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ANNUAL ACTIVITY REPORT

NATIONAL INSTITUTE OF WIRELESS COMMUNICATIONS
INCT-CSF

APPLIED RESEARCH IN WIRELESS WIDEBAND COMMUNICATION SYSTEMS

2010
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Institute Universities

- Federal University of Rio Grande do Norte (UFRN)
- Catholic University of Rio de Janeiro (PUC/Rio)
- Federal University of Minas Gerais (UFMG)
- Federal University of Pará (UFPA)

Main Researchers

- Adaildo Gomes D’Assunção, UFRN (Coordinator)
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- Marlene Sabino Pontes, PUC-RJ
- Gláucio Lima Siqueira, PUC-RJ
- Laércio Martins de Mendonça, UFRN
- Humberto César Chaves Fernandes, UFRN
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- Carlos Leônidas da Silva Souza Sobrinho, UFPA
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Administration Committee

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- José Ricardo Bergmann (Vice-Coordinator)
- Gervásio Protásio dos Santos Cavalcante
- Fernando José da Silva Moreira
- Flávio José Vieira Hasselmann
**CNPq / Institute Research Groups**

- **Microwaves and Antennas Group**  
  Adaildo Gomes d’Assunção (Coordinator), UFRN.

- **Antennas**  
  Flávio José Vieira Hasselmann and José Ricardo Bergmann (Coordinators), PUC/RJ.

- **Radio Propagation and Wireless Communication Systems**  
  Luiz Alencar Reis da Silva Mello and Marlene Sabino Pontes (Coordinators), PUC/RJ.

- **Applied Electromagnetism**  
  Gervásio Protásio dos Santos Cavalcante (Coordinator), UFPA.

- **Antennas, Propagation and Electromagnetic Theory**  
  Fernando José da Silva Moreira (Coordinator), UFMG.

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**Our Mission**

To consolidate the cooperation between the research groups from PUC, UFMG, UFRN and UFPA, with the end result of creating a structure (based on measurement and modeling) to implement access technology, which targets the viability of strategic applications in the country. Another objective is the training of human resources, at the undergraduate and graduate levels, as well as in the dissemination of production, services, and public services of new technology involved in the use of Digital TV and Radio.

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**Our Goals**

- To experimentally and theoretically determine the characteristics of the propagation channel in the VHF and UHF ranges in tropical and equatorial regions.
- To develop mathematical models for the forecasting of VHF and UHF range coverage, for use in digital TV systems.
- To carry out measurements of the electrical characteristics of the ground by means of field intensity in the medium wave range.
- To propose a propagation model which allows the consideration of the irregular profile of the terrain, and which optimizes the planning of the digital radio systems.
- To propose a new ground conductivity map for Brazil.
- Development of propagation models, project techniques and computational tools for the WiMAX networks in urban, suburban and rural areas.
- To plan, coordinate and optimize the WiMAX networks in urban, suburban and rural areas.
- To develop project techniques and antenna analysis for signal reception of fixed and mobile users and for 3G broadband services and WiMAX.
- To develop formulas in the time and frequency domains for scattering by antennas (reflector and microstrip) and selected frequency surfaces to be used in digital broadcasting and UWB systems.
- To develop adaptive algorithms for signal processing in antenna arrays.
- To develop techniques using artificial intelligence for television and broadcasting use.
Main Research Topics

• Measurements and propagation models at MW, VHF and UHF for application in the deployment of digital TV and radio systems in Brazil.

• WiMax network planning – Measurements and propagation models.

• Antennas for the reception of signals by fixed and mobile users and broadband services.

Summary of Results to Date

To date, four workshops were promoted by INCT-CS, with the participation of researchers and students in the cities of Belem, Natal, and Belo Horizonte. Furthermore, RF measurement campaigns were carried out in Rio de Janeiro, Sao Paulo, Belo Horizonte, Belem, and Natal. Since 2009, several Doctoral dissertations were supervised: 3 at UFRN, 2 at PUC-RJ, and 1 at UFMG. Regarding Masters theses: 11 at UFRN, 3 at PUC-RJ, and 2 at UFMG have been supervised. Results of these studies were published in major conferences (IMOC 2009, COMPUMAG 2009, IWATA 2010, EuCAP 2010, Antem 2010, CEFC 2010, EuMC) and technical journals. Publications in technical journals are listed in a following section.

There were four measurement campaigns, two in Sao Paulo (medium wave) and two in Belo Horizonte (VHF), to determine the propagation characteristics in urban and suburban areas. We performed a measurement campaign in Rio de Janeiro in the UHF band to characterize the channel systems in SFN Digital TV. In Rio de Janeiro and Natal, measurement campaigns were conducted to characterize the propagation channel systems WiMAX. The results were used in the development and optimization of prediction models to 3.5 GHz. In Belem, measurements were performed at 5.8 GHz.

We developed new configurations of microstrip antennas and frequency selective surfaces (FSS) for applications in wireless communications systems. Aspects related to the miniaturization of such antennas are being investigated through the use of fractal structures and substrates with high permittivity. Antennas for broadband and multiband services are being investigated. The increased bandwidth of FSS is being investigated by the use of fractal geometries and coupled structures. Techniques were developed for modeling omnidirectional dual-reflectors based on Geometrical Optics (GO). The objective is to develop design techniques where there is a need to model only one of the reflector surfaces, keeping the other classical (ie, generated by conic sections). The desired radiation profile for the omnidirectional coverage is the cosecant-square elevation in the plane of the antenna. Furthermore, formulations were developed for asymptotic integral operators that allow the determination of complete response of parabolic reflector antennas excited by feeders with arbitrary temporal behavior. The objective is to obtain tools for the analysis and design of UWB antennas.
Main Publications

Developed Research Activities (2009-2010)

- CETUC-PUC/Rio
- GAPTEM/UFMG
- LEA / LCT – UFPA
- GMA/UFRN
1. A Brief Description of CETUC-PUC/Rio

The Center for Telecommunication Studies at the Catholic University of Rio de Janeiro is a complementary unit of the Technical-Scientific Center at the Pontifical Catholic University of Rio de Janeiro, created in 1965 to conduct research, coordinate and carry out teaching activities at the graduate and postgraduate levels (Masters and Doctorate) and develop projects in the telecommunications area. The teaching activities are performed by the Department of Electrical Engineering at PUC-Rio. Postgraduate activities take place within the Postgraduate Program in Electrical Engineering, which received a grade of 6 in the most recent CAPES assessment. The professors are involved in the areas of applied electromagnetism and communications systems. CETUC has 9 laboratories and one mechanical shop. It also has a library specialized in telecommunications. Additional information on this project can be found on the CETUC website (www.cetuc.puc-rio.br).

