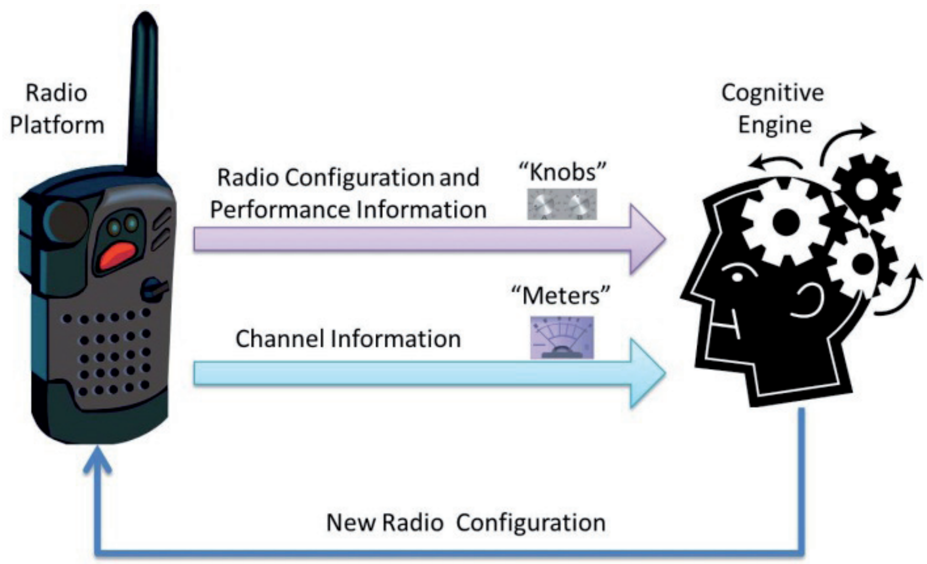
Radio Science Bulletin

ISSN 1024-4530

INTERNATIONAL
UNION OF
RADIO SCIENCE

UNION
RADIO-SCIENTIFIQUE
INTERNATIONALE



No 342
September 2012

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

Contents

Front cover: The original Virginia Tech cognitive engine concept for cognitive radio. See the paper by Charles W. Bostian and Alexander R. Young on pp. 16 - 25.

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Editorial

Our Papers

Making accurate measurements of the electric field and temperature in biological media is a challenge. Simultaneously making such measurements with a single probe, without perturbing the quantities being measured, is an even more significant challenge. In their contributed paper, Pierre Jarrige, Gwenaël Gaborit, Lionel Duvillaret, Sophie Kohler, Nicolas Ticaud, Delia Arnaud-Cormos, and Philippe Lévèque describe an electro-optic probe that meets this challenge in an impressive manner. The paper begins with a review of the need for making such measurements, and the approaches used in the past. The operating principles of the new probe are then explained. The probe uses fiber optics to monitor the polarization state of an electro-optic crystal. The polarization-state measurements detect the variations in the birefringence of the crystal, which are dependent on the variations in the electric field (which occur on short time scales) and on the temperature (which varies on a longer time scale). The difference in time scales allows the two effects to be separated and measured. The authors derive a figure of merit for electro-optic crystals to be used in such a probe, and explain how this was used to determine their choice of crystal. They then describe the experimental setup for frequency-domain measurements, and how the electric-field and temperature specifications of the probe were determined for CW measurements. How both temperature and electric-field measurements can be used to determine the specific absorption rate (SAR) are explained. Experiments were performed to measure the SAR using both temperature and electric field, and simulations were also performed. Good agreement was obtained among the values from both types of measurements and the simulation. Experiments verifying the suitability of the probe for time-domain measurements are described. The abilities to measure kV nanosecond pulsed electric fields, regardless of waveform, and the thermal effects due to such fields, were demonstrated. The paper describes the use of an elegant combination of optical physics and engineering to solve an interesting bioelectromagnetic measurement problem.

In their invited Commission C *Review of Radio Science* paper, Charles Bostian and Alexander Young provide a very readable introduction to and review of the field of cognitive radio. The paper starts with the definition of cognitive radio, and where the concept began. The reasons why cognitive radio are important are introduced. The degree to which a radio can be cognitive, and the relationship between cognitive radio and adaptive radio, are discussed. The paper then turns to a description of how cognitive radios work. The basic architecture of a cognitive radio is reviewed. The cognition process is explained. This is followed by a review of the early prototypes of cognitive radios. The types of cognitive radios currently being used and studied, and the technologies that make them possible, are reviewed. Applications of cognitive radio are considered. This includes cognitive radio as a solution to the limitations of radio hardware, cognitive radio as a solution to problems associated with antennas and propagation, and cognitive radio's use with autonomous vehicles. The paper concludes with a guide to where readers can learn more about this important topic.

The efforts of Sana Salous, the Associate Editor for Commission C, in bringing us this paper are gratefully acknowledged.

Our Other Contributions

Kristian Schlegel has provided us with two book reviews in this issue. One is from one of our Young Scientists, and both cover books that are likely to be of current interest to radio scientists.

There are calls for papers for several conferences in this issue, and for the *Radio Science Bulletin*'s special issue on the "Role of Radio Science in Disaster Management." The deadlines for paper submission for most of these are shortly after you will receive this issue, so I urge you to take advantage of the opportunities they present.

The *Radio Science Bulletin* is always looking for good papers. I urge you to consider submitting a paper to the *Bulletin*. We are usually able to provide rather rapid publication, and we give our authors the opportunity to reach the whole community of radio scientists. You can submit a paper directly to me (r.stone@ieee.org).

Ross

In Memoriam

Hans Joachim Liebe
1934 - 2012

Hans Joachim Liebe, an internationally recognized expert in radiowave physics, and developer of the widely-used Millimeter-wave Propagation Model (MPM), passed away peacefully on August 2, 2012, after a long and courageous battle with Parkinson's disease. He was the son of Margarete and Fritz Liebe, and was born in Insterburg, East Prussia, Germany, on January 21, 1934. He married Roswita Borgwardt in 1963, and they were married 49 years. In 1964, he graduated magna cum laude from the Technical University of Berlin, where he earned the PhD in Electrical Engineering. In 1965, he moved from Germany to the United States with his family.

Dr. Liebe worked for the Institute for Telecommunications Sciences (ITS) in Boulder from 1966 until his retirement in 1995. Dr. Liebe was awarded the Senior US Scientist Humboldt Award (1976), Department of Commerce Silver Medals (1984 and 1991) for meritorious service and outstanding publications, and the IEEE Harry Diamond Memorial Award (2002) for distinguished technical contributions in the field of millimeter-wave propagation. Dr. Liebe was a Life Fellow of the IEEE, and a member of the US National Committee of the International Union of Radio Science (USNC-URSI) Commissions A and F.

Over many years of continued study, Dr. Liebe developed reliable expressions for the complex refractivity of moist air, which is basic to all millimeter and sub-millimeter wave-propagation problems, inclusive of those in communications, navigation, and remote sensing. During the course of this model development, Dr. Liebe overcame many experimental difficulties and, to a large extent, verified the overlap between spectroscopic measurements and field measurements. His publications included basic studies of the absorption by gaseous water vapor and oxygen, as well as absorption by liquid water. In his thirty-year effort to obtain valid data on atmospheric loss and delay properties, he obtained a model that is highly accurate from RF frequencies up to approximately 1000 GHz. This model is in widespread use today, in applications as diverse as weather forecasting, satellite broadcasting, and radar. Dr. Liebe's work has been and remains vital to the remote-sensing community, where almost all ground- and satellite-based microwave and millimeter radiometric techniques take advantage of his models. His more recent work on cloud absorption is also becoming increasingly important, as will his work on Zeeman splitting of the O_2 absorption lines at mesospheric altitudes.

Dr. Liebe's meticulous work and models are widely recognized throughout the global scientific community. He established a reputation for accurate measurements within 20 GHz to 100 GHz well before commercial equipment was widely available in this range. He used spectroscopic theory to extend his estimates up to 1000 GHz, where there were very few reliable measurements available and at a time when very little quantitative knowledge of absorptive and refractive spectra was available in this spectral range. His work is nowadays the basis for remote-sensing techniques currently being used for or considered for major airborne and spaceborne campaigns, including the geosynchronous microwave imager/sounder instrument and passive sub-millimeter-wave cloud-ice mass sensors. Dr. Liebe's work constituted both outstanding science and a substantial contribution to radiowave propagation practice, as exhibited, for example, by the adoption of his work by the International Telecommunication Union Study Group III of ITU-R.

Hans' careful attention to the development of the MPM propagation model was only superseded by the warmth of his personality – which was equally well known among his colleagues. In addition to his world-class technical achievements, Hans was a loving father and husband, who cherished spending time with his family in the great outdoors. He was an avid swimmer, hiker, skier, and tennis player. In addition to his wife of 49 years, Roswita, he leaves behind his two daughters, Christi Liebe (Jon Gilbertson) of Carnation, WA; and Annette Liebe (husband Scott MacLowry) and granddaughter Isabel Rose, all of Bend, OR; and a sister, Elvira Christians, of Berlin, Germany.

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Electro-Optic Probe Devoted to Simultaneous Electric-Field and Temperature Measurements in Biological Media for Dosimetric Assessments

Pierre Jarrige
Gwenaël Gaborit
Lionel Duvillaret
Sophie Kohler
Nicolas Ticaud
Delia Arnaud-Cormos
Philippe Lévèque

Abstract

Here, we present the suitability of an electro-optic probe for performing simultaneous electric-field and temperature measurements in the case of bioelectromagnetic experiments such as specific absorption rate (SAR) assessments, or the characterization of in-situ nanosecond pulsed electric fields (nsPEF). In the frequency domain, the millimeter-sized probe, immersed in a water solution, reached a sensitivity of $170\,\mathrm{mVm^{-1}Hz^{1/2}}$, and presented a dynamic range exceeding 70 dB. Furthermore, temperature measurements led to a resolution of 22 mK. These abilities were used to perform dual SAR assessments by simultaneous electric-field and temperature measurements. Thanks to its ultra-wide bandwidth, the electro-optic probe is particularly suited for high transient electric-field measurements in the time domain. Pulses with different shapes and intensities were visualized and investigated.

1. Introduction

Radio frequencies constitute a part of the electromagnetic (EM) spectrum extensively exploited for many domestic, industrial, and medical applications. Their massive use has led to new questions about the potential effects on health of this non-ionizing radiation. Together with the knowledge of the different interaction mechanisms and the physical quantities involved, quantifying the effects resulting from exposure to electromagnetic radiation is thus a major issue.

For this purpose, the SAR is the reference dosimetric parameter used to quantify the energy absorbed by tissues. It can be assessed in two ways: by measuring the electric field in the exposed biological medium, or by measuring the temperature rise resulting from the RF exposure. Consequently, there are two types of instrumentation for assessing SAR: temperature sensors and electric-field probes. The first type is based on the use of thermistors, or consists of the use of a thermo-optical effect [1-3]. Electric-field probes can be divided into two major families: metal-based probes and electro-optic (EO) probes. Currently, probes dedicated to the measurement of the RF electric field in a biological environment are composed of three orthogonal dipoles completed by a rectifier element (such as diode-loaded dipole sensors [4, 5]), to probe each field component with high sensitivity and across a broad frequency band. The operating principle of such probes was exhaustively described in [6]. Electro-optic probes [7], based on the Pockels effect, allow a vectorial measurement of the electric field. Due to their fully dielectric construction, they have no metal element that will disturb the electric field to be measured. Otherwise, the millimeter sizes of the chosen electro-optic crystals allow a minimally invasive measurement. Compared to metal-based probes, the only weakness of electro-optic probes is their sensitivity. In terms of bandwidth, measurement dynamics, linearity of the probe response, selectivity, and spatial and temporal resolution, electro-optic probes are at least equivalent to or more efficient than electric-field probes.

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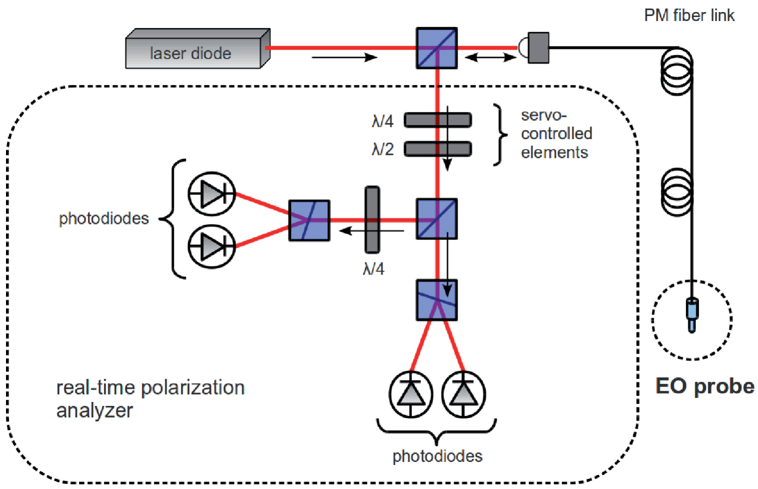

Figure 1. A schematic diagram of the optical bench, including the servo control system and the pigtailed probe.

Moreover, the developed electro-optical probe can achieve high-intensity wideband signal measurements in the sub-nanosecond duration range. Indeed, pulsed electric fields (PEFs), and especially nanosecond pulsed electric fields, are currently under investigation due to their potential applications in medicine, biotechnology, and the environment [8, 9]. In such experiments, the monitoring of some physical parameters, such as the *in-situ* electric field and the induced temperature rise, is very important for controlling the effects of the nanosecond pulsed electric fields on the exposed biological cells.

In this work, we focus initially on the operating principle of the developed probe and the associated optical bench. The choice of the electro-optic crystal – which is the sensing element of the probe – is discussed, and a figure of merit dedicated to biological experiments is established. In Section 2, the electro-optic probe's performance in the frequency domain is characterized in terms of its electric-field and temperature measurement capabilities. The aim is to characterize the suitability of the probe for performing dual SAR assessments from simultaneous electric-field and temperature measurements. Section 3 is devoted to measurements in the time domain, particularly for the characterization of nanosecond pulsed electric fields in biological media, and for the discrimination of their thermal effects. Two high-voltage generators allowed us to investigate pulses with different shapes and intensities. For each domain, the corresponding experimental setup is detailed.

