautiful Sofia and the nearby historic and scenic sites such as Rila Monastery.

Let's end with the words of François Lefeuvre "On behalf of the URSI Board, and on my proper name, allow me to congratulate the ISRSSP'07 organisation committee for the selected scientific topics. Allow me also to congratulate the participants for their broad view of radioscience. A half day "Forum on RadioScience and Telecommunication" will be organized at the 2008 URSI GA in Chicago. The participants to the ISRSSP symposium have the chance to participate in that forum. In conclusion, the International Symposium on Radio Systems and Space Plasmas is of great interest for URSI."

Blagovest Shishkov
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CONFERENCE ANNOUNCEMENTS

The 10th Specialist Meeting on Microwave Radiometry and Remote Sensing Applications (MicroRad 2008)

Florence, Italy, 11 - 14 March 2008

The 10th Specialist meeting on Microwave Radiometry and Remote Sensing Applications (MicroRad 2008) will be held in Florence on 11-14 March 2008 organized by the Center for Microwave Remote Sensing (Ce.Te.M.) and the Institute of Applied Physics of Florence (IFAC-CNR), Italy. Past meetings were held in Rome (three times), Florence (two times), Boulder (two times), Boston, and Puerto Rico (the last one). The meeting has been always sponsored by URSI Comm-F. Other sponsors are ESA, JAXA, GRSS, IEEE Italy Section, and ASI (Italian Space Agency).

The meeting, which is the most important specialist meeting on microwave radiometry, aims to provide an international forum for reporting progress and recent advances in microwave radiometry for environmental remote sensing and global monitoring of the Earth. The meeting is planned over four days, with eight organized oral and poster sessions on new research results and instrument design in the field of microwave remote sensing of land, ocean and atmosphere. We expect about 150 scientists, mostly from US and Europe, will be participating.

Topics

Suggested topics of the meeting are:

- Theory of microwave radiometry
- Inversion of radiometric data
- Radiometric observations of the atmosphere
- Polarimetric radiometry and applications
- Novel Radiometric imaging systems
- Observation from advanced satellite systems
- Potential new applications for climate and global change
- New technological development
- Anticipated radiometric missions

The Meeting Chairs are Simonetta Paloscia and Giovanni Macelloni (IFAC-CNR, Florence, Italy) and the Steering Committee is composed by Al Gasiewski, University of Colorado Boulder, CO (USA), Martti Hallikainen, HUT, Espoo, Finland, Jin Au Kong, MIT, Cambridge, MA (USA), Roger Lang, G. Washington University- Washington DC (USA), Frank Marzano, University "La Sapienza", Rome, Italy , Eni Njoku CalTech/ NASA JPL, - Pasadena, CA (USA), Simonetta Paloscia, CNR-IFAC, Florence, Italy, Paolo Pampaloni, CNR-IFAC, Florence, Italy, Nazzareno Pierdicca, University "La Sapienza", Rome, Italy , Steven Reising, Colorado State University, Fort Collins, CO (USA), Domenico Solimini, University Tor Vergata, - Rome, Italy, Calvin T. Swift, University of Massachusetts, Amherst, MA (USA), Jothiram Vivekandanan, - NCAR, Boulder, CO (USA) andEd R. Westwater, CIRES- University of Colorado Boulder, CO (USA)

The members of the Steering Committee will organize specialized sessions, and will decide on the distribution of regular papers within the sessions. The Proceedings of the conference are usually published in IEEE – IEEEXplore system, in order to guarantee a high visibility of the papers.

The deadline for abstract submission is October 22, 2007.

Contacts

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Web Site: http://www.microrad2008.org.

9th International Workshop on Finite Elements for Microwave Engineering

Bonn, Germany, 8 - 9 May 2008

The International Workshop on Finite Elements for Microwave Engineering is a highly focussed biennial event. It provides an ideal meeting place for researchers and practitioners active in theory and application of the finite element method (FEM) in radio frequency and microwave engineering. There will be oral sessions only. The Workshop is chared by R. Dyczij-Edlinger, Saarland University, Germany and T. Eibert, Universitaet Stuttgart, Germany and co-chaired by G. Pelosi, University of Florence, Italy .

The Workshop takes place in the city of Bonn, the birthplace of Ludwig van Beethoven and former capital of West Germany. The conference site, Hotel Dreesen, is beautifully located at the Rhine river, with a scenic view of the surrounding wine lands and hills.