Research activities in antennas and propagation began with the very creation of CETUC in 1965. Initially, VHF and UHF antenna prototypes were developed for radio transmission and rural telephones, whose design and manufacturing technology was passed on to the then incipient national industry. Accompanying the implementation of the microwave-based ground communication system was the development of parabolic reflectors and conventional feeders, as well as passive repeaters. During the 1970s, with the perspective of launching a domestic communication satellite, research efforts were directed toward the study of feeders and reflector systems that would integrate future ground stations. In this phase, diagonal and corrugated multimode horn prototypes were developed. A double-reflector system was also designed for the C-band, transferred to industry through the Center for Research and Development (CPqD) of TELEBRAS. To accompany the growing capacity of telecommunication companies along with the consolidation of CPqD laboratories in the 1980s, antenna synthesis and analysis methods were developed for communications in the microwave band to meet the demands of the National Communications System. Starting in 1990, in addition to the important support of CPqD/TELEBRAS, the team professors also took part in international agreements entered into by INTELSAT for the exploratory development of satellite interlacing in equatorial regions and of loaded antennas for satellite communications. Additional support for the research was provided by specific projects financed by the Study and Project Financer (FINEP) and by the Program for Centers of Excellence (PRONEX) of the Ministry of Science and Technology (MCT) within the project “Applied Research in Telecommunications”. CETUC was the recipient of the first university project (Engineering of Broadband Networks and Services) financed by FUNTTEL.

2. Research Activities Developed by CETUC-PUC/RIO

During the period 2009-2010, CETUC-PUC/Rio developed the following research activities.

2.1 – Measurements and propagation models in VHF and UHF medium waves for use in the implementation of digital TV and radio systems in Brazil

2.1.1 Field intensity measurements, delay profiles and analysis of the results in the medium wave, VHF and UHF bands

A medium wave propagation measurements campaign carried out in São Paulo, BR. The hybrid signal composed of an analog signal (AM) and a digital signal was transmitted during a short period of time, broadcasting the same content, in diurnal and nocturnal transmission. Measurements were carried out in 1210 kHz and 790 kHz.
2.1.1.1 Measurements setup

Measurements were carried out in 1210 kHz and 790 kHz in the city of São Paulo, Brazil. Figure 1 presents a schematic configuration of the transmission modules.

Reception was carried out with a mobile station of Inmetro (Instituto Nacional de Metrologia, Normalização e Qualidade).

A diagram of the reception system is shown in Figure 3.
The AOR7030 receiver measures the intensity of received signal (electrical field) and the signal-to-noise ratio of DRM digital signal. Signal-to-noise measurement is based on the modulation error ratio (MER) [3], which measures the quality of the received signal. This parameter includes the contribution of all failures that the received signal has suffered, not only the noise contribution. In this way, this measurement provides an indication of the receiver ability to correctly decode the signal. The AOR7030 receiver calculates MER each 400 ms (or at each transmitted frame of DRM signal). For subjective analysis of audio quality, the receiving setup contained also two analog AM radios and one UNIWAVE radio.

2.1.1.2 Measurements campaigns

The assessment of DRM system is divided in two analysis, as follows:

- performance evaluation: it verifies the robustness of DRM digital signal the coverage area and digital audio quality;
- compatibility with existing AM analog systems: it analyses the mutual interference between the digital signal and existing AM systems, including the hybrid simulcast signal;

The coverage area of a broadcast digital signal is defined as the area within a contour of field intensity, where the signal loss is almost imperceptible. The extension of this area depends on the effective radiated power, and, in the case of terrestrial medium waves, it depends on the ground electrical conductivity. Another issue is the ability of the signal to resist deterioration until it reaches the receiver. Man made noise, atmospheric noise and inter-system interference are the main causes of the signal deterioration.

The DRM coverage evaluation was done with measurements of the received signal along radial and circular routes. The radial routes allowed the knowledge of the extension of DRM coverage area. The circular routes were directed to the study of special environments in São Paulo city, where the received signal could be exposed to degrading conditions like tunnels, power lines and noise.

Measurements were registered during the displacement of the mobile unit. DRM frames have the length of 400ms and their specification is defined in document ETSI TS 102 349 [3]. The parameters to be registered are defined in the software of the receiver. The sets of both campaigns have information about hour, signal intensity, doppler shift, delay spread, syncronization flags, signal-to-noise ratio of logic channels, geographical coordinates and mobile velocity. The routes of the mobile station in each campaign are shown in Figure 4 and Figure 5.

![Figure 4 – Measurement routes – Campaign 1](image_url)
2.1.1.3 Measurements results

As a sample of the measured results, Figure 6 and Figure 7 show a comparison between measured values of received field intensity in campaign 1 and those predicted by Recommendation ITU-R P-368 and a similar prediction method, used by Anatel, the Brazilian Telecommunications Regulatory Agency.
The signal to noise ratio required for good reception was evaluated based on the average value of field intensity at fixed points, the corresponding signal to noise ratio and the measured audio quality (AQ). Figure 8 and Figure 7 show the results.
2.1.2 Published papers and thesis

The following papers were published as a result of the work in this research area:


The following Masters thesis is under development:

a) Maurício Vilela Guerra. Efeitos de Propagação em redes de TV Digital de Frequência Única (SFN). Dissertation (MSc in Electrical Engineering) - Pontifícia Universidade Católica do Rio de Janeiro.

2.2 – WiMAX network planning – Propagation measurements, models and computer tools

2.3 Propagation measurements at SHF

Wideband propagation channel measurements at 3.5 GHz were performed in an urban area in Rio de Janeiro, Brazil. Results include multipath delay profile characterization and comparison of measured path loss and predictions using ITU-R and SUI models.
2.3.1 Measurements setup

The OFDM channel sounder [1] used in this campaign permits measurements on all frequencies simultaneously, similarly to a chirp sounder.

The equipment was configured to obtain one sample per second, each sample including six OFDM symbols. To facilitate the recovery of OFDM symbols, guard intervals of half a symbol duration were introduced. For practical reasons, each measurement run was recorded over a 15 minutes of collected data, producing data files of 200 MB per run.