2. An Electro-Optic Sensor for Bioelectromagnetic Metrology

2.1 The Operating Principle of the Electro-Optic Device

The developed electro-optic probe can simultaneously measure the temperature variations and the electric field over a wide frequency band (a 1 kHz to 10 GHz frequency range). This ability is the consequence of two physical effects that simultaneously appear: the Pockels effect, which relates the linear variation of the refractive indices of an electro-optic crystal to the applied electric field, and the thermo-optical effect, which reveals the temperature dependence of these indices. Many optical configurations allow exploitation of these effects. In our case, we chose to develop a sensor based on the polarization-state modulation of a laser beam, probing both dielectric axes of the electro-optic crystal (see Figure 1). The total de-phasing, $\Delta\phi$, between the only two permitted polarizations (which was introduced during the round trip in the crystal) can thus be written as the sum of two contributions:

$$\Delta\phi\left(T,\vec{E}\right)=\Delta\phi_0\left(T\right)+\Delta\phi_E\left(\vec{E}\right). \qquad (1)$$

This includes a de-phasing, $\Delta\phi_0$, linked to the intrinsic birefringence, which is temperature-dependent. It also includes an additional de-phasing, $\Delta\phi_E$, linked to the electric-field-induced birefringence:

$$\Delta\phi_0\left(T\right)=\frac{2\pi L\Delta n_0}{\lambda}, \qquad (2)$$

$$\Delta\phi_E\left(\vec{E}\right)=\frac{2\pi L\Delta n_E}{\lambda},$$

where L is the effective length of the crystal (equal to twice its physical length), T is the temperature, λ is the laser-diode emission wavelength (1550 nm), Δn_0 is the natural birefringence, and Δn_E is the electric-field-induced birefringence.

The optimal working point of the system is defined by a specific optical arrangement, already described in [10].

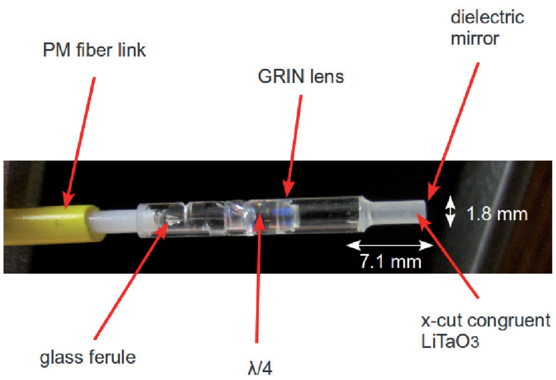

Figure 2. A photograph of the pigtailed electro-optic probe.

This allows a linear modulation of the optical power with the electric field to be measured, together with the highest modulation depth. As the intrinsic birefringence, Δn_0, is temperature dependent, each variation of this latter factor produces an additional variation of the polarization state of the laser beam, and thus a parasitic drift of the optimal working point. To compensate for these drifts, two servo-controlled wave plates, $\lambda/4$ and $\lambda/2$, allow adding a de-phasing opposite to the de-phasing induced by the temperature variations, in real time (see Figure 1). Since the system is continuously locked on its optimal working point, the electric field can thereby be measured with accuracy, and the temperature variations can be deduced from the orientations of the two motorized wave plates. The decorrelation of electric-field effects from those due to temperature variations is possible because these effects occur on different time scales: a low-pass filter (< 20 Hz) is used to obtain the temperature variations, while a high-pass filter allows obtaining the electric field.

The polarization-state modulation of the laser probe beam is then converted into an amplitude-modulated electrical signal by a photodiode, the output of which can be connected to a spectrum analyzer or to an oscilloscope. Temperature variations are directly read via a software interface that also monitors the accuracy of the servo-control system.

Figure 2 gives a picture of the electro-optic probe. The laser beam emerges from a polarization-maintaining optical fiber (PMF), terminated by a glass ferule. It crosses a GRIN lens, in order to be collimated. An internal quarter-wave plate, the neutral lines of which make an angle of 45° about the polarization-maintaining optical fiber's dielectric axes, then transforms the linearly incident polarization into a circular polarization, which consequently probes the dielectric axes of the electro-optic crystal in a balanced way. This crystal – which constitutes the interaction medium between the laser beam, on one hand, and both ambient electric field and temperature, on the other hand – consisted of a 7.1 mm long congruent x-cut lithium tantalate ($LiTaO_3$) crystal. The laser beam is then reflected by a dielectric mirror on the tip of the probe, and is finally re-injected into the same polarization-maintaining optical fiber. Its polarization state carries all required information on the electric-field and temperature variations to be measured.

2.2 Figure of Merit of an Electro-Optic Crystal for Bioelectromagnetic Experiments

As seen in the previous section, the electro-optic crystal is the transduction element of the probe. Its choice was crucial, and had to be made by taking into account specific criteria related to the environment in which it was to be immersed. Despite the fact that its physical and chemical properties had to be compatible with those of biological media (insolubility, non-toxicity, etc.), its relative permittivity had to be close to those of biological media in the frequency range of interest in order to ensure a low wave-impedance mismatch between the electro-optic probe and the medium. Moreover, the refractive indices were linearly linked to the temperature variations by the thermo-optical coefficients. These latter coefficients thus related the sensitivity of the crystal to temperature variations, and had to be as high as possible.

To build a figure of merit for electro-optic crystals devoted to electric-field measurements, L. Duvillaret et al. [11] introduced the concept of the sensitivity vector, $\Delta\vec{K}$. This vector relates the theoretical vectorial dependence of the refractive indices to the applied electric field:

$$\Delta n_E = \Delta\left[n_+\left(\vec{E}\right) - n_-\left(\vec{E}\right)\right] = \overrightarrow{\Delta K}\vec{E}\,. \tag{3}$$

n_+ and n_- are the eigen-dielectric axes of the electro-optic crystal. Pragmatically, the sensitivity vector is a pertinent tool. On the one hand, it allows determining which orientation of the crystal will offer the highest electric-field sensitivity (through the analysis of its modulus). On the other hand, it allows knowing the corresponding orientation of the sensitivity axis (the direction of the applied electric field for which the induced birefringence will be the highest).

By taking into account all these criteria, we chose an x-cut congruent $LiTaO_3$ crystal. The crystal belonged to the symmetry class (3m). Its electro-optic tensor, which gives the vectorial dependence of the refractive index with the electric field, was the following:

$$\begin{pmatrix} 0 & -r_{22} & r_{13} \\ 0 & r_{22} & r_{13} \\ 0 & 0 & r_{33} \\ 0 & r_{51} & 0 \\ r_{51} & 0 & 0 \\ -r_{22} & 0 & 0 \end{pmatrix}. \tag{4}$$

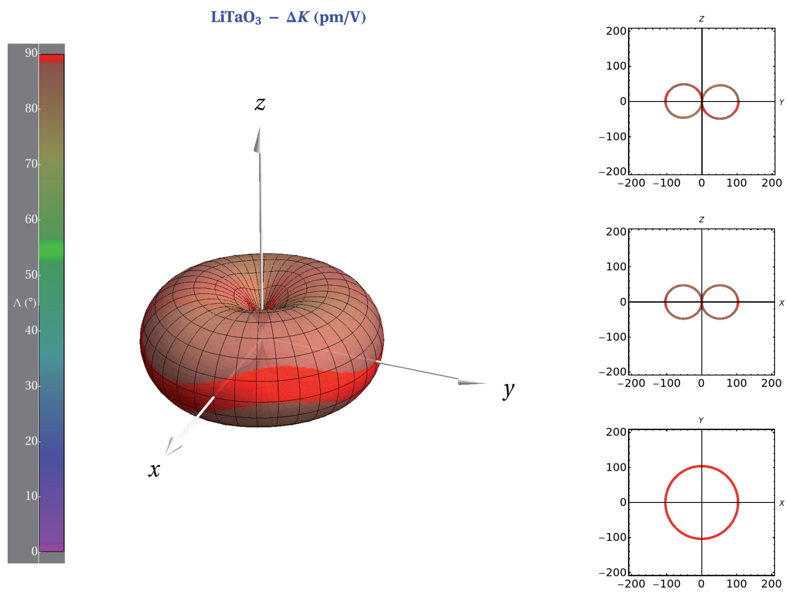

Figure 3. A three-dimensional representation of the sensitivity vector for the case of a congruent $LiTaO_3$ *crystal. The color range gives information on the angle between the laser beam's wave vector and* $\Delta\vec{K}$ *. On the right-hand side are plotted the three sections of the three-dimensional representation along (yOz), (zOx) and (xOy).*

Figure 3 shows a three-dimensional representation of $\Delta\vec{K}$ for the case of $LiTaO_3$. As seen, for an *x*-cut $LiTaO_3$ crystal, a maximum of the sensitivity vector modulus was obtained with an orientation along the *z* axis (corresponding to the sensitivity axis). The probe was thus sensitive to one component of the electric field, lying in the transverse plane of the propagation direction of the probe's laser beam. The two other components were obtained by changing the electro-optic probe's position. That led to a complete vectorial characterization of the electric field.

Otherwise, the electro-optic crystal's permittivities, which were 42.6 and 42.8 [12], were very close to those of biological media in the GHz range.

As far as thermo-optic coefficients are concerned, they were previously evaluated, thanks to an in-house dedicated optical-characterization bench. As the crystal acted as a polarization-state modulator, the physical parameter of interest was thus the birefringence induced due to temperature variations, $\partial\Delta n/\partial T$, which was found to be equal to $19.6\times10^{-6}\ \mathrm{K}^{-1}$. For an inner-crystal round trip, the expression of the natural de-phasing as a function of the temperature variations can be written as follows:

$$\frac{\partial\Delta\phi_0}{\partial T} = \frac{4\pi L}{\lambda}\frac{\partial\Delta n_0}{\partial T} . \qquad (5)$$

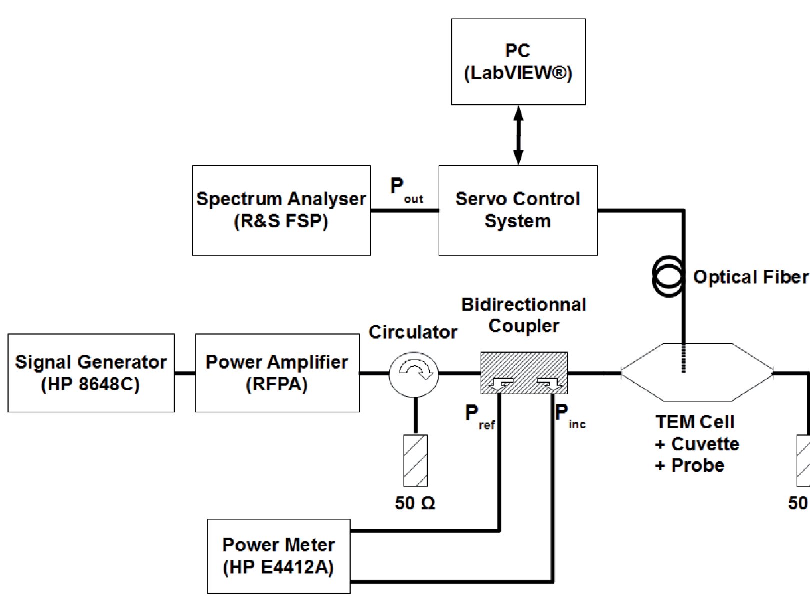

Figure 4. The experimental setup.

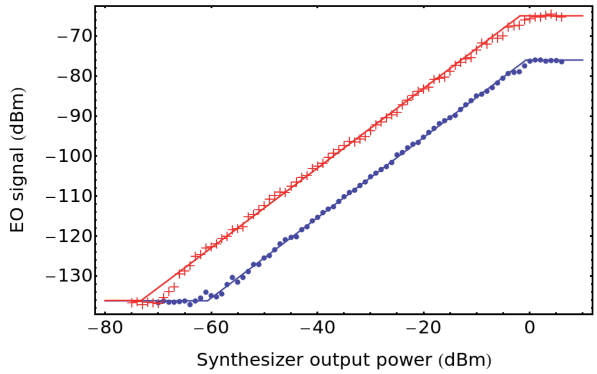

Figure 5. The linearity measurements of the electro-optic probe and the associated fitting curves in air (blue dots) and in the water solution (red crosses).

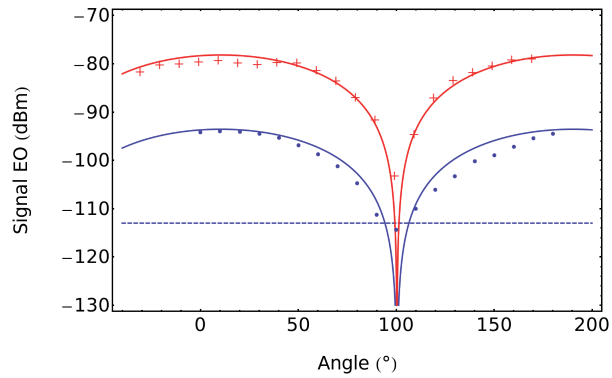

Figure 6. The selectivity measurements performed in air (blue dots) and in the water solution (red plus markers). The dashed threshold represents the direct electromagnetic coupling between the generator and the measurement apparatus.

In the present case, a value of 43.8°/K was found. This demonstrated a good induced sensitivity of the laser-beam polarization state to the temperature variations, thanks to the electro-optic crystal's thermo-optic coefficients.

3. Frequency-Domain Measurements

3.1 Experimental Setup

The first step of our investigations was to measure both electric-field and temperature variations in a biological solution exposed to a 1.8 GHz CW signal, corresponding to the GSM carrier frequency. The experimental setup is depicted in Figure 4. A signal generator delivered a 1.8 GHz CW signal. A 40 dB gain RF amplifier was connected to the generator, and was followed by an RF circulator with a 50 Ω load in order to protect it from reflected power. For the exposition, we used a transverse electromagnetic (TEM) cell in which a plastic cuvette, filled with a water solution, was placed. The dielectric constant and the electrical conductivity of the solution were measured with a dielectric probe kit, and were equal to 77 and 1.7 S/m, respectively, at 1.8 GHz. The electro-optic probe was inserted vertically in the solution, and the output of the servo control system was connected to a spectrum analyzer.

3.2 Electric-Field and Temperature Specifications of the Probe in a CW Regime

To characterize the electro-optic probe response in terms of linearity and selectivity, electric-field measurements were carried out, both in air and in the solution [13]. Figure 5 presents the electro-optic probe's response as function of the RF input power. The electro-optic probe's response in air was linear over a dynamic range of 60 dB, while it was linear over more than 70 dB in the solution. These values were limited on the one hand by the Johnson noise floor of the spectrum analyzer (–136 dBm), and on the other hand by the saturation of the RF amplifier. The linear-fitting curves of the measurements yielded slopes of 1.004 ± 0.004 and 0.997 ± 0.007 respectively in the air and in the water solution. These values demonstrated an excellent proportionality between the electro-optic probe's output power and the RF input power. The sensitivity, E_{min}, defined as the minimum detectable electric field, was calculated using the following equation:

$$E_{min} = \frac{1}{d}\sqrt{\frac{2Z10^{-3+\frac{P_{min}[\mathrm{dBm}]}{10}}}{\Delta f}}, \qquad (6)$$

where d is the distance between the septum and the grounded plate, Δf is the resolution bandwidth, Z is the characteristic impedance of the TEM cell, and P_{min} is the minimum detectable input power. Values of sensitivities obtained in air and in the solution were $720\ \mathrm{mVm^{-1}Hz^{-1/2}}$ and $170\ \mathrm{mVm^{-1}Hz^{-1/2}}$, respectively, thus leading to a gain of 13 dB in the solution. This increase of the electro-optic probe's sensitivity in the biological medium was induced by the presence of a higher inner-probe electric field, linked to the lower mismatch between the electro-optic crystal's and the ambient medium's permittivities.