Topics

Technical areas covered by the Workshop include, but are not limited to

- Adaptive Methods
- Advanced FEM Techniques Formulations, Solvers, Discrete Representations
- Optimization Techniques, Parameter Space Sweep
- Time domain FEM Theory and Applications
- Mathematical Aspects of FEM
- FEM Applications Antennas, Materials, Bio-electromagnetics, Electromagnetic Compatibility, Circuits and Circuit Boards
- Hybrid Methods – Theory and Applications FE-BI/FDTD, FE-FV/Circuit Simulators/High-Frequency Techniques, Coupled Physics FEM for RF-MEMS
- FEM Applications Waveguides, Components, Active Devices, Lumped Elements
- Multigrid- and Domain Decomposition Methods
- CAD / Meshing Advances and Tools
- FEM Applications in Other Disciplines

Abstracts

One-page abstracts of no more than 500 words are due by 25 January 2008. Full papers based on selected workshop contributions will be published in a special issue of the journal Electromagnetics.

Contact

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Saarland University, Building C63
P.O. Box 15 11 50
D-66041 Saarbrucken, Germany
Phone: +49 681 302 2551, Fax: +49 681 302 3157,
Web: http://www.lte.uni-saarland.de/fem2008/

URSI CONFERENCE CALENDAR

September 2007

International Conference on Electromagnetics in Advanced Applications (ICEAA 07)
Torino, Italy, 17 - 21 September 2007
cf. Announcement in the Radio Science Bulletin of December 2006, p. 79.
Contact: Prof. Roberto D. Graglia, Chair of ICEAA Organizing Committee, Dipartimento di Elettronica, Politecnico di Torino, Corso Duca degli Abruzzi, 24, 10129

Torino, Italy, E-mail: roberto.graglia@polito.it or Prof. Piergiorgio L. E. Uslenghi, Chair of ICEAA Scientific Committee, Department of ECE (MC 154), University of Illinois at Chicago, 851 South Morgan Street, Chicago, IL 60607, USA, E-mail: uslenghi@uic.edu.

EMC Zürich 2007
München, Germany, 24-28 September 2007
Contact : Prof. Dr. P. Russer, Symposium President, TU Munich, Germany and Prof. Dr. R. Vahldieck, General Chairman, ETH Zürich, IFH, Switzerland, Tel: +41 44 632 2951, Fax: +41 44 632 1198 , e-mail: info@emczurich.ethz.ch , http://www.emc-zurich.ch/

STAMMS2 - Spatio-Temporal Analysis of Multipoint Measurements in Space
Orleans, France, 24 - 28 September 2007
Contact: STAMMS2 sécretariat, LPCE/CNRS and Université d'Orléans, 3A avenue de la Recherche Scientifique, F-45071 Orléans, France, Fax: +33 238 63 1234, Web: http://stamms2.cnrs-orleans.fr

October 2007

From Planets to Dark Energy: the Modern Radio Universe
Manchester, UK, 1-5 October 2007
cf. Announcement in the Radio Science Bulletin of December 2006, p. 80.
Contact : Prof. Ph. Diamond, Jodrell Bank Observatory, University of Manchester, Macclesfield, Cheshire SK11 9DL, UK, fax +44 1477-572618, E-mail : pdiamond@jb.man.ac.uk , majordomo@jb.man.ac.uk , Web : http://www.jb.man.ac.uk/mru2007/

Scientific and Fundamental Aspects of the Galileo Programme
Toulouse, France, 2-4 October 2007
cf. Announcement in the Radio Science Bulletin of December 2006, p. 81.
Contact : Dr. Bertram Arbesser-Rastburg, ESA-ESTEC, TEC-EEP, Postbus 299, NL-2200 AG Noordwijk, the Netherlands, fax +31 71 565-4999, Organisation Committee: Martine.Segur@anae.fr, Scientific Committee: Clovis.de.Matos@esa.int, Web : www.congrex.nl/07a06

Metamaterials 2007 - The First International Congress on Advanced Electromagnetic Materials for Microwaves and Optics
Rome, Italy, 22-26 October 2007
cf. Announcement in the Radio Science Bulletin of December 2006, p. 81.
Contact : Dr. Said Zouhdi, Electrical Engineering, University Pierre et Marie Curie, Paris, France + Laboratoire de Genie Electrique de Paris LGEP-Supelec, Fax : + 33 1 69 41 83 18, E-mail : sz@ccr.jussieu.fr