The transmitter was set-up on the top of a building at the Catholic University of Rio de Janeiro. The region has a relative flat terrain with moderately high residential buildings surrounded by hills. Fig. 1 shows the distribution of buildings in the measurements area. Fig. 2 shows the measurements routes.

A 15 dBi sector antenna with 120° HBW was mounted at 42 meters of height above ground level with no vertical tilt. A MS2781B Anritsu signal generator and a class A power amplifier were configured to provide 1 watt EIRP.

The receiver set up includes a 5 dBi antenna, a low noise amplifier with 30 dB gain, a GPS receiver and a signal vector analyser Anritsu MG3700A. The receiver system was mounted in a vehicle and data were collected while travelling in the urban neighbourhood with an average speed of 40 km/h. The bandwidths of 20 MHz, 7 MHz, 3.5 MHz and 1.75 MHz used in measurements provide multipath resolutions of 15 m, 42.9 m, 85.7 m and 171 m, respectively.

2.3.2 Propagation loss measurements

The propagation loss was obtained from temporal measurements of in-phase (I) and quadrature (Q) components. Considering the GPS error, the measured power values of all points within a 8 meters radius was averaged to provide the received power for a specific geographical coordinate. Figure 2 shows the measurements routes.

The measured propagation loss was compared with two ITU-R propagation models, ITU-R P.1546-3 for distances over 1 km and ITU-R P. 1411-3 for distances below 1 km.
It can be observed that the model in Rec. ITU-R P. 1546 significantly overestimates the attenuation whereas the model in Rec. ITU-R P. 1411 significantly underestimates it. Additionally, comparison was made against the SUI point-to-area prediction models. The SUI models provide the best prediction results but still tend to underestimate for short distances and overestimating for longer paths.
2.3.3 Delay spread measurements

Data processing to obtain the channel impulse response consists of multiplying the received signal (Y) on the frequency domain by the inverse of a replica of the transmitted signal (X). Additional correction is made in order to compensate the effects of hardware components (antennas, connectors, cables and amplifiers). To allow this correction an impulse response (CAL) was obtained on an open area with no obstructions.

The Inverse Fourier Transform of the resulting vector in equation (1) provides the power delay profile of a specific measurement.

The CFAR (Constant False Alarm) cleaning procedure was applied received signal to identify the actual multipath components. A total of 2440 power delay profiles were obtained along 13 different routes in the measurements region. The average value and the standard deviation of the RMS delay spreads obtained from the measured power delay profiles in each route are shown in Table 2. For the whole set of measured data the average value of the RMS delay was 0.196 ms with standard deviation of 0.161 ms.

The probability density function (PDF) and the cumulative distribution function (CDF) of the RMS delay spread were obtained for LOS and NLOS conditions.
2.4 Indoor propagation measurements and modeling

Considering typical indoor environments with different morphologies, as furnished offices, the FDTD technique was adapted for the prediction of indoor coverage of SIMO systems (Simple Input Multiple Output). Results were validated through comparison with predictions with analytical methods (ray tracing) and measured data.

The method was used to predict the coverage in a complex environment, consisting of several rooms with a variety of door, walls and furniture varied geometry and materials.

The investigation of coverage patterns at different time instants allowed verification of the expected pulse evolution through the environment. This was confirmed by the analysis of the received signal received in different points, either in line-of-sight and non line-of-sight situations.

In the same environment, a measurements campaign of Digital TV signals at UHF and simulation results were confirmed by the experimental data, further validating the methodology. The program was also tested, with very good results, against simulations and experimental results (made available by IMST GmbH, Germany) of UWB (Ultra Wide Band) signal characterization.

2.5 Point-to-area propagation modeling

Using the measurements results given in section 2.2.1, a first study of two models were developed. As a first study, to predict propagation loss in urbanized areas.
The first model considers two distinct situations, line-of-sight (LOS) and non line-of-sight conditions. Starting with the SUI model, for the NLOS conditions a dependency with distance was introduced in the path attenuation factor in the form \( \gamma = a + b \cdot d + c / d \). Multiple nonlinear regression provided \( a = 3.83 \), \( b = -0.0002 \) and \( c = 1600 \).

\[
L_{\text{LOS}} = 82.5 + 10 \cdot (3.83 - 0.0002d + 1600 / d) \log(d / 100)
\]

For the any loss case an expression based on the free space loss with a correction constant provided good results:

\[
L_{\text{LOS}} = 112.8 + 20 \log(d / 100)
\]

With this hybrid model the average error obtained against the measured data is -0.036 dB with a standard deviation of 8.37 dB. The following figure shows a comparison between measured propagation loss and values predicted with this model, as a function of the distance to the transmitter.

Figure 17 – Predicted (model 1) and measured values of the propagation loss

The second model uses a single expression for both cases with the inclusion of an additional term, proportional to the single knife edge diffraction loss of the main obstacle in the path profile between transmitter and receiver.

\[
L_{\text{LOS}} = 84.5 + 10 \cdot \log(2.97 + 1430 / d) \cdot \log(d / 100) + 0.27 \cdot \text{Diff}
\]

With this model the average error obtained against the measured data is 0.0044 dB with a standard deviation of 8.0 dB. The following figures show a comparison between measured propagation loss and values predicted with this model, as a function of the distance to the transmitter, and the histogram of residues.
Figure 18 – Predicted (model 2) and measured values of the propagation loss

Model 1 is recommended for a simplified evaluation, without the knowledge of the terrain profile. Model 2 can be used for a more accurate calculation.

2.5.1 Published papers and thesis

The following papers were published as a result of the work in this research area:


The following thesis have been concluded or are under development:


1. A brief description of GAPTEM/UFMG

The Group of Studies in Antennas, Propagation, and Electromagnetic Theory (GAPTEM) of the Federal University of Minas Gerais (UFMG) is composed by professors from the Department of Electronics Engineering of UFMG and by undergraduate and graduate students in Electrical Engineering of UFMG. The group’s activities are geared to teaching and researching in the areas of telecommunications and applied electromagnetism, aimed at solving engineering problems involving analysis and synthesis of antennas and microwave devices, numerical simulation of radio wave propagation for the characterization of radio channels, and the development of theoretical and numerical tools dedicated to solve such problems.