At a second time, selectivity measurements were performed. The selectivity corresponded to the ability of the electro-optic probe to measure one component of the electric field while rejecting the orthogonal components. The electro-optic probe's output power was recorded for each 10° rotation angle of the TEM cell around the probe's longitudinal axis. The TEM cell input power was set to 27 dBm. The results obtained both in air and in the water solution are presented in Figure 6. They could be fitted using the following sinusoidal shape:

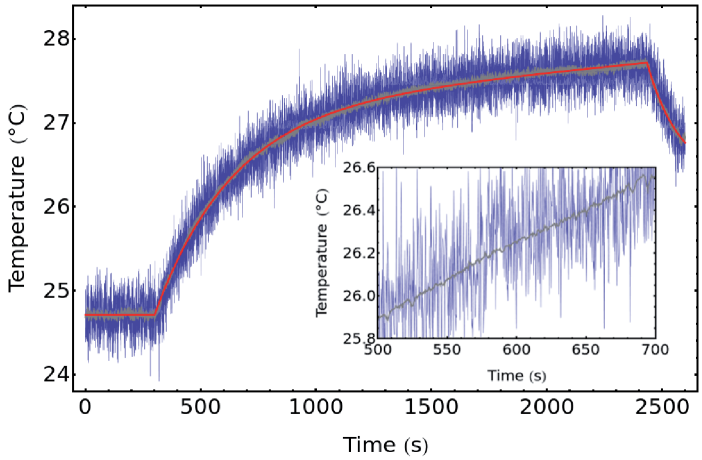

Figure 7. The temperature measurements recorded by the electro-optic probe (gray curve), by the reference Luxtron probe (blue curve), and the theoretical fit (red curve).

$$P_{out} = 10\log_{10}\left[\cos^2\left(\theta + \theta_0\right)\right], \quad (7)$$

where θ is the angular value, and θ_0 is an offset origin. As observed, the measurements and fits were in good agreement. In air, the selectivity was found to be 20 dB, while in solution, a value of 35 dB was obtained. As for linearity measurements, an increase of the electro-optic probe's sensitivity of 13 dB was deduced.

The next step was to quantify the temperature variations of the water solution resulting from exposure to a 1.8 GHz CW signal. The experimental setup remained the same, but the plastic cuvette was replaced by a Petri dish, inserted horizontally into the TEM cell. To assess the performance of the electro-optic probe, a comparison was made with a standard optical probe marketed by Luxtron. Figure 7 presents the temperature evolution of the water solution exposed to a 1.8 GHz CW signal. The temperatures of the two probes were recorded simultaneously before, during, and after the exposure. The input power was set to 28.5 dBm.

To quantify the resolutions of the probes, we used a mono-exponential fit relating the thermal diffusion between the solution connected to the room thermostat:

$$T(t) = T_0 + A_1\left[1 - e^{-(t-t_1)/\tau_1}\right]H(t-t_1)H(t_2-t) \quad (8)$$

where T_0 is the ambient temperature at the beginning of the exposure, H is the Heaviside function, and τ_1 is the thermal time constant of the exposure setup. Excellent agreement was observed between the measurements and the fit. The temperature resolutions of the two probes were extracted from these measurements. They were 197 mK and 27 mK for the Luxtron probe and the electro-optic probe, respectively.

3.3 Dual SAR Assessments

Previous results have demonstrated the ability of the electro-optic probe to distinctly measure the electric field and the temperature variations. The specific absorption rate (SAR), which is the standard dosimetric parameter for quantifying the energy absorbed by tissues, is linked to each of these two physical quantities:

$$SAR_T = C\left.\frac{\partial T}{\partial t}\right|_{t=0} \text{ [W/kg]}, \quad (9)$$

$$SAR_E = \frac{\sigma E^2}{\rho} \text{ [W/kg]}, \quad (10)$$

where C is the specific heat capacity of the biological medium, $\partial T/\partial t$ corresponds to the initial slope of the temperature rise, E is the electric field in the medium, and ρ and σ are respectively the medium's density and electric conductivity.

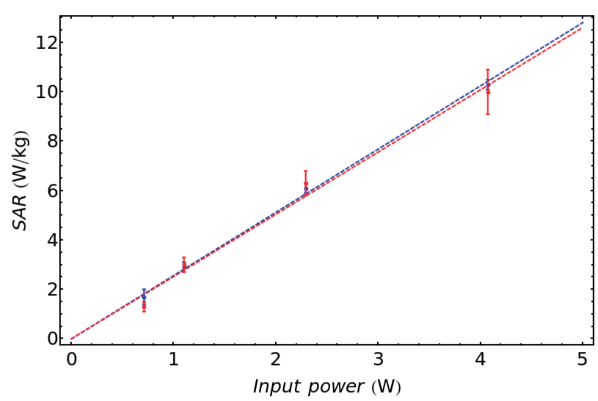

Figure 8. The SAR profiles calculated from both the electric field (red curve) and the temperature variations (blue curve) as functions of the input power. The corresponding theoretical fits are in the dashed lines.

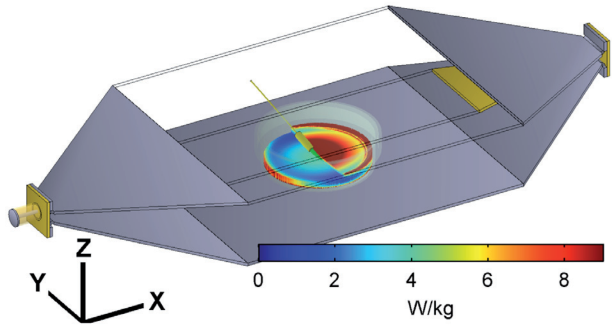

Figure 9. The FDTD-simulated SAR. The SAR was computed for the whole solution and for the electro-optic probe's equivalent volume. To illustrate the SAR distribution in this volume, a quarter volume was removed.

The purpose here was to perform a simultaneous electric-field and temperature measurement in order to achieve a dual-SAR assessment. The experimental setup remained the same. The electric-field and temperature variations were simultaneously recorded for four different input powers. Associated SAR_E and SAR_T values, respectively calculated from the electric-field and the temperature variations, and their relative deviations, are plotted in Figure 8. From the electric-field measurements, a mean SAR efficiency of 2.44 ± 0.42 W/kg/W was determined. This value presented a good level of consistency with the value deduced from the temperature variations, which was 2.56 ± 0.12 W/kg/W, corresponding to a relative deviation of 5% between the two results.

These experimental SAR values were then compared to the simulated SAR. Numerical simulations were conducted using an in-house code based on the Finite-Difference Time-Domain (FDTD) Method [14, 15]. The whole structure – consisting of the TEM cell, the Petri dish, and the water solution – was modeled. The three-dimensional structure was meshed with a uniform 0.2 mm × 0.2 mm × 0.2 mm mesh grid, and the SAR distribution was computed from the electric field (see Figure 9). The mean SAR value and the standard deviation were computed over a volume corresponding to the electro-optic crystal, and equaled 2.65 ± 2.0 W/kg/W, and were thus close to the experimental values. These results demonstrated the suitability of the electro-optic probe for performing SAR assessments from simultaneous electric-field and temperature measurements [16].

4. Time-Domain Measurements

4.1 Experimental Setup

This section focuses on evaluating the performance of the electro-optic probe in the time domain, especially in terms of pulsed electric-field measurements. For this purpose, the experimental setup depicted in Figure 10 was used. Two 50 Ω high-voltage generators were used. One was switched by a laser and delivered monopolar kilovolt (kV) nanosecond pulses. The other delivered rectangular-shaped kV nanosecond pulses. Pulses were sent via a coaxial cable to a 44 mm × 12 mm × 12 mm electroporation cuvette with two integrated electrodes, and filled with a buffered salt solution ($\varepsilon_r = 78$ and $\sigma = 0.31$ S/m) to ensure a 50 Ω equivalent electrical impedance [17]). The two electrodes were separated by a gap of 4 mm, into which the electro-optic probe was vertically immersed. The output of the servo control system was connected to a 12 GHz-bandwidth oscilloscope used for the real-time display of the pulses. Pulses were also measured upstream of the cuvette thanks to a tap-off, a three-port device the main line of which was 50 Ω and the measurement port of which was 4950 Ω, allowing a voltage measurement on the oscilloscope with a 1:100 ratio.

4.2 Nanosecond Pulsed-Electric-Field Characterization

Figure 11 shows the pulse voltage measured upstream of the cuvette, thanks to the tap-off, and the voltage measured

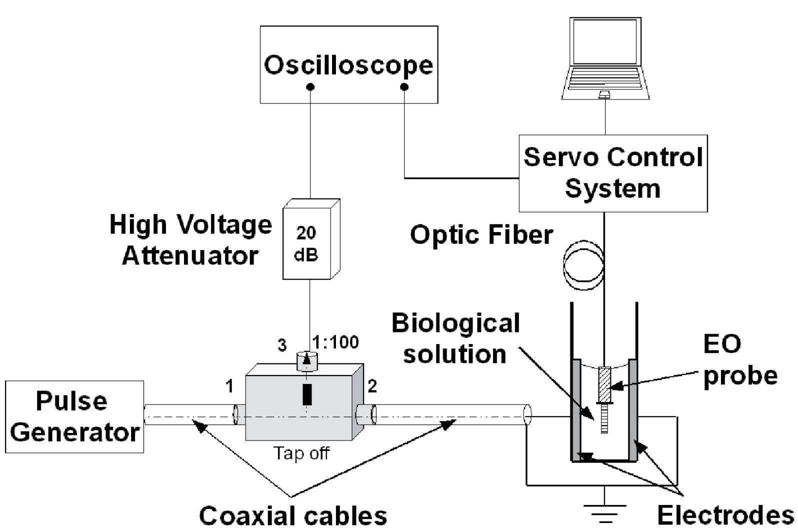

Figure 10. The setup used for the time-domain measurements.

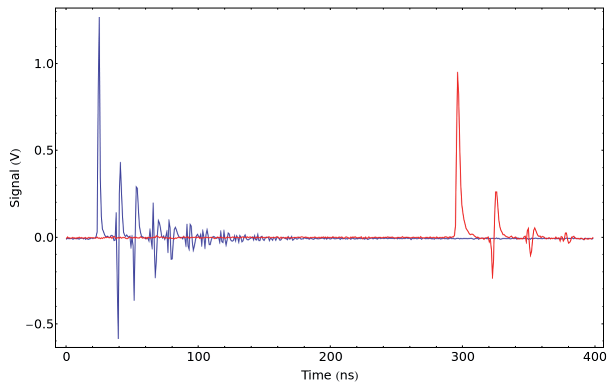

Figure 11. The profiles of the pulses measured upstream of the cuvette (blue curve) and in-situ by the electro-optic probe (red curve). These are signals averaged over 10,000 pulses.

in-situ by the electro-optic probe. Measurements were performed with the 2.6 ns monopolar-pulse generator. Several reflected pulses were observed on the curves. They resulted from frequency variations of the cuvette's impedance. On the upstream signal, two times more reflected-pulse echoes were observed, due to the fact that there were reflections propagating in the main line between the cuvette and the generator. Each round trip of the reflected pulse was thus measured twice on the upstream channel, and once in the cuvette.

In order to compare upstream-of-the-cuvette and *in-situ* pulses, their profiles were normalized and temporally readjusted. This comparison was made for both the 2.6 ns and 10 ns pulse generators (Figure 12).

It appears that the rising and falling fronts of the pulses compared were slightly different: the *in-situ* pulses presented a width extension. This extension was attributed to a dispersion of the pulse in the water solution, the dielectric properties of which were frequency dependent, and thus could affect the frequency spectrum of the pulses. This comparison highlighted the importance of an *in situ* measurement that allows precisely knowledge of the real shape of the pulse within the biological environment. This is crucial in the case of cell electroporation experiments, in which precisely monitoring the durations and amplitudes of both pulses is a major issue, in order to control their effects (reversible or not) on the cell [18].

Using the monopolar pulsed electric-field generator, a characterization of the linearity of the electro-optic probe's response was conducted in the time domain. For that purpose, the applied voltage was tuned from 400 V to 3200 V, and the electro-optic signal was recorded for each step of the applied voltage. The results are shown in Figure 13.

As for the frequency-domain measurements, the electro-optic probe presented a linear response over the range of interest, as a correlation coefficient of $R^2 = 0.9993$ was obtained. From the mean value of the noise floor and the slope of the linear fit, a value of 2.5 kV/m in an analysis bandwidth of 12 GHz was extracted for the sensitivity of the electro-optic probe. It must be taken into account that this value was obtained from a noise floor corresponding to a signal averaged over 200 electric-field pulses.

4.3 Discrimination of the Induced Thermal Effects

This section deals with the discrimination of thermal effects induced by nanosecond pulsed electric fields. 10,000 monopolar pulses were applied to the solution, with an electric-field strength of 450 kV/m and a repetition rate of 1 kHz. The exposure time window was thus 10 s. Figure 14 shows the temperature variations recorded before, during, and after the exposure.

A temperature rise of 0.3 K was observed, thus revealing a minor thermal effect induced by the nanosecond pulsed electric fields, in spite of their number and their high repetition rate. The theoretical fit was built by solving a

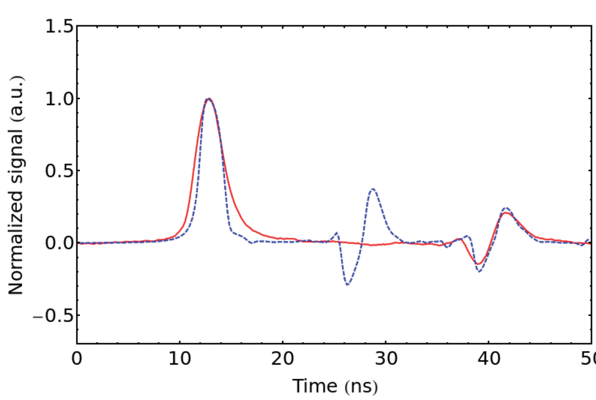

Figure 12a. A comparison between the upstream-of-the-cuvette profiles (blue dashed curves) and the in-situ profiles (red solid curves) for 2.6 ns pulses.