11th URSI Commission F Triennial Open Symposium on Radio Wave Propagation and Remote Sensing
Rio de Janeiro, Brazil, 30 October - 2 November 2007
cf. Announcement in the Radio Science Bulletin of March 2007, p. 57.
Contact : Dr. Emanoel Costa, CETUC-PUC/Rio, Brazil (Chair, Propagation), Luciano Vieira Dutra, INPE, Brazil (Chair, Remote Sensing), Web: http://wwwusers.rdc.puc-rio.br/ursif/

November 2007

APSAR 2007 - Asia-Pacific Conference on Synthetic Aperture Radar
Huangshan city, Anhui province, China, 5-10 November 2007
Contact : Mr. Mengqi Zhou, Chinese Institute of Electronics, P.O. Box 165, 100036 Beijing, China, Phone : +86 10-6816 0825, Fax : +86 10-6828 3458, E-mail : mqzhou@public.bta.net.cn , Web: http://www.cie-china.org/APSAR2007/index.htm

EuCAP 2007 - The Second European Conference on Antennas and Propagation
Edinburgh, United Kingdom, 11-16 November 2007
Contact : The Institution of Engineering and Technology, Paul Newell / Simon Blows / Emily Woodman, Event Services, Michael Faraday House, Six Hills Way, Stevenage, Hertfordshire SG1 2AY, UK, Tel: +44 1438 765648/ 765653, Fax: +44 1438 765659, Email: eucap@ietevents.org, http://www.eucap2007.org/

VLF 2007 - 10th International VLF Seminar
Zvenigorod, Moscow Region, Russia, 12 - 15 November 2007
Contact: VLF2007, IZMIRAN Troitsk, Moscow Region, 142190 Russia, Tel: +7 (495)3340120, Fax: +7 (495) 3340124, Email: vlf2007@izmiran.ru, WEb: http://www.izmiran.ru/VLF2007

December 2007

APMC 2007 - 2007 Asia-Pacific Microwave Conference
Bangkok, Thailand, 11-14 December 2007
cf. Announcement in the Radio Science Bulletin of September 2006, p. 51.
Contact : Dr. Chuwong Phongcharoenpanich, General Secretary of APMC 2007, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand, E-mail:kpchuwon@kmitl.ac.th, Web:http://www.apmc2007.org/

February 2008

ICRS 2008 - International Conference on Radio Science
Jodhpur, India, 25-29 February 2008
cf. Announcement in the Radio Science Bulletin of June 2007, p. 56.

Contact : Prof. O.P.N. Calla, Director ICRS, OM-NIWAS, A-23 Shastri Nagar, Jodhpur 342003, Rajasthan, India, Fax +91 291-2626166, E-mail : opncalla@yahoo.co.in , E-mail : http://radioscience.org/default.html

March 2008

MicroRad 2008 - the 10th Specialist Meeting on Microwave Radiometry and Remote Sensing of the Environment
Florence, Italy, 11 -14 March 2008
cf. Announcement in the Radio Science Bulletin of September 2007, p. 55 -56
Contact: Dr. Simonetta Paloscia, CNR-ITAC, Via Madonna del Piano, 10, 50019 Sesto Fiorentino, Firenze, Italy, Fax: +390 55 5226467, Email: info@microrad2008.org, Web: htpp://www.microrad2008.org

May 2008

IES2008 - 12th International Ionospheric Effects Symposium
Alexandria, Virginia, USA, 6-8 May 2008
Contact : JMG Associates Ltd., IES Symposium Managers, 8310 Lilac Lane, Alexandria VA 22308, USA, Fax: +1-703-360-3954, Web : http://www.ies2008.com/index.html

META'08, NATO Advanced Research Workshop:Metamaterials for Secure Information and Communication Technologies
Marrakesh, Morocco, 7 - 10 May 2008
cf. Announcement in the Radio Science Bulletin of June 2007, p. 57.
Contact: Prof. Saïd Zouhdi, Laboratoire de Génie Electrique de Paris (LGEP-Supélec), Plateau de Moulon, 91192 Gif-Sur-Yvette Cedex, France, Tel: +33 1 69851660, Fax: +33 169418318, Email: said.zouhdi@supelec.fr, Web site: http://meta.lgep.supelec.fr

9th International Workshop on Finite Elements in Microwave Engineering
Bonn, Germany, 8 - 9 May 2008
cf. Announcement in the Radio Science Bulletin of September 2007, p. 55.
Contact: FEM2008 Secretariat, c/o Theoretische Elektrotechnik, Saarland University, Building C63, P.O. Box 151150, D-66041 Saarbrucken, Germany, Tel: +49 681 302 2551, Fax: +49 681 302 3157, Web: http://www.lte.uni-saarland.de/fem2008