The research activities undertaken by GAPTEM/UFMG led to the establishment of several partnerships and projects with other research groups in Brazil, including CETUC/PUC-Rio, UFPA, and UFRN. The group is presently formed by two professors and 11 graduate students (six of them doctoral candidates). During the years 2009 and 2010, 2 Doctoral and 4 Master’s Dissertations were concluded, 8 articles were published or accepted for publication in technical journals and 19 papers were presented in national and international conferences. One of the group’s graduate students (Mr. Williams Lara de Nicomedes) won the Emerald Compel to a young researcher award for the best Paper presented at IGTE 2010.

2. Research Activities Conducted at GAPTEM/UFMG

During the years 2009 and 2010, the following activities were conducted at GAPTEM/UFMG:

2.1 – Measurements in medium waves, VHF and UHF for the implementation of digital radio broadcast in Brazil

Measurement campaigns to evaluate the DRM+ system were performed in the metropolitan area of Belo Horizonte, Minas Gerais, involving two FM broadcasting stations: UFMG Educativa Radio and Itatiaia FM Ltda. Radio. UFMG Educativa is a station of educational nature of UFMG, with its transmitter located in the city of Contagem. The station operates on low power, working with 1.5 kW at 104.5 MHz. Radio Itatiaia has its transmitter located in Belo Horizonte and constitutes one of the most traditional broadcasters in the city. The transmission power is 30 kW at 95.7 MHz.

The tests occurred in distinct phases for each station according to the schedule below:

- **Phase 1: UFMG Radio**
  - DRM+ Equipment installation and initial testing: 29/01 to 05/02/2010
  - Start of measurements: 07/02/2010
  - End of measurements: 05/03/2010

- **Phase 2: Itatiaia Radio**
  - DRM+ Equipment installation and initial testing: 09/04 to 14/04/2010
  - Start of measurements: 17/04/2010
  - End of measurements: 12/05/2010

For combined digital DRM+ and analog FM transmission, a specific transmitter-antenna group for digital signal was installed at the transmitting stations. The model and the position of the antenna were chosen in an attempt to match the digital coverage with existing analog. The parameters used for the combined irradiation were Frequency Separation $\Delta F = 200$ kHz and Protection Ratio $\Delta P = 13.7$ dB for UFMG Radio and $\Delta P = 19.8$ dB for Itatiaia Radio. The characteristics of the stations are summarized in Table 1.
Table 1: Transmitting station parameters

<table>
<thead>
<tr>
<th></th>
<th>UFMG Educativa Radio</th>
<th>Italiaia FM Radio</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location</strong></td>
<td>Latitude:19° 55’11”S</td>
<td>Latitude:19° 58’14” S</td>
</tr>
<tr>
<td></td>
<td>Longitude:44° 0’ 48 W</td>
<td>Longitude: 43° 55’ 41” W</td>
</tr>
<tr>
<td><strong>Carrier frequency [MHz]</strong></td>
<td>104.5</td>
<td>95.7</td>
</tr>
<tr>
<td><strong>EIRP [W]</strong></td>
<td>793</td>
<td>22,165.0</td>
</tr>
<tr>
<td><strong>Antenna Height [m]</strong></td>
<td>25</td>
<td>19</td>
</tr>
</tbody>
</table>

![Figure 1: Scheme used in FM broadcasting transmitting stations](image)

Figure 1 displays the equipment diagram of the broadcasting stations. The audio signal generated by the studio is sent to both analog and digital transmitters and the antennas have height Ha (analog) and Hd (digital). Thus, through this setup it is possible to compare the performances of both radiated signals and also the interference between them. Table 2 details the equipments used.
Table 2: Transmission stations main equipment description.

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UFMG Educativa Radio</strong></td>
<td></td>
</tr>
<tr>
<td>FM antenna (analog)</td>
<td>Manufacturer: Trans-Tel, Model: TTFM3A (2 elements), type: FM ring, gain: 0 dBi</td>
</tr>
<tr>
<td>FM antenna (digital)</td>
<td>Manufacturer: Ideal, Model: FA1RS (1 element), type: FM ring, gain: -1.3 dBi</td>
</tr>
<tr>
<td>FM analog transmitter</td>
<td>Manufacturer: Lys Electronic, Model: LT-2,5kW-FMV, Power: 1.5 kW</td>
</tr>
<tr>
<td>FM digital transmitter</td>
<td>Nautel RF amplifier, Power: 70 W DRM+ modulator</td>
</tr>
<tr>
<td><strong>Itatiaia FM Radio</strong></td>
<td></td>
</tr>
<tr>
<td>FM antenna (analog)</td>
<td>Manufacturer: Electronics Research (ERI), Model: SHPX-2AC (2 elements), type: bent dipole, gain: 2.13 dBi</td>
</tr>
<tr>
<td>FM antenna (digital)</td>
<td>Manufacturer: Mectrônica, Model: MT-FMC2 (2 elements), type: FM cycloid, gain: 1.24 dBi</td>
</tr>
<tr>
<td>FM analog transmitter</td>
<td>Manufacturer: Broadcast Electronics, Model: FM-30, Power: 19.9 kW</td>
</tr>
<tr>
<td>FM digital transmitter</td>
<td>Nautel transmitter model NV-10, Power: 500 W DRM+ modulator</td>
</tr>
</tbody>
</table>

The measurements were collected using the measurement mobile unit from EBC (Empresa Brasil de Comunicação) whose were equipped by the various entities involved in the measurement campaign. The car, a Mercedes Benz Sprinter van, was adapted for the allocation of various devices, prepared for the measurement of RF parameters (electric field amplitude, bandwidth, modulation) and recording of audio content. Figure 2 shows the equipment diagram used in measurement mobile unit.

The system consists of two antennas for RF measuring: a Kathrein monopole antenna and a Kathrein Rohde & Schwarz biconical antenna. Both can be connected to the spectrum analyzer to record the waveform of the signal or connected to the DRM receiver for demodulation and storage of digital content. The digital audio is recorded into Notebook 01 with GPS interface and analyzed by the software provided by the DRM consortium. The reception of analog audio is performed by an analog FM receiver and stored on the notebook 02. All data collected is stored on a portable hard disk (HD). Table 3 displays the description of the equipment involved.