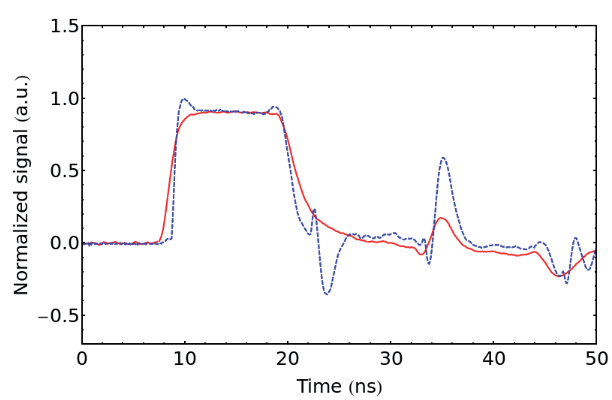

Figure 12b. A comparison between the upstream-of-the-cuvette profiles (blue dashed curves) and the in-situ profiles (red solid curves) for 10 ns pulses.

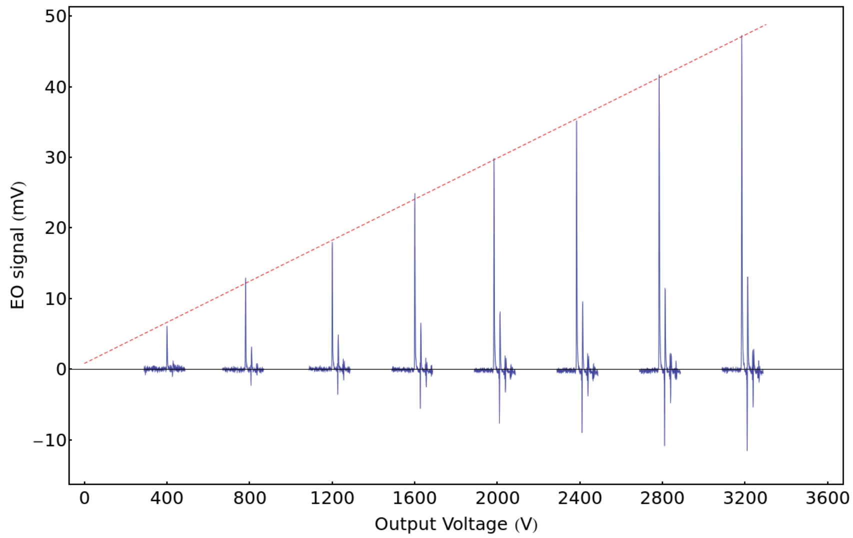

Figure 13. The linearity of the electro-optic probe's response in the time domain: the in-situ measured pulsed electric field (blue curves) as a function of the applied voltage. A linear fit is represented by the dashed line.

system of interdependent differential equations, respectively governing the thermal behavior of the water solution and the electro-optic crystal. In the case of the electro-optic crystal, their resolutions led to a thermal behavior divided into three parts, before, during, and after the exposure:

$$T_e = \begin{cases} T_e \\ T_e + B + C + e^{\frac{-t+t_1}{\tau_b}} B\alpha_2 + e^{\frac{-t+t_2}{\tau_b}} \left(B\alpha_1 - C\right) \\ T_e + \left(B\alpha_1 - C\right) e^{\frac{-t}{\tau_c}} \left[e^{t_1} + e^{t_2}\right] + B\alpha_2 e^{\frac{-t}{\tau_b}} \left[e^{t_2} - e^{t_1}\right] \end{cases} \tag{11}$$

with

$$B = \frac{P_b \tau_b}{C_b},$$

$$C = \frac{P_c \tau_c}{C_c}, \tag{12}$$

$$\alpha_1 = \frac{\tau_c}{\tau_b - \tau_c},$$

$$\alpha_2 = \frac{\tau_b}{\tau_b - \tau_c},$$

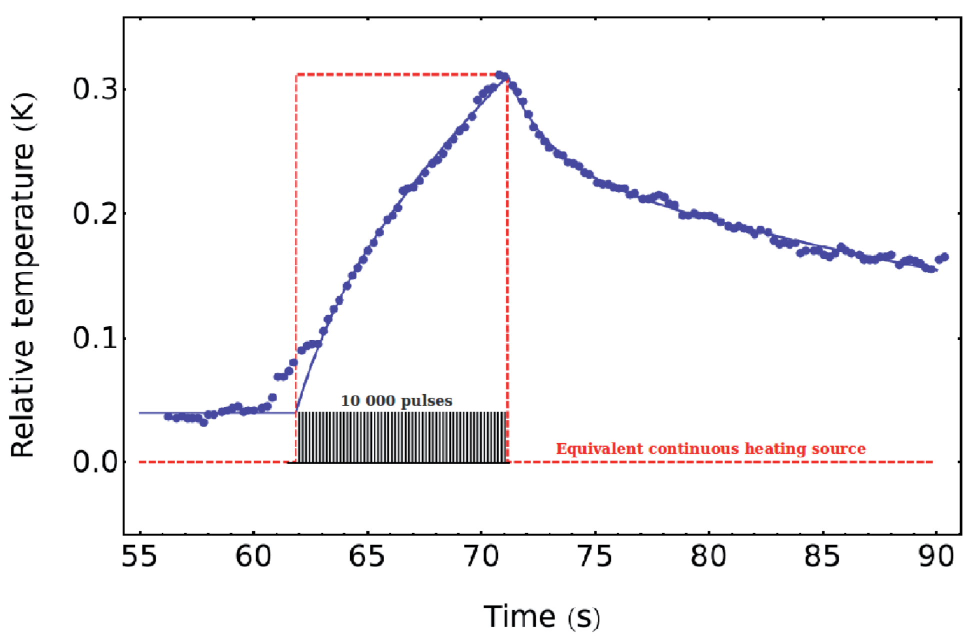

Figure 14. The temperature rise of the water solution induced by 10,000 monopolar kV pulses with a repetition rate of 1 kHz.

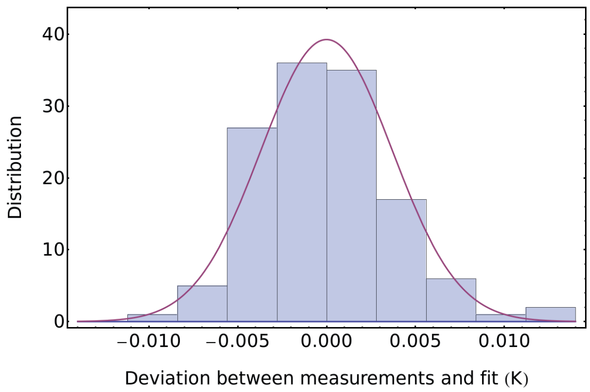

Figure 15. The Gaussian-shaped difference between the theoretical fit and the measurements.

where C_i is the heat specific capacity, τ_i is the thermalization time constant, and P_i is the thermal power induced by the nanosecond pulsed electric fields, all for a medium *i*. For that purpose, two assumptions were made. First, the 10,000 pulses were considered to be a continuous heat source during the exposure time window. Second, we considered the biological medium to act as a thermostat for the electro-optic crystal, and that the air acted the same for the biological medium. A very good agreement was obtained between the fit and the experimental data. The distribution of the difference between the theoretical fit and the data, plotted in Figure 15, presented a Gaussian shape, with a standard deviation of only 3.6 mK. From this model, we also extracted the thermalization time constants of the electro-optic probe and of the solution, which were $\tau_{EO} = 1.8$ s and $\tau_{bio} = 33$ s, respectively. These two values showed that the response time of the probe was short enough to monitor the temperature of a biological solution.

5. Conclusion

A first series of measurements allowed highlighting the ability of the probe to accurately measure the electric field and the temperature evolutions in a biological solution exposed to a CW signal (with a sensitivity of 170 $\mathrm{mVm^{-1}Hz^{-1/2}}$ and a temperature resolution of 27 mK). It thus constituted a suitable dosimetric instrument, as it allowed a dual SAR assessment, thanks to the simultaneous characterizations of the electric-field and temperature variations. Furthermore, it was possible to accurately measure kV nanosecond pulsed electric fields (whatever their shape, monopolar or rectangular) in a biological solution disposed in an electroporation cuvette. The linearity of the electro-optic probe's response as a function of the electric field to be measured was also validated. Moreover, the simultaneous nature of the measurement made a pulsed-induced thermal-effect characterization possible. These effects showed the ability of the probe to discriminate between very small temperature variations (a resolution of 3.6 mK, in this case).

6. Acknowledgments

The authors would like to acknowledge the DGA (French Military Programs Management and Procurement Agency) for financial support.

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Cognitive Radio : A Practical Review for the Radio Science Community

Charles W. Bostian
Alexander R. Young

Abstract

A cognitive radio is a transceiver that is (a) *aware* of its environment, its own capabilities, and its user's needs, priorities, and limitations; (b) *able to take intelligent action* based on that awareness; and (c) *capable of learning* from experience. This paper traces the practical development of cognitive radio from Mitola's original concept through the first workable architecture (a software cognitive engine controlling a mode- and frequency-agile RF system, commonly but not always a software-defined radio). This paper describes representative prototypes, and discusses the usefulness of cognitive radios in eliminating or alleviating antenna- and propagation-induced channel problems.

1. The Idea of Cognitive Radio and Why it is Important

1.1 The Beginning

For the purposes of this paper, a cognitive radio is a transceiver that is (a) *aware* of its environment, its own capabilities, regulations governing its behavior, and its user's needs, priorities, and limitations; (b) *able to take intelligent action* based on that awareness; and (c) *capable of learning* from experience.[1] Joseph Mitola originated the idea of a cognitive radio about 2000 [1]. (An inspiring visionary, Mitola also originated the term "software-defined radio.") He presented a cognitive radio as a kind of super-intelligent personal data assistant (PDA), operating at the application level, which would communicate conversationally with its user and set up whatever radio links were necessary to satisfy the user's needs.[2] While Mitola's thesis focused on the application layer, his work soon inspired other research groups to look at cognitive radio as a solution to physical-layer problems [2].

1.2 Why Cognitive Radio is Important

The beginnings of cognitive radio coincided with the recognition at the Defense Advanced Research Projects Agency (DARPA), the Federal Communications Commission (FCC), and other US government agencies that a different approach to spectrum access was badly needed [5-7]. The demand for spectrum for broadband mobile devices was outrunning the supply. Top-down frequency management, based on exclusive spectrum occupancy, was seen to be both inadequate and extremely inefficient. Policy makers envisioned a future in which cognitive radios could opportunistically find and use vacant spectrum, sharing it based on a cooperative and priority-based system that allowed decentralized intelligent management of interference.

At the same time, radio-frequency (RF) technology was rapidly changing. CMOS technology made low-cost RF front ends available, but these typically required frequent adjustment of hardware parameters in response to changes in frequency, bandwidth, or output power. Concurrently, it became possible for microprocessors to perform many radio functions, and the software-defined radio was born [8]. Since a cognitive radio is aware of its own operational capabilities and needs, researchers anticipated that it could intelligently adjust its own internal hardware and software parameters as necessary to meet its instantaneous physical-layer performance requirements.

These factors all converged with the idea of cognitive radios as transceivers that dynamically access the spectrum, sharing it with other users, and optimizing their performance across multiple objectives and constraints. They would do this intelligently and learn from experience, all with minimal user involvement. Cognitive radios would deal intelligently with the propagation-induced channel imperfections well known to the URSI community.

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

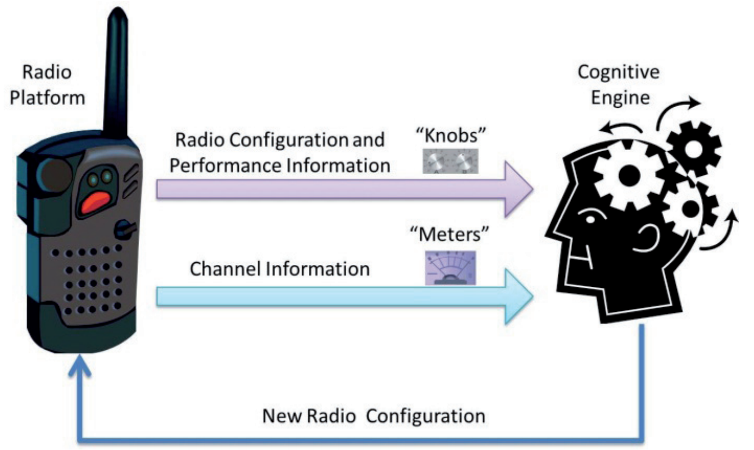

Figure 1. The original Virginia Tech cognitive engine concept.

1.3 ...But Can a Radio Really be Cognitive?

Cognitive radio is an application of artificial intelligence (AI). That carries a lot of baggage, ranging from difficulties of definition to the observation that while everyone may agree that the proposed solution to an unsolved problem is clearly AI, it is not recognized as AI once the problem is solved.[3] This carries over to cognitive radio in the *cognitive versus adaptive* quandary, in which a working radio that solves a new problem is often described as adaptive rather than cognitive. For us, the key distinction is that a "smart" radio is *cognitive* if it is capable of learning, and it is *adaptive* if it is not. We feel that a truly cognitive radio is capable of surprising its designers by arriving at unexpected solutions to problems and remembering these for future applications, while an adaptive radio is limited to a finite set of "designed in" outcomes. However, this distinction does not keep researchers (ourselves included) from calling their products "cognitive" even when some obvious learning-enabling features are not implemented in order to allow the operator rather than the radio to make key decisions, as in our Public Safety Cognitive Radio [9].

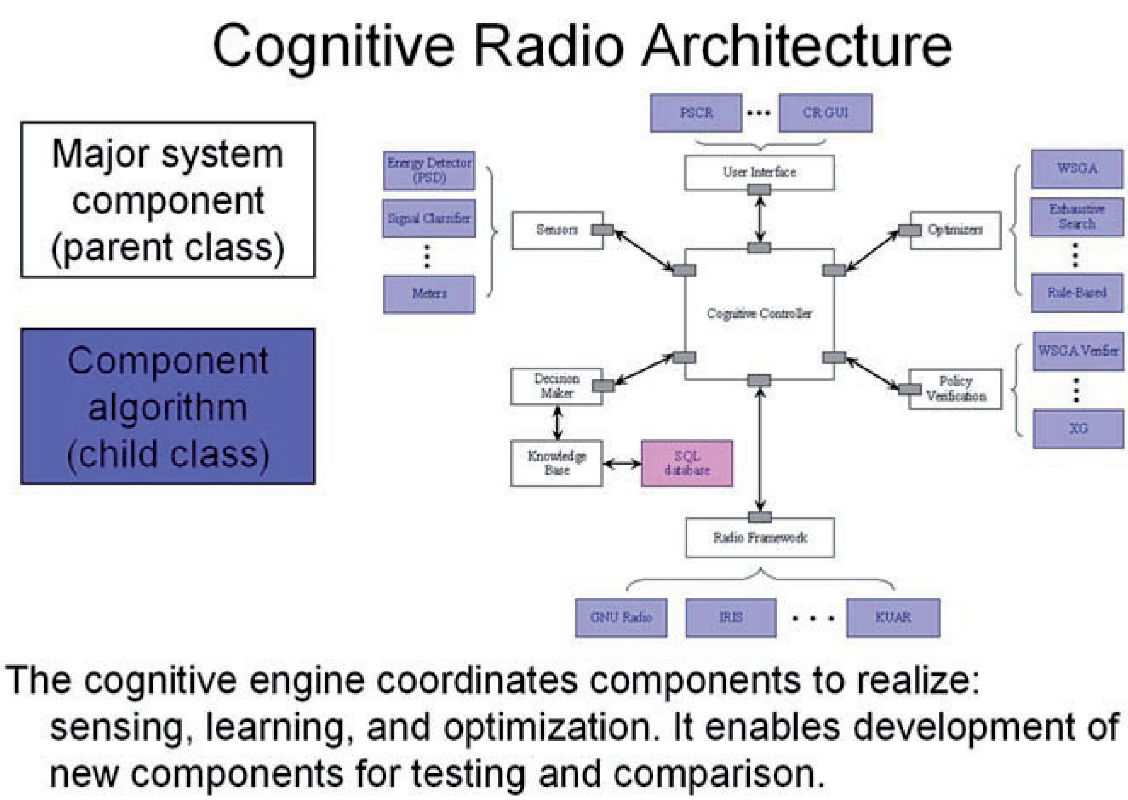

Figure 2. A modular cognitive-radio architecture.