ISEA-12 - 12th International Symposium on Equatorial Aeronomy
Crete, Greece, 18 - 24 May 2008
Contact: Christos Haldoupis, Physics Department, University of Crete, Heraklion, Crete 71003, Greece, Tel: +30 2810 394222, Fax: +30 2810 394201, Email: isea12@physics.uoc.gr, chald@physics.uoc.gr, Web: http://isea12.physics.uoc.gr/

July 2008

COSPAR 2008 - 37th Scientific Assembly of the Committee on Space Research and Associated Events "50th Anniversary Assembly"
Montreal, Canada, 13 - 20 July 2008
cf. Announcement in the Radio Science Bulletin of March 2007, p. 58.
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, E-mail : cospar@cosparhq.cnes.fr, Web : http://www.cospar2008.org

EUROEM 2008 - European Electromagnetics
Lausanne, Switzerland, 21-25 July 2008
Contact : EUROEM'08, EPFL-STI- LRE, Station 11, CH-1015 Lausanne, Switzerland, Tel : +41-21-693 26 20, Fax : +41-21-693 46 62, E-mail: information@euroem.org, Web : http://www.euroem.org

August 2008

URSI GA08 - XXIXth URSI General Assembly
Chicago, IL, USA, 9-16 August 2008
Contact : URSI Secretariat, c/o INTEC, Ghent University, Sint-Pietersnieuwstraat 41, B-9000 Ghent, Belgium, Tel. : +32 9 264 3320, Fax : +32 9 264 4288, E-mail : info@ursi.org

September 2008

EMC Europe 2008
Hamburg, Germany, 8 - 12 September 2008
Contact: EMC Europe 2008, Harburger Schlossstrasse 6 - 12, 21079 Hamburg, Germany, Tel: +49 40 76629 6551, Fax: +49 40 76629 6559, Email: info@emceurope2008.org, Web: http://www.emceurope2008.org

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

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

News from the URSI Community

NEWS FROM A MEMBER COMMITTEE

HUNGARY

THE MOBILE-OPTICAL-WIRELESS (MOW) CONFERENCE

Budapest, Hungary, 14 - 18 May 2007

The Mobile-Optical-Wireless (MOW) conference week was held in Budapest, Hungary from 14 to 18 May, 2007. It was organized in cooperation with the URSI Hungarian National Committee, IEEE AP/ComSoc/ED/MTT Societies Joint Chapter in Hungary, the European Microwave Association as well as the Budapest University of Technology and Economics, the Hungarian Academy of Sciences and the Scientific Society for Telecommunications and Informatics.

The MOW conference week was composed of 5 different meetings: the 12th Colloquium on Microwave Communications (Microcoll), the 7th Mediterranean Microwave Symposium (MMS), the 18th International Electromagnetic Fields and Materials (EMFM) conferences, as well as an optical communications Workshop and Summer School.

The main part of the conference week was the joint organization of two conferences: the Microcoll and the Mediterranean Microwave Symposium. In the program of the 3 day long two parallel held conferences there were 130 papers including 19 invited talks. The participants came from 32 countries.

The participants could listen to an interesting and high level program which was even enhanced by the invited speakers. Among them there were 10 IEEE distinguished lecturers: 2 from Antennas and Propagation Society, 2 from Communications Society, 2 from Electron Devices Society and 4 from Microwave Theory and Techniques Society. Some of the distinguished lecturers came to the conference from the USA only for a single day to present their talk.

The papers have been published in a joint Proceeding's Book of the two conferences. The details of the program can be seen on the web site:

www.diamond-congress.hu/mow2007

The best contributed papers will be published in an extended form in the Proceedings of the European Microwave Association.

The European Microwave Association gave 3 Awards to the best young scientist's papers. The first Prize was shared by Anne-Laure Billabert from France and Yifey Li form the USA, the 3rd Prize was given to Olena Boryskina from Ukraine.

The conference site was in the hilly area of Budapest in the new Europa Conference Center. The social program consisted of a Welcome Party and a Banquet. The banquet was held outside of the city. It contained a horse show, a dinner with live gipsy music and a folk's dance with bon fire. The participants enjoyed both the technical and the social programs.

The Journal of Atmospheric and Solar-Terrestrial Physics

SPECIAL OFFER TO URSI RADIOSCIENTISTS

AIMS AND SCOPE

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

Complimentary Information about this journal:
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Information for authors

Content

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Style and Format

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

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