![Figure 2: Equipment diagram used in measurement mobile unit.](image-url)
Table 3: Measurement mobile unit equipment description

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kathrein Antenna</td>
<td>Manufacturer: Kathrein, Model: K51164, type: monopole, frequency range: 58 to 300 MHz, gain: 1.85 dBi</td>
</tr>
<tr>
<td>Biconical Antenna</td>
<td>Manufacturer: Rohde &amp; Schwarz, Model: HK116, type: biconical, frequency range: 20 to 300 MHz, gain: 1.2 dBi</td>
</tr>
<tr>
<td>FM antenna</td>
<td>Standard FM automotive antenna</td>
</tr>
<tr>
<td>GPS system</td>
<td>Manufacturer: Navilock, Model: NL302U</td>
</tr>
<tr>
<td>Spectrum analyzer</td>
<td>Manufacturer: Anritsu Company, Model: Spectrum Master MS2711D, frequency range: 100 KHz A 3 GHz</td>
</tr>
<tr>
<td>DRM+ receiver</td>
<td>Manufacturer: DRM+ consortium</td>
</tr>
<tr>
<td>Notebook 01 (DRM+ software)</td>
<td>Manufacturer: MSI, Processor: Intel Atom N270 1,6 GHz, Windows XP</td>
</tr>
<tr>
<td>Notebook 2 (Audio Recording)</td>
<td>Manufacturer: Lenovo, Processor: Intel Core 2 Duo 2.20GHz Linux Ubuntu</td>
</tr>
<tr>
<td>FM Analog receiver</td>
<td>Manufacturer: Rolls Corporation, Model: RS79</td>
</tr>
<tr>
<td>Portable HD</td>
<td>Manufacturer: Western digital, Model: WD1600XMS 160 Gbytes</td>
</tr>
</tbody>
</table>

To evaluate DRM+ coverage the received signal was measured along radial and closed (circular) routes. The radial routes allow the knowledge of the extension of DRM coverage area. The closed routes provide information for the study of particular environments. Fixed measurement reference points were defined on each route and also signal recording were carried out along the path between these points. The routes for each station are listed below with their respective extensions.

**UFMG Radio**

Radial 1 (R1): Southwest Route = 20.5 km  
Radial 2 (R2): South Route = 19 km 
Radial 3 (R3): Northeast Route = 24 km  
Radial 4 (R4): Northwest Route = 27.3 km  
Circular 1 (C1): Urban Route 1 = 14.1 km  
Circular 2 (C2): UFMG Route = 7.9 km  
Circular 3 (C3): Industrial Route = 6.8 km  
Circular 4 (C4): Urban Route 2 = 9 km

**Itatiaia Radio**

Radial 1 (R1): Northeast Route = 68 km  
Radial 2 (R2): South Route = 50.5 km  
Radial 3 (R3): Southeast Route = 31.2 km  
Radial 4 (R4): North Route = 59.9 km  
Radial 5 (R5): West Route = 56.8 km  
Circular 1 (C1): Urban Route 1 = 14.1 km  
Circular 2 (C2): UFMG Route = 7.9 km  
Circular 3 (C3): Industrial Route = 6.8 km  
Circular 4 (C4): Urban Route 2 = 9 km  
Circular 5 (C5): Urban Route 3 = 7 km

Figures 3 and 4 exhibit, respectively, the routes to the UFMG Radio and Itatiaia Radio phases. The Radio UFMG phase gathered 31 fixed points with distances ranging from 2 to 22 km from the transmitter. In the case of Itatiaia Radio was collected 41 fixed measurements points with distances to the transmitter ranging from 2 to 51 km. It is noteworthy that the moving measurements during the displacement between fixed points must be processed to eliminate the fast fading and obtain the average received power.

The established routes cover different terrains and environments, providing different propagation scenarios. Measurements were collected in dense urban environment, sub-urban, countryside, open countryside with vegetation, irregular terrains and areas with many obstacles (tunnels, bridges, buildings, transmission lines for electricity, etc). For further details of the routes, relevant events and obstacles are written in a occurrence spreadsheet throughout the entire campaign. The verification of the equipment functionality was performed every day by measures carried out in a fixed reference point.
To evaluate the DRM+ system, two different available modulation schemes for the MSC channel was used: QAM-4 and QAM-16. At all considered points the RF parameters and audio content was recorded for the two modulations. The radio frequency signal is sampled for five minutes at each fixed point and the time average is stored on the spectrum analyzer. Furthermore, during this interval, it was recorded the analog and digital audio and DRM+ software analyzed quality parameters of digital audio. During the moving measurements, the RF waveform storage was performed in an interval of 200 ms and audio content recorded on the entire journey.

Finally, after the processing of the measures of all trades, one can extract information such as field strength, bandwidth, analog/digital amplitude ratio, analog and digital audio signal to noise ratio and the behavior of the broadcasting systems mobile reception situation.

Figure 3: Measurement routes during UFMG Radio transmission
2.2 - Development of models for the prediction of path loss and delay spread in VHF e UHF

Computational models based on asymptotic techniques (ray tracing in conjunction with the Uniform Theory of Diffraction) and integral equations are being developed for the simulation of radio wave propagation in urban and rural areas. The objective is the creation of theoretical and numerical tools for application in the characterization of radio systems, including time domain characterization of broadband radio channels.


As consequences of the research, the following articles were published:


**Abstract:** In this study, heuristic uniform theory of diffraction coefficients are suited to account for scattering by lossy conducting wedges. The novel heuristic solution is determined from other previously developed heuristic coefficients, combining their characteristics to improve the
estimation of radiowave propagation in urban scenarios. Slope diffraction is also considered to account for double-diffracted fields in consecutive wedges. Maliuzhinets’ coefficients provide base solutions to validate the novel formulation. The novel solution is then applied to the wave propagation in a typical urban scenario, and results are compared against measurements provided in the literature.


Also, the following Doctoral and Master’s Thesis were concluded or are in progress:


2.3 - Development of techniques based on the method of moments for the analysis of cylindrical microstrip antennas

At GAPTEM/UFMG, in partnership with Prof. Odilom Maroja C. Pereira Filho (UFPE), techniques were developed for the analysis of cylindrical microstrip antennas using the method of moments. These antennas consist of a cylindrical conductor which is constructed within a cylindrical-sector cavity filled with dielectric. A cylindrical antenna is printed on the interface between dielectrics, and is fed by a coaxial cable inside the conductor. This geometry has the potential to minimize the mutual coupling between elements in arrays of cylindrical microstrip antennas, and thus make possible a precise synthesis of these antennas. Microstrip antennas stand out for their ability to conform to curved surfaces.