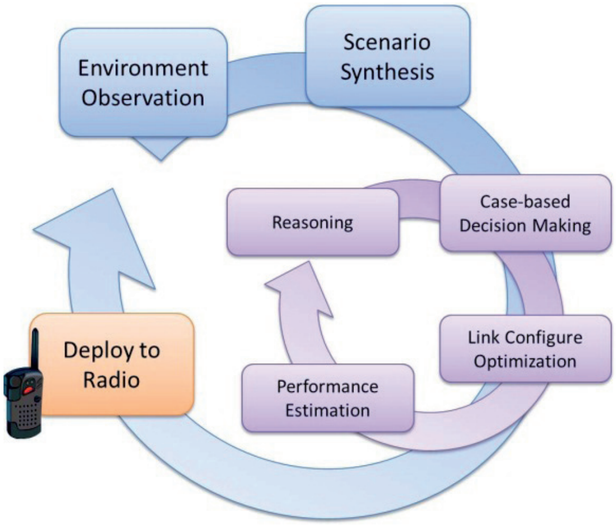

Figure 3. The structure of the implemented cognition loop.

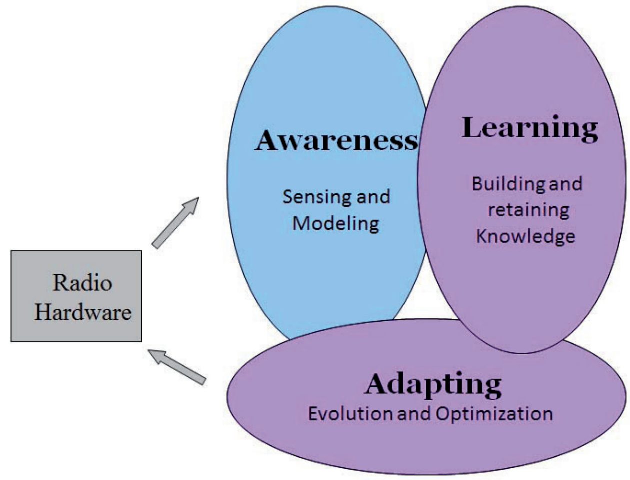

Figure 4. The original cognition loop concept.

2. How Cognitive Radios Work

2.1 Cognitive Radio Architecture

The first successful cognitive-radio architecture consisted of an intelligent software package called a cognitive engine, controlling an electronically controlled mode-agile and frequency-agile RF platform (called, in context, "the radio"). This is commonly – but not necessarily – a software-defined radio (SDR). Figure 1 provides an early view of this concept. In terms originated by Christian Rieser, the cognitive engine "turns the radio's knobs" and "reads the radio's meters," functioning very much as a human operator would. In later versions of this architecture, a central cognitive controller accesses a variety of modules containing sensors, optimizers, policy verifiers, and radio platforms (Figure 2).

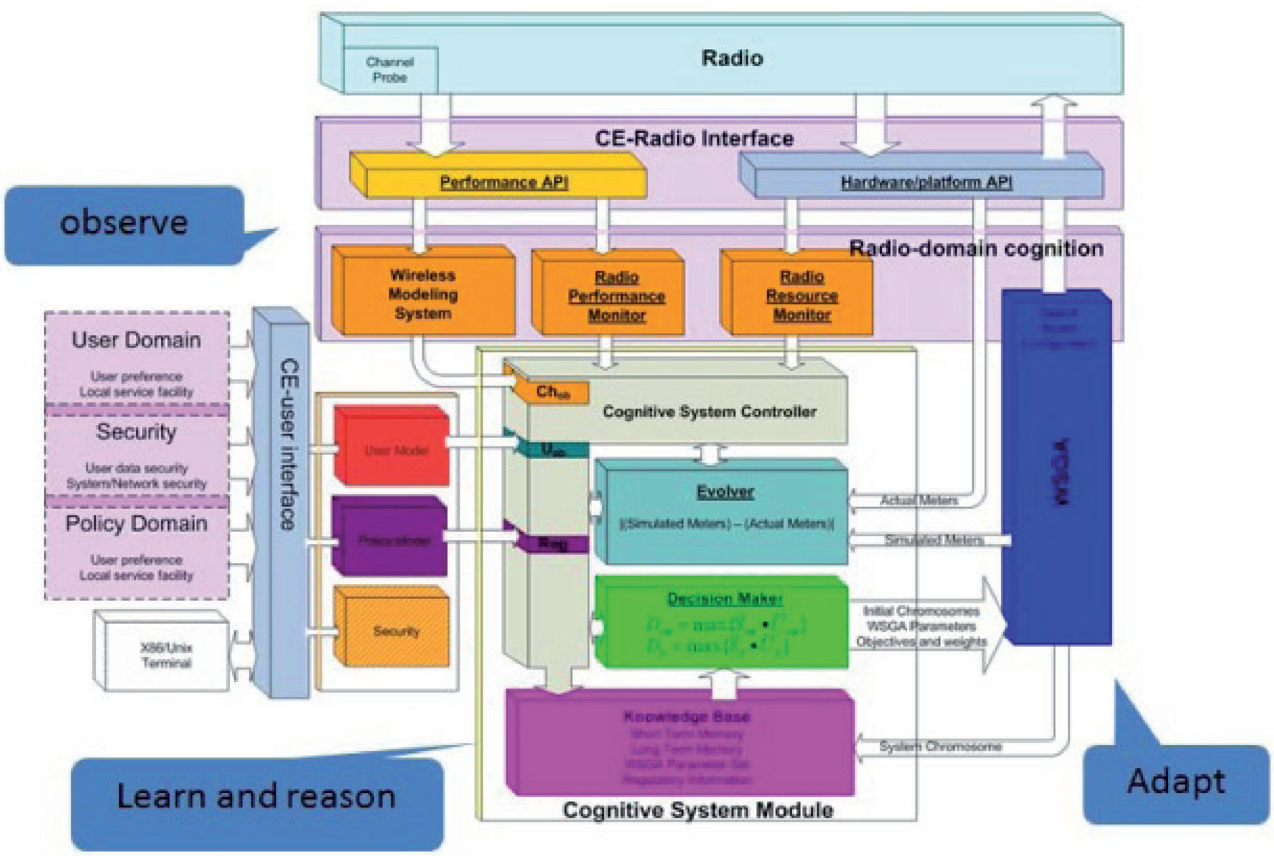

Figure 5. The first complete version of Virginia Tech's cognitive-engine software architecture.

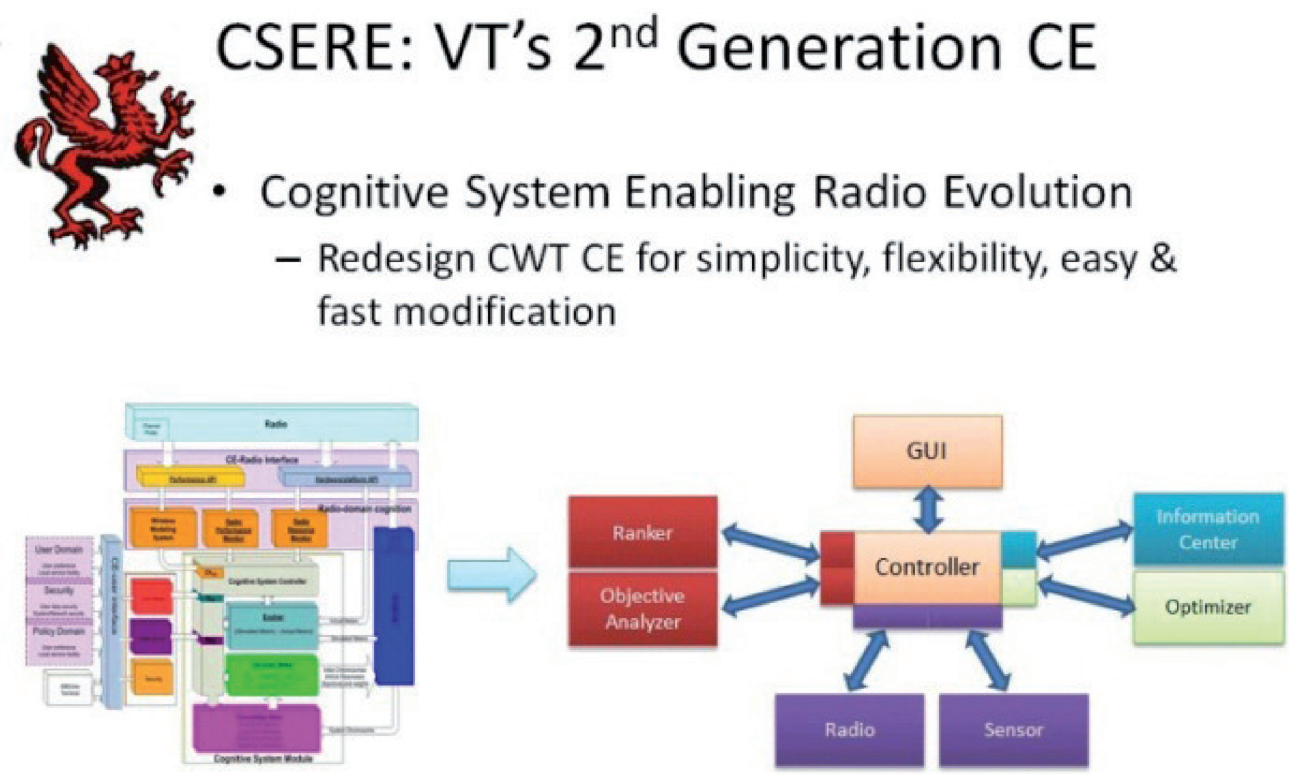

Figure 6. The second-generation Virginia Tech cognitive engine.

2.2 The Process of Cognition: Executing a Cognition Loop

Mitola described the cognition process in terms of the radio executing a cognition loop [11]. The Virginia Tech (VT) cognitive engine implemented Mitola's loop, and added an inner loop (Figure 3). It introduced *predict* and *compare* functions to guide the cognitive engine in choosing parameter values, and to ensure that the cognitive engine understood the situation with which it was dealing.

Referring to Figure 3, the process starts with the radio platform, which reports its observations to the cognitive engine (CE). The cognitive engine combines this RF data with the output of other sensors, and with its knowledge of the user's needs and the policies and limitations governing its operation. It then synthesizes a scenario (e.g., "I am dealing with co-channel interference from a QPSK signal"). The cognitive engine queries its knowledge base to see if it has encountered this scenario (case) before, and, if so, what action it took. It uses the results to determine starting values for radio parameters, and passes these to a genetic-algorithm-based multi-objective optimizer that attempts to optimize the radio's performance (optimum performance is defined as complete satisfaction of the user's needs). If the cognitive engine is unable to synthesize a scenario, it will load the optimizer with a set of random parameters and see what happens. When this process is finished, the optimizer generates an array of knob settings (settable radio parameters) that will be passed to the radio platform. As part of the optimization process, the cognitive engine has predicted what the radio's performance will be after each trial set of radio parameters are applied, and it will compare the final set of these predictions with the actual radio's performance to determine whether or not it took the correct action. The new knob settings are loaded into the radio and the radio's observations are reported to the cognitive engine; the actual and predicted performances are compared and the results stored; and the cycle begins again. An important reason for making this comparison is to determine whether or not the cognitive engine correctly synthesized the scenario during the previous cycle. Clearly, it did not if the knob settings calculated in the previous cycle made the performance worse. The cognitive engine will remember this, and revise its assumed scenario and try something different.

Genetic algorithms provide both a computationally efficient trial-and-error optimization process, and also a way to implement learning, patterned on nature's way of remembering successful adaptations. While the technique can be criticized for its tendency to quickly get close to an optimum solution and then either take long times to reach the exact optimum, or even oscillate between suboptimum solutions, for purposes of practical radio operation, getting close to the optimum is sufficient.

Our first complete cognitive engine implementing the algorithm of Figure 3 and Figure 4 is shown in Figure 5 [12]. It was a complicated multithreaded software system written in *C* and running under *Linux*. In our recent work, we have replaced this with a much simpler single-threaded version written in *Python*, shown in Figure 6.

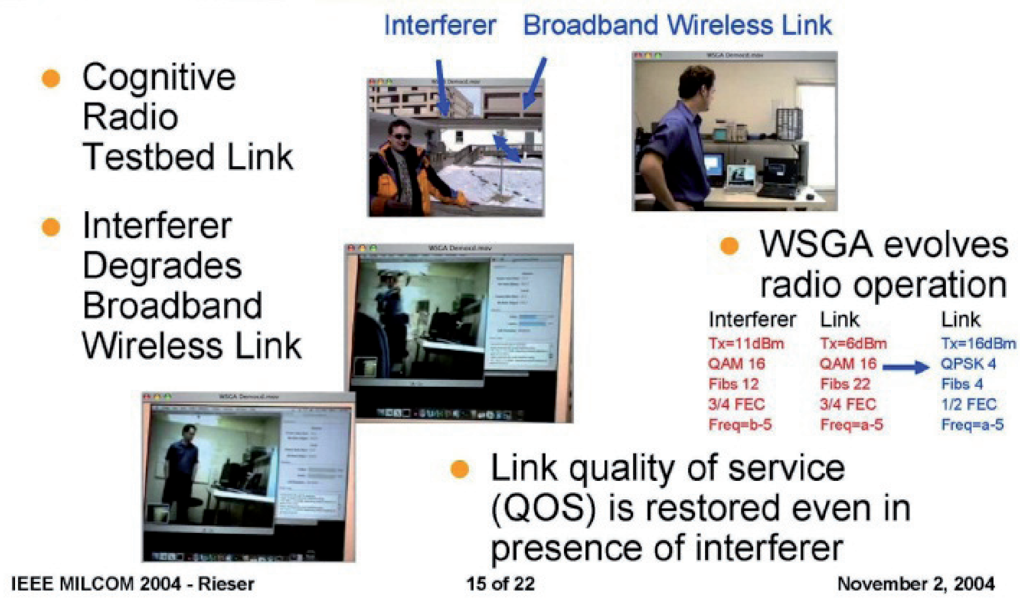

Figure 7. The first demonstration of a cognitive radio.