As consequences of the research, the following articles were published:


The following Master’s Thesis was concluded:


2.4 - Synthesis and analysis of omnidirectional antennas providing uniform coverage

At GAPTEM/UFMG, in partnership with CETUC/PUC-Rio, numerical and asymptotic techniques are being developed for the synthesis and analysis of omnidirectional reflector antennas. These antennas have wideband features and may be used in WiMAX and LMDS systems. One of the objectives is to control the antenna radiation pattern in the vertical plane, in order to provide uniform coverage. This is accomplished by modeling the reflector surfaces. Several analysis techniques are being used, in particular the physical optics (PO) and the method of moments (MoM). Meshless (Mesh Free) techniques are also being investigated for future application in the analysis of reflector antennas.


As consequences of the research, the following articles were published or accepted for publication:

a) Fernando J. S. Moreira and José R. Bergmann, “Shaping Axis-Symmetric Dual-Reflector Antennas by Combining Conic Sections,” IEEE Transactions on Antennas and Propagation, accepted for publication.

Abstract: A simple procedure for the shaping of axisymmetric dual-reflector antennas is described. The shaping procedure is based on the consecutive concatenation of local conic sections suited to provide, under geometrical optics (GO) principles, an aperture field with uniform phase, together with a prescribed amplitude distribution. The procedure has fast numerical convergence and is valid for any circularly symmetric dual-reflector configuration. To illustrate the procedure two representative configurations are investigated. The GO shaping results are validated using accurate method-of-moments analysis.

b) Úrsula C. Resende, Fernando J. S. Moreira, and Odilon M. C. Pereira Filho, “EMFIE and MEFIE Formulations for the Analysis of Scattering from Dielectric and Composite Bodies of Revolution,” Microwave and Optical Technology Letters, accepted for publication.

Abstract: In this paper the electromagnetic scattering from dielectric and composite bodies of revolution are analyzed by the electric-magnetic field integral equation (EMFIE) and the
magnetic-electric field integral equation (MEFIE), which are customarily overlooked in the literature. A standard method-of-moments (MoM) technique is applied for the numerical solution of the surface integral equations. Several dielectric and composite geometries are analyzed through the bandwidth and results are compared to those of well-established Müller and PMCWHT integral equation formulations. Investigated case studies indicate that the MoM Z matrices yielded by the EMFIE and MEFIE are as well-conditioned as those provided by the Müller and PMCWHT formulations.


**Abstract:** In this work, we apply a meshless-based method to a set of integral equations arising in electromagnetic wave propagation and scattering. The objective is not only to solve these equations through a meshless-based method, but also to find a way to build shape functions that could work for any cross-sectional geometry. We have found that the Moving Least Squares (MLS) approximation is not able to provide useful shape functions in every situation. This technique relies on matrix inversions and, according to the geometry, singular matrices can occur. In order to avoid this problem, we have taken the Improved Moving Least Squares (IMLS) approximation, that does not depend upon matrix inversions and then applied it to a number of cross-sectional geometries.


**Abstract:** This work presents a formulation for shaping the main reflector of a dual-reflector antenna designed to offer an omnidirectional coverage with an arbitrary radiation pattern in the vertical plane. The subreflector is generated by an axis-displaced ellipse and the main reflector is shaped to achieve a prescribed far-field radiation pattern. The shaping procedure is based on geometrical optics (GO) principles. Two distinct far-field ray structures are investigated. The GO-shaping results are validated by an analysis using an accurate method of moments technique.


g) Fernando J. S. Moreira and José R. Bergmann, “Omnidirectional Dual-Reflector Shaping by Concatenating Conic Sections,” 4th European Conference on Antennas and Propagation (EuCAP 2010), Barcelona, Spain, April 2010.


k) Williams L. Nicomedes, Renato C. Mesquita, and Fernando J. S. Moreira, “2D Scattering Integral Field Equation Solution through a IMLS Meshless-Based Approach” 17th International

i) Fernando J. S. Moreira and José R. Bergmann, “Shaping Axis-Symmetric Dual-Reflector Antennas by Consecutively Concatenating Conic Sections,” 2009 International Microwave and Optoelectronics Conference (IMOC 09), Belém, PA, Brazil, pp. 359—362, November 2009.


Also, the following Doctoral and Master’s Thesis were concluded or are in progress:


2.5 — Development of numerical and asymptotic techniques for the analysis of electromagnetic transients in antennas

Numerical and asymptotic techniques are being developed for the analysis of UWB (Ultra Wide Band) antennas directly in the time domain. The interest in the analysis of transient wave phenomena has increased with recent advances in the development of narrow-pulse radars and antennas for the transmission of signals with high data rates. Possible applications are: remote sensing, target identification, UWB wireless communication systems, and digital broadcasting.

As consequences of the research, the following articles were published:

Abstract: This work presents some important concepts for the temporal characterization of reflector antennas based on the determination of the transient antenna response together with a useful definition of the early-time antenna radiation pattern. The concepts are useful in the analysis and design of reflector antennas intended for high resolution radars and for high capacity digital, and UWB communication systems.


c) Cássio G. Rego, “Closed-form solution for integral operators applied to the calculation of radiated fields from parabolic reflector antennas,” 2009 International Microwave and Optoelectronics Conference (IMOC 09), Belém, PA, Brazil, pp. 441—446, November 2009.

The following Doctoral and Master’s Thesis were concluded or are in progress:


1 A brief description of LEA/ITECC/UFPA

The Laboratory of Electromagnetism Applied (LEA) was created in 1984 by teachers Gervásio Cavalcante and João Tavares Pinho, researchers of Eletrical Post-Graduate Program (PPGE). With the creation of PPGE was structured area of Applied Electromagnetics, which in its first phase emphasized the training of human resources. Along with the LEA Group was created in Electromagnetism Applied Research, which has been directing its activities towards the real needs of the area, considering, where possible, the regional aspect. The arrival of new researchers to Group with operations in telecommunications and computer science led to the creation of new research groups, including the Group of Information Technology, Communication and Automation - TICA, the Group of Numerical Analysis in Applied Electromagnetics - LANE, coordinated by Professor Carlos Leonidas, and Signal Processing Group, with which the researchers of the LEA develop a series of projects in R & D. Finally, the NESC was created - Center for Energy Systems and Communications, which integrates research groups of PPGE, the areas of Power Systems, Applied Computing and Telecommunications. These last two areas, plus the LEA are part Laboratories Numerical Analysis and Electromagnetics (LANE), the Laboratory of Signal Processing (LAPS) Laboratory of Network Planning for High Performance (LPRAD).