3. First Prototypes

The first prototype cognitive radios, employing the VT cognitive engine and genetic algorithms, were built by Rieser et. al. in 2004 [13, 14]. The RF unit was a 5.8 GHz Proxim *Tsunami* radio, with the following electronically settable knobs: transmitter power, modulation type and index, forward error correction (FEC), uplink/downlink time-slot ratio (“fibs”), and center frequency. The test radios established a video link on a fixed frequency. A jammer was then turned on. The radios were not allowed to change frequency, but cooperatively adjusted all of the other knobs to minimize the effect of the jammer. If the jammer went away and subsequently returned, the radios remembered their earlier settings, and immediately returned to them.

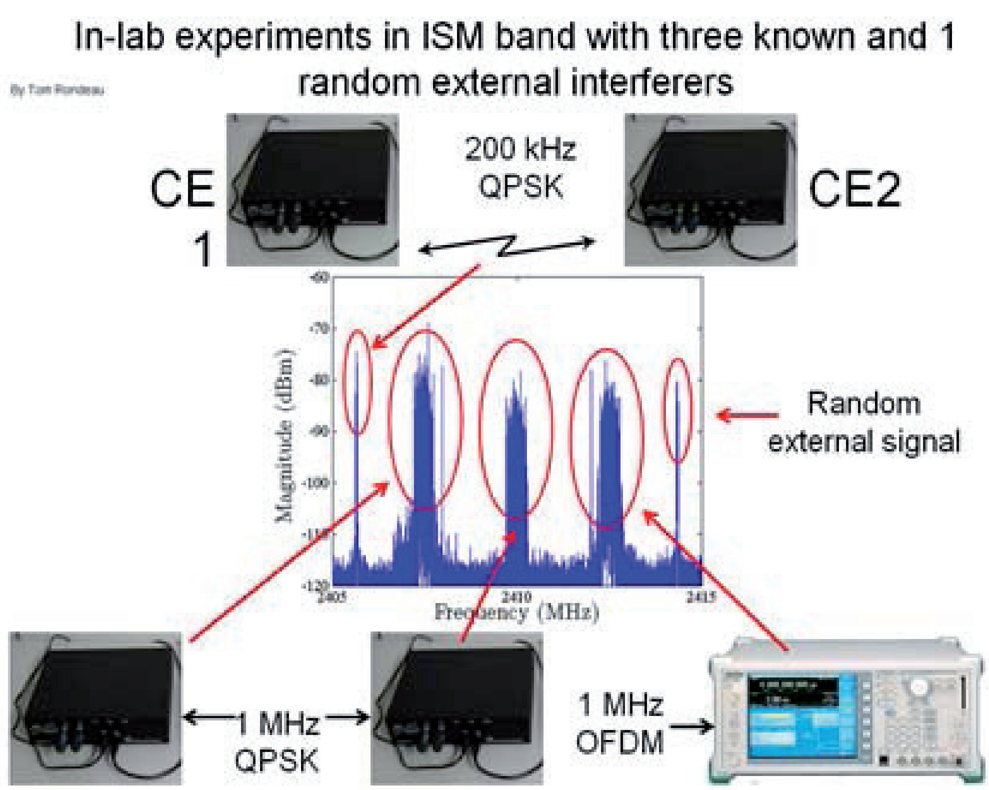

Figure 8. A cognitive-radio demonstration at DySPAN 2007.

Figure 7 shows the radio setup, the video images before and after the cognitive engine eliminated the jammer's interference, and the before and after knob settings, as evolved by the cognitive engine's *Wireless System Genetic Algorithm*.

The initial prototype was soon followed by a software-defined-radio-based cognitive radio that used an Ettus Research Universal Software Peripheral 1 (USRP-1). In a demonstration at DySPAN 2006, a pair of these radios operating in an interference-filled environment found an open frequency, and established and optimized a data link. At this point, the learning and optimization parts of the cognitive engine were fully operational, and the user could assign relative weights to the parameters that were to be optimized (see Figure 8 [15]).

4. A Brief Survey of Working Radios and Supporting Technology

4.1 RF Platforms

Academic cognitive-radio development has focused primarily on two families of software-defined-radio platforms. The most popular with physical-layer/RF-oriented researchers is the low-cost Ettus Research line of Universal Software Radio Peripherals (USRPs) [16]. These cover dc to 6 GHz. While they are commonly associated with the *GNU Radio* software [17], they are also used with other systems, including the *VT Software Communications Architecture*-based *OSSIE* [18], and *IRIS*, developed at Trinity College, Dublin, Ireland [19]. A computationally more powerful and more expensive platform, favored particularly by network-oriented researchers, is the Rice University WARP (Wireless Open Access Research Platform) board [20]. Researchers at the University of Kansas developed an innovate platform called the Kansas University Agile Radio (KUAR), which, while very attractive for cognitive-radio research, never became widely available [21]. A brand new entry in the RF platform market is the Phi from Per Vices [22]. The Phi is a PCI Express-card platform that installs directly into a computer chassis. This integration eliminates any wire interconnect, allowing extremely high transfer rates, up to 8 Gbps. The Phi covers 100 kHz to 4 GHz with up to a 200 MHz bandwidth, and, like the USRP, works with *GNU Radio* [23].

The WARP board and the later USRP models incorporate significant processing power. In laboratory prototypes, some or all of the software-defined-radio and cognitive-engine software typically runs on a separate general-purpose processor, such as a high-end laptop. Recent work on mobile and portable applications employs cognitive engines and software-defined-radio software that run on single-board computers, such as the Beagleboard [24].

While software-defined radios dominated the early years of cognitive-radio building, this is changing, in response to the availability of low-cost CMOS transceiver chips such as the Motorola RFIC series and the Hope RF RFM22B (Figure 9) [25]. A cognitive engine can rapidly reconfigure these by loading new values into registers. The development time, the cost, and the power consumption are a small fraction of that for a software-defined radio with similar capabilities.

4.2 Prototypes

The most widely deployed DSA (dynamic spectrum-access) radios are those using the XG ("Next Generation") technology developed under DARPA sponsorship [26]. An advanced hand-held prototype, incorporating XG, and an excellent platform for implementing a variety of cognitive-radio applications is the DARPA WNaN ("Wireless Network after Next") radio [27, 28].

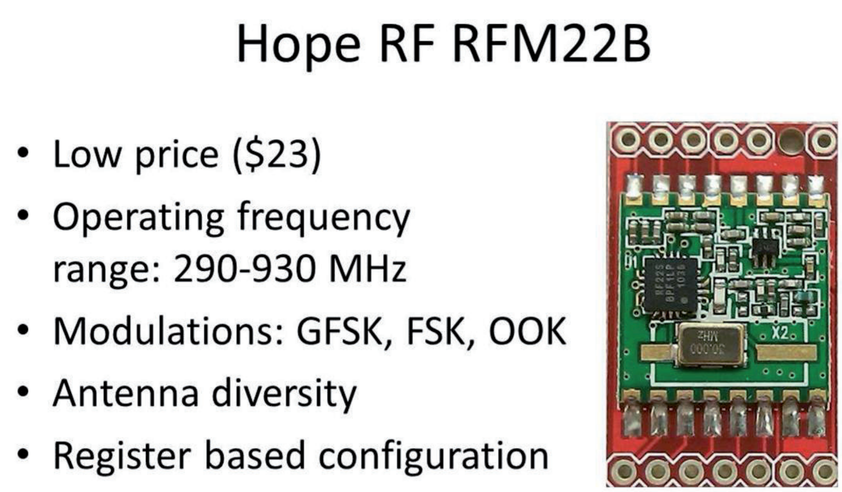

Figure 9. The Hope RF FRM22B, an attractive RF platform for low-cost cognitive-radio development.

Researchers at the Canadian Communications Research Centre have developed an 802.11-based prototype cognitive radio called both the WiFi CR and CORAL. They describe this as a building block for building cognitive radios and networks capable of performing dynamic spectrum access and other cognitive functions [29, 30].

Virginia Tech researchers have set up what is probably the first permanently deployed, large-scale cognitive and software-defined-radio network test bed emphasizing PHY and MAC reconfigurability. With 48 nodes, the Cognitive Radio Network Testbed (CORNET) covers 100 MHz to 4 GHz. It is based primarily on the Ettus USRP2 motherboard, with a Motorola RFIC4 daughterboard. Code for each node runs on its own Intel Xeon processor-based server. While used primarily for dynamic spectrum access to date, it offers users a large and flexible test bed on which researchers can try out almost any proposed cognitive-radio code [30].

Hardware realizations of cognitive-radio functions other than dynamic spectrum access are rare. [31] presented a practical demonstration of how a cognitive radio can achieve significant savings in overall system power by managing the power-supply voltage in accordance with its knowledge of channel conditions: i.e., by trading off channel bit errors against memory errors in a way that maintains constant link performance.

5. Cognitive Radio Applications

5.1 Cognitive Radio as a Solution to Radio Hardware Limitations

Marshall has called attention to the problems caused by radio front-end intermodulation products when radios operate in a densely occupied spectral environment [32, 33]. High-level interfering signals, the spectra of which are well outside of the intended receiver's detection bandwidth, can raise the pre-detection noise floor to a point where the link fails. The common solution of incorporating front ends with ever-higher third-order intercept points quickly becomes too costly, both economically and in terms of radio power consumption. Marshall's work showed that a cognitive radio able to choose the operating frequency corresponding to the lowest level of intermodulation noise entering the front-end filter can operate successfully with dramatically lower linearity requirements than a non-cognitive radio restricted to operating on a randomly assigned frequency in the same band. As an example, a cognitive radio with a 30% bandwidth front-end filter achieved – with a -27 dBm IIP_3 – the same probability of overload as a non-cognitive radio with an IIP_3 of -5 dBm, for spectral occupancy conditions typical of downtown Chicago, IL [34].

5.2 Cognitive Radio as a Solution to Antenna and Propagation Problems

Although much published work has focused on cognitive radio as a means of expanding spectrum availability through interference management, the prospect of overcoming antenna and propagation impairments by cognitive means is important. A comprehensive overview of propagation channel models useful for cognitive radio design was given in [35]. We think that cognitive remediation of propagation impairments is particularly attractive for those mobile applications in which the cognitive engine can affect the vehicle orientation, position, and attitude, trading radio and mobility parameters off against each other. In a preliminary example, signal-strength measurements allowed a swarm of micro-unmanned-aerial vehicles to control their separation distances in a way that maximized both connectivity and sensor coverage [36, 37]. By recognizing whether throughput on a particular link is being limited by interference, noise, fast fading, shadowing, absorptive attenuation, depolarization, etc., a cognitive radio may quickly select a set of parameters that improve or even optimize the radio's performance for the current situation. Lindhé and Johansson demonstrated that throughput was improved when a robot was aware of its radio's SNR and could adapt its motion to "spend slightly more time at positions where the channel is good" [38]. Recent work by Camp, Knightley, and their students and collaborators, clearly established that radios using only SNR-based adaptation consistently under-performed context-aware radios that were able to identify channel type, and use this information with SNR in their adaptation algorithms [39, 40]. While these authors favored "adaptive radio" terminology, their techniques pointed the way to context-aware cognitive radios that can deal with short-term fading and other propagation impairments.

5.3 Cognitive Radio and Autonomous Vehicles

Autonomous vehicles and cognitive radios are very similar in function, performing corresponding tasks in differing domains: the three-dimensional spatial domain for autonomous vehicles, and the radio-frequency domain for cognitive radios. The operational flow of both cognitive radios and autonomous vehicles can be summarized as follows: (1) analyze the environment, (2) make and execute a decision, (3) evaluate the result, and (4) repeat the process as necessary.

In spite of this similarity, very little crossover exists. Until recently, the two fields of research have pursued parallel tracks, solving similar problems in isolation, without the benefit of shared resources or contrasting points of view. However, there has been some effort in recent years to bring the worlds of cognitive radio and autonomous vehicles together.

Early work on combining autonomous radios and autonomous vehicles simply presented the concept of using a cognitive radio, such as VT's cognitive radio engine, as the communication subsystem of an autonomous vehicle [41]. An autonomous vehicle can carry several radios (remote control, telemetry, backup communications, emergency stop system). Replacing these radios with a single flexible and agile radio-communications system can provide spectral efficiency, improved link performance, reliability, and interoperability. These and other benefits are driving the adoption of cognitive radio in railroad systems [42].

More recent efforts aim to integrate RF information into the motion-planning and autonomous-vehicle decision-making processes. Autonomous-vehicle relay links may use a decentralized algorithm that considers the gradient of the link SNR as in [43], or a centralized algorithm that considers basic geometry for link optimization as [44]. Swarms of mobile robots may exploit the fading characteristics of an environment to maintain throughput of a relay chain as in [45] (see also Section 5.2)

While current and previous efforts have explored the possibilities of position-aware communications as well as communication-aware motion, the obvious and logical next step is to combine the two concepts for true integrated decision making across both the motion and RF domains. Unified multi-domain decision making considers RF and motion information together in a single unified decision-making process. The result is a system with two equally important degrees of freedom: RF agility and physical mobility. Current work by the authors leverages this combined decision making for unmanned aerial vehicles (UAVs) in a scenario where a UAV is flying a nominally cyclic or repeating flight path. As the UAV traverses the path, it experiences varying RF effects, including multipath propagation and terrain shadowing. The goal is to provide the capability for the UAV to learn the flight path with respect to motion and RF characteristics, and modify radio parameters and/or motion behavior proactively to mitigate adverse effects.

CSERE is the core of our UAV research platform, dubbed UAV CSERE. The platform is based on a Beagleboard-xM, integrating a Hope RF RFM22B RFIC and the Lego Mindstorms NXT 2.0 robotics kit [46], for a compact fully autonomous mobile cognitive-radio platform. CSERE coordinates and controls both the robotic (motion) behaviors as well as the RF communication aspects of the experimental platform. CSERE's decision making allows the mobile platform to observe and adapt to its changing environment (see [47] for full details).

6. For Further Reading

For more-detailed information, we direct the reader to [48-51]. For an early but highly influential review article, see [52]. The April 2009 issue of the *Proceedings of the IEEE* contained a number of significant papers detailing progress through 2008, including details of the Virginia Tech (VT) contributions in [53], and a comprehensive overview in [54]. For an excellent ten-year retrospective on cognitive radio, see [55].

7. Acknowledgments

This material was based upon work supported by the National Science Foundation under Grant No. CNS-0519959. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation (NSF).

This material was based on research sponsored by Air Force Research Laboratory under Agreement #FA8750-11-2-0014. The views and conclusions contained herein are those of the authors, and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied, of Air Force Research Laboratory or the US government.

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1 We acknowledge that there are many definitions of cognitive radio. For the ITU-R definition, see [3]. Haykin expressed the definition of a cognitive-radio system in his five principles of cognition [4].

2 In some ways, the practical part of Mitola's vision is fulfilled by the iPhone 4 and Siri, although most people would not call these cognitive radios.

3 While this observation may well have originated earlier, we thank Karen Zita Haigh for first bringing it to our attention: see reference AFRL 11 in [10].

Book Reviews for Radioscientists

[Editor's note: The Young Scientists who received an award at the 2011 Istanbul URSI GASS were asked to review their favorite textbook, even if it was a classic book. This is in contrast to our usual reviews, where we try to have new books reviewed. The reviews in this issue are from Young Scientists.]

Microwave Engineering

By David M. Pozar, New York, John Wiley & Sons, 2012; ISBN : 978-0-470-63155-3.

Microwave Engineering is one of the many publications of Dr. David Pozar, an emeritus professor at the University of Massachusetts at Amherst. Four editions have been published during the 22 years of success of *Microwave Engineering* with electrical engineering faculties around the world. The interest of teaching with the aid of this written tool have motivated translations of the original textbook into Chinese, Greek, and Korean.

Dr. Pozar wrote his book under the philosophy of avoiding the handbook approach, in which "a large amount of information is presented with no or little explanation or context." He did well. Good practices in microwave engineering require the understanding of basic electromagnetic concepts, which are presented in a very elegant way along the chapters. This is why even though my main interests are related to EMC, I use this microwave textbook for checking from time to time, not only the principles of microwave devices, but also the basics of transmission-line theory, waveguides, and scattering parameters.

In the latest version of his book (fourth edition, 2012), Dr. Pozar made an effort to present to a deeper extent the foundations of noise analysis and nonlinear distortion, microwave circuits, and wireless systems. Due to its recent publication, I am not familiar with the new contents, but after several years using the second and third editions, I am confident that they are the necessary concepts to arrive at useful results.

What is very attractive about this textbook is that it is very suitable for microwave courses in electrical engineering faculties. The contents are presented in a way in which – with or without deep electromagnetic explanations – the analysis of microwave devices is straightforward. Furthermore, there are plenty of proposed references and online resources for teaching, such as *PowerPoint* slides and solutions manuals, which were handwritten by Dr. Pozar.

For those interested in the electromagnetic bases of microwave engineering, the preliminary Chapters 1, 2, and 3 of the textbook cover the main concepts involved in transmission-line and wave-propagation analysis. The fundamental bases of electromagnetics are briefly described in the first chapter, as in any classical textbook of electromagnetics. Dr. Pozar decided to go directly to the heart of the matter by presenting the solutions to the wave equation, and the consequences of solving it in lossless and lossy media.

Some engineers who prefer circuit analyses rather than field concepts may skip this first chapter, and go directly to the fundamentals of transmission-line theory in Chapter 2. This is one of my favorite chapters of the textbook, because it contains a broad view of important topics explained in simple words. In this part of the book, one finds the step-by-step solutions to the telegrapher's equations for structures with and without losses. The first pillars of impedance matching are gently introduced, with the explanation of the quarter-wave transformer in the frequency and time domains, which I believe is a must before dealing with the analysis of any microwave device. Another interesting feature of this chapter is the introduction of the Smith chart and its use. For those still interested in field analysis, there is a derivation of the circuit telegrapher's equations for a coaxial structure, followed by a compendium of the per-unit-length parameters of other traditional geometries. This latter material is one of my frequent reasons for consulting this book.

Once the concepts have been well defined in Chapter 2, one can jump to the analysis of microwave devices presented in Chapters 4 to 8, or to the analysis of microwave circuits in Chapters 10 to 13.

However, skipping Chapter 3 is not recommended for those interested in correctly understanding the propagation along two-conductor (so-called transmission-line) or single-conductor (waveguide) structures. The many possible structures for guiding microwave energy are fully discussed here, and it is very common to open the book on this chapter to review the TM and TE configurations of several structures. The mathematical analyses of the propagation modes along traditional structures include the parallel-plate waveguide, rectangular and cylindrical waveguides, coaxial cables, microstrip and strip lines, and grounded dielectric sheets. At the end, the fundamental concepts for dispersion analysis are discussed.

The microwave network analysis is dealt with in Chapter 4. From my point of view, this is one of the difficult chapters for newcomers, because of the many concepts involved here. Dr. Pozar included in this chapter the introduction of the scattering matrix; other two-port network equivalents such Z, Y, and T parameters; signal-flow graphs; discontinuities and modal analyses; and waveguide excitations. From time to time, this chapter turns out to be the "avoided" chapter, since some of these concepts may not be necessary for understanding all the specifics of microwave analyses, and each of these require more time to be fully understood (after several years of practice).

Chapters 5 to 8 deal with the main devices used in microwaves. They are fully straightforward to read, and contain the necessary concepts and expressions for understanding how the devices work. Each of the chapters constitutes a big topic in faculty courses, and I usually only came back for very specific doubts about each of the devices therein explained. Chapter 5 explains the many methods for impedance matching and tuning. Chapter 6 introduces resonators, cavities, and their excitation. Chapter 7 talks about power dividers and directional couplers. Finally, in Chapter 8, an overview of filtering techniques in microwaves is given.

The first section of the book (Chapters 1 to 8) is dedicated to linear devices. Nonlinear devices, such as ferromagnetic materials and semiconductors, are the topics of the book from Chapters 9 to 14. The properties of ferrites and the propagation of fields inside them are dealt with in Chapter 9. Ferrite circulators, shifters, and isolators are discussed as separate sections of the chapter.

Active-circuit design constitutes a separate branch of microwave engineering, which is covered in Chapters 10 to 13. Since the third edition of the textbook, two new chapters were created in which better insight is given for amplifiers, oscillators, and mixers. As explained before, a direct jump from Chapter 2 to this section seems fair, since little electromagnetic theory is dealt with in these chapters. However, quick visits to the concepts presented in Chapter 4 could be a nice complement for the reading. Students or engineers who are interested in microwave transistors and diodes are referred to Chapters 10 and 11. These chapters deal with the analysis of noise and nonlinear distortion, and microwave semiconductor devices, respectively. The main techniques for amplifier design with microwave transistors are explained in Chapter 12. Chapter 13 is a separate chapter dedicated to the design of oscillators and mixers, in which the concept of phase noise is very well explained.

Finally, the arrangements of the microwave devices and circuits in daily-use scenarios, such as radar systems or microwave links, are explored in the closing chapter. Dr. Pozar included an overview of several applications in which very practical aspects are also commented upon. The reviewed systems include general-purpose wireless systems, microwave links, radar systems, radiometer systems, and heating.

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Ultra Wide Band Antennas

edited by Xavier Begaud, London and New York, Wiley-ISTE, 2010; ISBN: 978-1-84821-232-9; Hardcover 100.20 €

This book is written at a level that every telecommunication engineer should be able to understand. The reader does not need to be an antenna expert or a UWB expert. Even if the different chapters of the book have been written by different authors, the coherence is not lost, even if the styles might be different.

All new concepts are clearly explained. After a description of the different kinds of UWB systems – both from the regulatory viewpoint as well as from the modulations being used, and from the viewpoint of novel applications (Chapter 1) – Chapter 2 gives a good overview of the history of antennas. The chapter even explains the origin of the word "antenna," with a beautiful illustration of one the nice four-masted sailing ships of the past (but still sailing). Of course, the chapter describes the classical approach for characterizing antennas. All concepts are well illustrated with pictures of real designs from the practical experience of the authors, as well as from computed and/or measured values of the important parameters, such as patterns and gains.

In the chapter devoted to specific UWB antenna theory (Chapter 3), generalizations applicable to wideband antennas are fully detailed and explained. The Friis transmission formula is generalized to take into account the phase (not only important for GPS antennas!). In parallel, the time-domain approach is worked out. This leads to a pair of related ATF (antenna transfer functions) and AIR (antenna impulse responses). It is shown that reciprocity in the time domain leads to derivatives or integrals leading to waveform distortions and dispersion, which could be characterized by group delay. More appropriate parameters for highly dispersive antennas, such as the differential group delay and standard deviation of the group delay, are introduced, and measured examples are given. After the introduction of those parameters, attention is focused on the reduction of the number of data to fully characterize a UWB antenna.

A few techniques, from the well-known SEM (Singularity Expansion Method) as well as the more classical SMEM (Spherical-Mode Expansion Method) to more recent combinations of both, are introduced and illustrated with practical examples.

The chapter entitled "Experimental Characterisation of UWB Antennas" (Chapter 4) is split into different parts. Here, the author did not choose to give the two options (frequency domain and time domain) in parallel, but consecutively discusses radiation and impedance (called electric characteristics) measurements first with the standard frequency-domain methods. This is followed by the more-specific time-domain methods, which evolved out of radar systems. At the end of the frequency-domain paragraph, the "poor man's" time-domain measurement technique is mentioned (a frequency-domain measurement followed by an FFT), with some advantages such as a broad dynamic range, but requiring other hardware, such as an anechoic chamber. Most of the chapter gives an overview of the history and the special equipment required to perform time-domain measurements, starting from the short-impulse generators and filters, over the sampling 'scopes, up to the numerical treatment of the collected data samples. The part devoted to the input-impedance characterization is obviously rather short, since this topic is well known.

After the computations and the measurements, the chapter describing the different types of UWB antennas (Chapter 5) logically follows. An attempt is made to classify those antennas into three different categories. The first category describes the frequency-independent antennas, and more particularly, log-spirals and conical spirals (belonging to the group of equiangular antennas), circular, trapezoidal, dipole log-periodic antennas, and sinuous antennas, all under the umbrella of log-periodic antennas. The second category describes the so-called elementary antennas. These are the more easily computed biconical antennas, discone antennas, and bowtie antennas. They include the more-recent circular monopole, triangular, and square antennas, as well as more complex monopoles (such as butterfly or printed monopoles, even if these last antennas are similar to Marconi's first antennas). Printed versions are discussed, as well as more-advanced ways to improve the performance. This includes improving bandwidth or even gain, by using more-directive elements (tapered-slot antennas, such as Vivaldi antennas, horns, or teardrop-shaped antennas). Finally, how to reach the limits of the antenna law of misery (how to miniaturize the antenna without losing too much gain!), as well as special application antennas for ground- or surface-penetrating radars, such as arrays of Valentine or dragonfly antennas, are discussed.

The last chapter is devoted to the propagation part of a UWB communication system. Indeed, two antennas are nearly never in free-space conditions, and the propagation effects due to both specular and diffuse scatterers play a very important role in the design of a performing UWB system. The author starts with discussing the ideal channel, then combining the transmitting and receiving characteristics of a complete system. New gain parameters in the case of coherent and incoherent reception are defined, as well as the (direction-specific) distortion. These are illustrated for different kinds of antennas, from the bicone to the horn. Coherent reception in both low and strong multipath densities (so, the real case) are then discussed, first without and then with a rake (time-delayed) receiver. Finally, the principles of incoherent reception are described, without too much detail. This is compensated for by illustrations of real, measured channels in the next paragraphs.

Finally, two small appendices discuss reciprocity and stationary-phase methods. Lists of abbreviations, authors, and references, as well as a useful index, conclude this very interesting book.

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RADIO 2012 - Radio and Antenna Days of the Indian Ocean
Mauritius, 24-27 September 2012
Contact: Vikass Monebhurrun, Dept of Electromagnetics, DRE-L2S, SUPELEC, 3, Rue Joliot-Curie, 91192 Gif-sur-Yvette Cedex, France, Fax +33 1 69851569, E-mail vikass.monebhurrun@supelec.fr, http://sites.uom.ac.mu/radio2012

October 2012

ISSSE 2012 - International Symposium on Signals Systems and Electronics
Potsdam, Germany, 3-5 October 2012
Prof. Rolf Kraemer, IHP GmbH, Dept. System Design, Im Technologiepark 25, 15236 Frankfurt (O), Germany, E-mail: Kraemer@ihp-microelectronics.com

ISAP 2012 - 2012 International Symposium on Antennas and Propagation
Nagoya, Japan, 29 October - 2 November 2012
Contact : Professor Koichi Ito, General Chair of ISAP2012, Chiba University, 1-33 Yayoi-cho, Inage-ku, Chiba-shi, Chiba 263-8522, Japan, Fax: +81-43-290-3327, E-mail: ito.koichi@faculty.chiba-u.jp, http://www.isap12.org

November 2012

IEEE-RFID-Technology and Applications 2012
Nice, France, 5-7 November 2012
Contact: Dr. Smail TEDJINI, General Chair of IEEE RFID-TA 2012, NPG-ESISAR, LCIS, 50, rue B. de Laffemas, BP 54, F-26902 VALENCE CEDEX 9, FRANCE, Fax +33 4 75 43 5642, http://lcis.grenoble-inp.fr/le-laboratoire/ieee-rfid-ta-2012-453132.kjsp

December 2012

ICMARS 2012 - International Conference on Microwaves, Antenna Propagation & Remote Sensing
Jodhpur, India, 11-15 December 2012
Contact : Prof. O.P.N. Calla, International Centre for Radio Science, Plot No1, Rano ji Ka Bagh, Khokhariya Bera, Nayapura, Mandore, Jodhpur 342304 Rajasthan, India, Tel +91 291 2571030, Fax +91 291 257 1390

April 2013

EUCAP 2013
Gothenburg, Sweden, 8-12 April 2013
Contact: Prof. G. Kristensson, Dept. Electrical & Information Technology, P.O. Box 118, S2-221 Lund; Sweden, E-mail Gerhard.Kristensson@eit.lth.se

URSI Commission F Triennial Open Symposium on Radiowave Propagation and Remote Sensing
Ottawa, Ontario, Canada, 30 April - 3 May 2013
Contact : Radio Propagation :Dr. R.J. Bultitude, Communications Research Centre, Satellite Comm. & Radio Propagation, 3701 Carling Avenue, Ottawa, ON K2H 8S2, Canada, Email : robert_bultitude@ursi-f-ts.com; Remote Sensing : Dr. Brian Brisco, Email : Brian_Brisco@ursi-f-ts.com, http://ursi-f-ts.com