Currently in LEA and LANE, whose teachers participate in this project, working about 50 students, including doctoral, masters and undergraduates. Most of these students is a fellow in research projects financed by funding agencies (CNPq, CAPES, FAPESP) or in partnership with businesses, primarily associated with resources of the computer (CTINFO), telecommunications (FUNTTEL) and energy (CTEnerg).
2 Research Activities Carried out by the LEA / LCT - UFPA

During the years 2009 and 2010, LEA / LCT - UFPA conducted the following research activities:


The model was developed for the study of the propagation of electromagnetic waves in semi-confined environment, taking into account the buildings and the trunks of trees. The chosen environment for test was Av. Brás of Aguiar, in the central area of Belém of Pará, where the measurements were made; with characteristics similar to those used in the model proposed, where the cups of the trees form a tunnel of foliages, confining the electromagnetic wave. This model calculates the behavior of the field in the vertical direction (in the sense of the elevation of the receiver) and in the horizontal direction (longitudinal displacement of the receiver).

Fig. 1 shows the Avenue Brás of Aguiar and the location of the transmitter antenna.

Fig. 1 - Illustration of the Av. Brás of Aguiar

Fig. 2 shows the pictorial illustration of the Avenida Brás of Aguiar and Fig. 3 illustrates the partial view of the urban environment with an area of dense vegetation characterizing a semi-confined environment.

Fig. 2 - Pictorial figure of the Av. Brás of Aguiar
As a consequence of the research, was published the following work:


Abstract: In this article the propagation loss in mobile cellular systems in semi-confined environment using parabolic equations is studied. The proposed model uses approximations for small and large angles of propagation, with the paraxial direction and its results are validated through a campaign of measurement and the ray tracing model. The semi-confined environment is represented by a street with large trees and shaped by a set of rectangles (representing the buildings) and a set of dielectric cylinders (representing the trunks of trees). In the campaign of measurements was used the frequency of 890 MHz The results compared with the experimental results and by ray tracing model showed good agreement, with a less computational effort.

2.2 - COST231-Hata and SUI Models Performance Using a LMS Tuning Algorithm on 5.8 GHz in Amazon Region Cities

The collected data have been acquired in cities on Para State at Amazon Region, Brazil. These cities are known by their woodland environments. The vegetation normally appears mixed with the residential and commercial constructions resulting in a single medium. An example of Amazon region city is shown in the following figure.

Different of the traditional measuring campaigns [1]-[2] that are made with continuous data collection in a mobile unit, this data acquisition has been performed by taking the punctual RSSI (Received Signal Strength Indicator) in 211 fixed clients installed in eight cities that have been contemplated with the Digital Inclusion Para State Government Project named NavegaPara [3]. The project consists of WLL (Wireless Local Loop) networks installed in the cities, bringing
broadband access and multimedia services. It is interesting to analyse this collected data because fixed clients have different distances with respect to their Base Stations and different installation heights. From the collected RSSI it can be found the path loss for each client. The process for obtaining the distances between the clients and base stations is based on the coordinates that was collected during the implantation stage.


As a consequence of the research, was published the following work:


Abstract — This paper presents a performance comparison between COST231-Hata and SUI Models through LMS tuning Algorithm for 5.8 GHz frequency band. The studied environment is based on the cities located in Amazon Region. After the adjustments and the simulations, SUI Model has shown a smaller RMS error when compared with COST231-Hata Model.

2.3 Other related publications


THESES COMPLETED – 2009 – Adviser - Gervasio Protásio dos Santos Cavalcante

1. Fatima Nazareth Baraúna
Title: CELLULAR MOBILE SYSTEMS MODELING IN INDOOR ENVIRONMENTS USING PARABOLIC EQUATIONS

2. João Furtado de Souza
Title: MODELING SYSTEMS RADIOPROPAGATION IN CELLULAR MOBILE ENVIRONMENTS USING PARABOLIC EQUATIONS

3. Simone das Graças Castro Fraiha
Title: LOCATION OF BEST ACCESS POINTS IN INDOOR ENVIRONMENTS IN WIRELESS SYSTEMS DESIGN

THESES IN PROGRESS


2. Rômulo Oliveira, Evaluation of models using Radiopropagação Computational Intelligence techniques for radio systems and TVDigitais, beginning in 2010 (Doctorate in Electrical Engineering) - University of Pará.

DISSERTATIONS COMPLETED – 2010

1. Igor Ruiz Gomez. Indoor Propagation Model for Multi-Storey at 2.4 GHz with estimation of QoS in VoIP calls. Dissertation (Masters in Electrical Engineering) - University of Parã, the National Council for Scientific and Technological Development.

2. Bruno Souza Castro Lyra. Propagation Model for Fixed Wireless Networks in the Band 5.8 GHz in Typical Cities of the Amazon region.. Dissertation (Masters in Electrical Engineering) - University of Parã, Coordination for the Improvement of Higher Education.
GUIDELINES FOR MASTERS IN PROGRESS


1. A Brief Description of GMA/UFRN

The microwave and antenna group (GMA) of the Department of Electrical Engineering at UFRN was created in 1982. The repercussions of studies conducted in the areas of antennas, propagation and mobile communications may be associated to the excellent quality of approved dissertations/theses. As a consequence, its researchers and students have regularly taken part in the main national (SBMO, CBMag and SBrT) and international (IEEE-AP-S, ICAP, EuCOM and IEEE MTT-S) symposiums and conferences. An international technical cooperation was established with INPT-Toulouse, through the CAPES-COFECUB program in the 1990s. The formation of doctors, as a result of collaboration with UFCG researchers since 1988 deserves to be mentioned, as well as the intense interaction with CEFET-PB researchers. GMA researchers have also taken part in the organization of 3 national symposiums (SBMO 1988, SBT 1993 and CBMag 2000) and 2 international conferences, IMOC 1997 (SBMO/IEEE MTT-S) and ITS 2002 (SBrT/IEEE COMSOC). Currently, GMA researchers are developing international technical cooperation activities with ENST-Paris, through the CAPES-COFECUB program, and with INPT-Toulouse, through the BRAFITEC program. Moreover, GMA researchers are also developing activities directed to the organization of IMOC 2011 (SBMO/IEEE MTT-S), which will take place in Natal, RN.