May 2013

EMTS 2013 - URSI Commission B International Symposium on Electromagnetic Theory
Hiroshima, Japan, 20-23 May 2013
Contact : Prof. G. Manara, Dept. of Information Engineering, University of Pisa, Italy, E-mail g.manara@iet.unipi.it, Website : http://ursi-emts2013.org

June 2013

RAST 2013 - New ways of Accessing Space for the Benefit of Society
Istanbul, Turkey, 12-14 June 2013
Contact : RAST2013 Secretariat, Turkish Air Force Academy (Hava Harp Okulu), Yesilyurt, Istanbul, Turkey, Fax : +90 212 6628551, E-mail : rast2013@rast.org.tr, http://www.rast.org.tr

July 2013

Beacon Satellite Meeting
Bath, Uk, 8-12 July 2013
Contact: Ms. Patrica Doherty, Boston University School of Management, 595 Commonwealth Avenue, Boston, MA 02215, USA, E-mail : pdoherty@bu.edu, Website : http://www.bc.edu/research/isr/ibss.html

September 2013

AP-RASC 2013 - AsiaPacific Radio Science Conference
Tapei, China SRS, 3-7 September 2013
Contact : Prof. K. Kobayashi, Chair, AP-RASC International Advisory Board, Fax: +886 2 23632090, E-mail: ctshih@tl.ntu.edu.tw, Website : http://aprasc13.ntu.tw

ICEAA-APWC-EMS conferences
Torino, Italy, 9-13 September 2013
Contacts: Prof. W.A. Davis, EMS Chair wadavis@vt.edu and Prof. Y. Koyama, EMS Vice-Chair koyama@nict.go.jp, http://www.iceaa.net

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

News from the URSI Community

NEWS FROM A MEMBER COMMITTEE

ITALY

Prof. Sigfrido Leschiutta

On May 25, 2012 a workshop ad memoriam of Prof Sigfrido Leschiutta has been organized by INRIM, Turin Academy of Science, and Politecnico of Torino to celebrate the achievements and inspirations of Prof Leschiutta in the time and frequency metrology field. Prof Leschutta was also an active member of URSI Commission A

One hundred people took part to the event including on opening lecture by the Nobel laureate Prof T. Haensch, lectures given by Dr Quinn, Emeritus Director of the BIPM and Prof Inguscio, Director of LENS in Firenze, followed by remembrances of colleagues and friends coming from the different fields were prof Leschiutta was mostly active. His ability and enthusiasms in the different fields of science and music was recalled. The event ended with a concert of the Accademia del Santo Spirito playing ancient instruments partly built by Prof Leschiutta. Mrs Magda Leschiutta and their 3 sons took part to the ceremony. More information on http://www.inrim.it/hof/SLeschiutta/25may2012/

Call for Papers

Radio Science Bulletin

Special Issue on the Role of Radio Science in Disaster Management

Between 1975 and 2009, 10,000 natural disasters in the world killed more than 2,500,000 people, with an amount of the damage totaling more than 1.7 trillion US dollars. The main causes were earthquakes, landslides, cyclones, storms, and floods, and infectious illness.

Science and technology can contribute to the reduction of the impact of these disasters. Radio science has a central role in the management of disasters. Radio science constitutes an essential component for supervising the environment, and for collecting data in order to feed forecasting models that have a large influence on the reliability of decision making. In the context of a significant destruction of infrastructure, radio communications become critical for the organization of rescue operations.

The objective of this special issue is to review contributions resulting from radio science in order to decrease the impact of such disasters, and to encourage the scientists to think of how they can contribute to reducing the impact of such events. The partial list below provides examples of the contributions of radio sciences

The main topics of interest include but are not limited to:

- Communication facilities for disaster management
- The use of radio techniques for disaster prediction
- Radio remote sensing for disaster detection, disaster management, and post-disaster programs
- All other topics related to the application of radio science to disaster prediction, detection, mitigation, management, and recovery

Guest Editors

Prof. Tullio Joseph Tanzi, Télécom ParisTech–LTCI/CNRS, Paris, France
Prof. François Lefeuvre, LPC2E/CNRS, URSI, Orléans, France
Prof. P. J. Wilkinson, IPS, Bureau of Meteorology, Australia

Papers must be written in English and describe original research not published or currently under review by other journals or conferences. Submissions should be sent in the format for the *Radio Science Bulletin* via e-mail to tullio.tanzi@telecom-ParisTech.fr.

Proposed schedule

Manuscript submission: **October 15th, 2012**
Expected publication: Second semester 2013

URSI Commission B
2013 International Symposium on Electromagnetic Theory

Hiroshima, Japan May 20-24, 2013

www.ursi-emts2013.org

General Information

The "2013 International Symposium on Electromagnetic Theory" (EMTS 2013) is organized by Commission B (Fields and Waves) of the International Union of Radio Science (URSI) and the Electronics Society of The Institute of Electronics, Information and Communication Engineers (IEICE). It will be held on May 20-24, 2013 in Hiroshima, Japan. Its scope covers all areas of electromagnetic theory and its applications.

Important Dates

Nov. 1, 2012	Deadline for receipt of YSA papers
Nov. 15, 2012	Deadline for receipt of papers
Jan. 15, 2013	Notification of authors regarding acceptance of papers, notification of YSA applicants
Mar. 15, 2013	Deadline for pre-registration of authors(All presenting authors must pre-register)
April 30, 2013	Deadline for pre-registration of participants
May 20, 2013	URSI Commission B School for Young Scientists
May 20-24, 2013	Symposium

Young Scientist Awards

Young Scientist Awards (YSA) have been planned for young scientists. For details, visit the website.

Suggested Topics

Contributions concerning all aspects of electromagnetic theory and its applications are welcome. Novel and innovative contributions are particularly appreciated. Special topics will also be announced in the Final Call for Papers in addition to the following list.

- New basic theoretical developments
- Scattering and diffraction
- Inverse scattering and imaging
- Time domain methods
- High-frequency methods
- Guided waves
- Solutions to canonical problems
- Propagation and scattering in layered structures
- Random media and rough surfaces
- Metamaterials and complex media
- Beam and pulse propagation and scattering in lossy and/or dispersive media
- Non-linear phenomena
- Antennas: general aspects
- Antenna arrays, planar and conformal
- Numerical methods: general aspects
- Numerical methods for integral and differential equations
- Hybrid methods
- Interaction of EM waves with biological tissues
- EM theory and applications for radio systems
- Antennas and propagation for communication systems:
- Smart antennas, UWB systems, etc.
- Mathematical modeling of EM problems

Submission and Further Information

The instructions for the submission of papers and the updated information on the Symposium will be available the Final Call for Papers and on the conference Web site. Copyrights of all accepted papers are to be transferred to tl IEICE.

All accepted and presented papers will be available throu IEEE Xplore.

URSI Commission B School for Young Scientists

The "URSI Commission B School for Young Scientists" w be organized for the first time at EMTS 2013 in Hiroshim In this one-day school, a series of lectures will be deliver by leading scientists in the Commission B community and young scientists are encouraged to learn the fundamentals and future directions in the area of electromagnetic theor Details will be announced later.

Conference Contacts

General questions and technical program:

Chair, Conference and Commission B of URSI
Prof. Giuliano Manara
Department of Information Engineering,
University of Pisa, Italy
E-mail: g.manara@iet.unipi.it

Questions regarding local arrangements:

Co-Chairs, Local Organizing Committee
Prof. Makoto Ando
Dept. of Electrical and Electronics Engineering
Tokyo Institute of Technology, Japan
E-mail: mando@antenna.ee.titech.ac.jp
Prof. Tsuneki Yamasaki
College of Science and Technology
Dept. of Electrical Engineering
Nihon University, Japan
E-mail: yamasaki@ele.cst.nihon-u.ac.jp

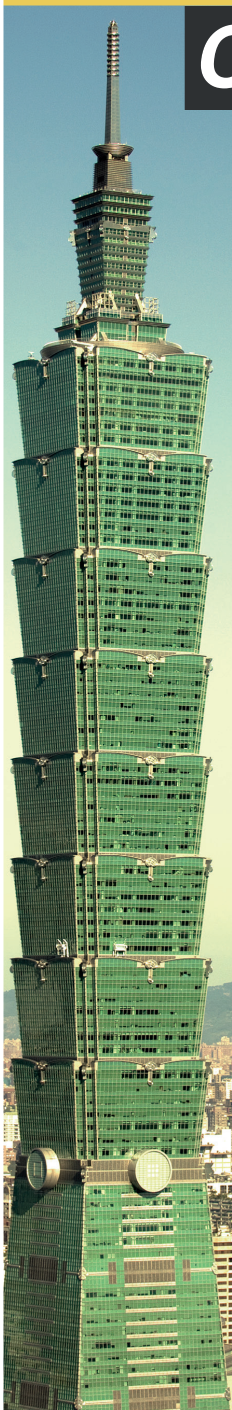
EMTS 2013 Japan Secretariat:

c/o DUPLER CORP.
3F Sun-Arch Bldg., 3-1 Nemoto, Matsudo,
Chiba 271-0077, Japan
Tel: +81-47-361-6030, Fax: +81-47-308-5272
E-mail: secretariat@ursi-emts2013.org

AP-RASC' 13

2013 Asia-Pacific Radio Science Conference

Howard International House, Taipei, Taiwan, September 3-7, 2013



Call for Papers

Website: http://aprasc13.ntu.edu.tw

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

Topics

- Electromagnetic Metrology
- Fields and Waves
- Radio Communication and Signal Processing Systems
- Electronics and Photonics
- Electromagnetic Environment and Interference
- Wave Propagation and Remote Sensing
- Ionospheric Radio and Propagation
- Waves in Plasmas
- Radio Astronomy
- Electromagnetics in Biology and Medicine

Young Scientist Programs

As in the URSI General Assemblies and Scientific Symposia, the following two programs are planned for young scientists:

- Student Paper Competition (SPC)
- Young Scientist Award (YSA)

Details on the Programs and the Application Guidelines are posted on the Conference website.

Special Issues

- AP-RASC'13 Special Issue will be published in "Radio Science".
- AP-RASC'13 Special Issue for Student Paper Competition will be published in "URSI Radio Science Bulletin".

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International Union of Radio Science (URSI)
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Bureau of Foreign Trade, MOEA
The Institute of Electrical and Electronics Engineers, Inc.(IEEE)

Secretariat

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Important Dates

Submission Deadline of One-Page Abstracts:
Feb. 28, 2013
Acceptance Notification:
April 30, 2013

Committees

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Ping-Cheng Yeh, National Taiwan Univ., Taiwan

Secretary
Tzong-Lin Wu, National Taiwan Univ., Taiwan

Electromagnetic Metrology Symposium

Organized by Commission A of the International Union of Radio Science

In coordination with the International Conference on Electromagnetics in Advanced Applications (ICEAA 2013) and the IEEE Topical Conference on Antennas and Propagation in Wireless Communications (IEEE APWC 2013)

September 9 – 13, 2013, Torino, Italy

The first Electromagnetic Metrology Symposium (EMS 2013) is organized by Commission A of the International Union of Radio Science (URSI) in coordination with the ICEAA and IEEE APWC Conferences. The three conferences will be held concurrently at the Torino Incontra Conference Center in Torino, Italy from Monday, September 9 through Friday, September 13, 2013. The three conferences share a common organization, registration fee, submission site, welcoming reception, coffee and lunch breaks, banquet, and social program. Detailed information is found on the conferences website: www.iceaa.org. EMS 2013 will consist of invited and contributed papers, workshops and short courses, and business sessions.

Suggested Topics for EMS
Metrology, measurements and standards in all areas of radio science, including:
Microwave to submillimeter measurements/standards
Quantum metrology and fundamental concepts
Time and frequency
EMC and EM pollution
Noise
Materials
Bioeffects and medical applications
Antennas
EM field metrology
Impulse radar
Planar structures and microstrip circuits
Interconnects and packaging

Information for Authors
Authors must submit a full-page abstract electronically by March 1, 2013. Authors of accepted contributions must register electronically by June 7, 2013. Instructions are found on the website. Each registered author may present no more than two papers. All papers must be presented by one of the authors. Authors who want their paper to be published on IEEE Xplore should follow the instructions on the website. Selected authors of EMS will be invited to submit a full-length paper for possible publication in the URSI Radio Science Bulletin.

Deadlines	Abstract submission	March 1, 2013
	Notification of acceptance	April 12, 2013
	Presenter registration	June 7, 2013

EMS Contacts Prof. William A. Davis, EMS Chair wadavis@vt.edu
Prof. Yasuhiro Koyama, EMS Vice-Chair koyama@nict.go.jp

Inquiries Prof. Roberto D. Graglia, Chair of Organizing Committee roberto.graglia@polito.it
Prof. Piergiorgio L. E. Uslenghi, Chair of Scientific Committee uslenghi@uic.edu

Information for authors

Content

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

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

Submissions

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

Style and Format

There are no set limits on the length of papers, but they typically range from three to 15 published pages including figures. The official languages of URSI are French and English: contributions in either language are acceptable. No specific style for the manuscript is required as the final layout of the material is done by the URSI Secretariat. Manuscripts should generally be prepared in one column for printing on one side of the paper, with as little use of automatic formatting features of word processors as possible. A complete style guide for the *Reviews of Radio Science* can be downloaded from http://www.ips.gov.au/IPSHosted/NCRS/reviews/. The style instructions in this can be followed for all other *Bulletin* contributions, as well. The name, affiliation, address, telephone and fax numbers, and e-mail address for all authors must be included with All papers accepted for publication are subject to editing to provide uniformity of style and clarity of language. The publication schedule does not usually permit providing galleys to the author.

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

Electronic Submission

A version of Microsoft *Word* is the preferred format for submissions. Submissions in versions of T_EX can be accepted in some circumstances: please contact the Editor before submitting. *A paper copy of all electronic submissions must be mailed to the Editor, including originals of all figures.* Please do *not* include figures in the same file as the text of a contribution. Electronic files can be send to the Editor in three ways: (1) By sending a floppy diskette or CD-R; (2) By attachment to an e-mail message to the Editor (the maximum size for attachments *after* MIME encoding is about 7 MB); (3) By e-mailing the Editor instructions for downloading the material from an ftp site.

Review Process

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

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I have not attended the last URSI General Assembly, and I wish to remain/become an URSI Radioscientist in the 2012-2014 triennium. Subscription to *The Radio Science Bulletin* is included in the fee.

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Professional affiliation: ____

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Areas of interest (Please tick)

☐ A Electromagnetic Metrology
☐ B Fields and Waves
☐ C Radio-Communication Systems & Signal Processing
☐ D Electronics and Photonics
☐ E Electromagnetic Environment & Interference
☐ F Wave Propagation & Remote Sensing
☐ G Ionospheric Radio and Propagation
☐ H Waves in Plasmas
☐ J Radio Astronomy
☐ K Electromagnetics in Biology & Medicine

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