The GMA Group is formed by 4 professors and more than 20 graduate students (9 of them are PhD students). In the last two years 3 PhD Dissertations were approved, as well as 6 Master Theses. Presently several students are working to conclude their graduate courses at UFRN, advised by GMA researchers. It should be emphasized that one of our PhD students is presently at Telecom ParisTech in Paris, in a cotutelle doctoral research program.

The works developed in our Group mainly those that were done by our graduate students have been published in technical journals and conference proceedings. In the last two years 7 papers were published in technical journals and 16 were presented in international conferences and symposiums and published in their proceedings. In the conferences organized by Brazilian Scientific Societies, more than 10 papers were presented and published in the conference proceedings. Lately 2 other papers were accepted for publication in technical journals.

In the last two years our researchers had a very good cooperation with professors from the Telecom ParisTech, in Paris, due to a CAPES-COFECUB Project, and from the INPT, in Toulouse, due to a Brafitec Project, both supported by CAPES. In Brazil, our researchers had an excellent cooperation with the professors from PUC-Rio, UFPA, and UFMG, due to the scheduled INCT-CSF activities that were started in the end of 2008. This cooperation included the organization of workshops as well as the participation in PhD Juries.
2. Research Activities Developed by GMA/UFRN

In 2009 and 2010, in the INCT-CSF Project, our main research activities were focused in two areas:

• Antennas for the reception of signals by fixed and mobile users and broadband services
• WiMax network planning – Measurements and propagation models.

We developed new configurations of microstrip antennas and frequency selective surfaces (FSS) for applications in wireless communications systems. Aspects related to the miniaturization of such antennas are being investigated through the use of fractal structures and substrates with high permittivity. Antennas for broadband and multiband services are being investigated. The increased bandwidth of FSS is being investigated by the use of fractal geometries and coupled structures.

The results of these works were published in the most important newspapers and symposiums and conferences. In particular our papers were presented in IEEE AP-S 2009, IMOC 2009, COMPUMAG 2009, iWAT 2010, EuCAP 2010, CEFC 2010 and EuMW 2010 as well as in MOMAG 2010.

As mentioned before, in the last two years 3 PhD Dissertations were approved, as well as 6 Master Theses. In the next sections these works are presented as well as some of the related papers that were published in conference proceedings and technical journals.

2.1 Antennas for the reception of signals by fixed and mobile users and broadband services

2.1.1 Development of antennas for UWB system applications

In the last years a special attention has been devoted to the development of UWB antennas. The UWB technology is a short range wireless technology for transmitting large amounts of data at very high-speed with very low power. Generally the effective isotropic radiated power (EIRP) must be smaller than -41.3 dBm/MHz between 3.1 to 10.6 GHz. The use of UWB systems needs efficient antennas to provide acceptable bandwidth requirements, and radiation pattern characteristics throughout the designated UWB spectrum. It is generally accepted that for antennas to be classified as ultra-wideband, the requirement will be to satisfy minimum fractional bandwidths of at least 20 % or 500 MHz or more.

The following conference paper was published:


Abstract—In this paper a new configuration of an Ultra Wideband (UWB) antenna is proposed. The antenna is an optimization of the circular monopole patch antenna with a slot type Split Ring Resonator (SRR) that is inserted in the radiating part. The SRR structure will work as a band stop filter for notching a frequency band between 5 to 6 GHz. A good agreement was observed between the simulated and measured results.
Presently D. B. Brito is preparing the final version of his PhD report, including metamaterial inspired antennas and FSS geometries. He also developed Fabry-Perot antennas. The advisers are Adaildo Gomes d’Assunção (UFRN) and Xavier Bégaud (Telecom ParisTech).

Also, the following Master’s Theses were approved:


2.1.2 Development of printed antennas with fractals, EBG structures, or metamaterial substrate.

The advance of wireless communications and the growth of its applications in recent years have made use of compact antennas multiband/broadband a great attraction of fundamental importance in commercial and military applications. The most common examples are found in a variety of portable wireless devices, such as cellular phones, handsets, palmtops, laptops, among others. The emergence of different wireless technologies, such as the GSM (Global System for Mobile Communications), RFID (radio frequency identification), Bluetooth, Wi-Fi and WiMAX, has served as a motivation to boost research in the search for lighter, compact and lower cost devices, as it is the case of microstrip patch antennas.

The ever increasing demand for compact radiators for application in modern communication systems, have improved the use of artificial materials properly engineered to achieve some antenna features. For instance, it has been proven that metamaterials can be applied to reducing the antenna size.
The following papers were published:


  Abstract—This article shows a new quasi-fractal microstrip patch antenna using the Minkowski curve at the radiant and nonradiant margin of this device. The structures analyzed were initially designed using the Ansoft Designer™ software that implements the method of moments. Some antenna prototypes were built and measured. The use of the inset-fed technique enables a good impedance matching, as can be confirmed by the low return loss obtained (<−25 dB) at the resonance frequencies. Antennas designed using the Minkowski curve presented a reduction of up to 42% when compared with a conventional inset-fed rectangular patch. © 2010 Wiley Periodicals, Inc. Microwave Opt Technol Lett 52:805–809, 2010.


![Figure 3. X-ray diffraction results for the BiNbO4 samples obtained using a brand Shimadzu XRD-6000.](image)
2.1.3 Development of single and coupled frequency selective surfaces (FSS)

Recently, we can observe an increasing demand on the multifunctional antennas for communication that requires the development of FSS with multi-band characteristics. The use of frequency selective surfaces (FSS) has been successfully proven as a mean to increase the communication capabilities of satellite platforms. In space missions such as Voyager, Galileo, and Cassini, the use of dual-reflector antennas with FSS sub-reflectors has made it possible to share the main reflector among different frequency bands. Therefore frequency selective surfaces with dual-band and multi-band responses have been studied by several researchers.

The following papers were published:


Abstract—Design and experimental investigations are presented for a dual-band frequency selective surface (FSS) with perfectly conducting rectangular patch elements. The work was developed in two steps. In the first step, two single-band FSS screens were designed to obtain resonant frequencies at 9.5 GHz and 10.5 GHz, each one with about 1.5 GHz bandwidth. In the second step, these single FSS screens were cascaded and separated by an air gap layer to achieve a dual-band response. The proposed dual-band FSS screen is easy to analyze and to fabricate with low cost materials and exhibits a low weight and easy to handle structure. © 2009 Wiley Periodicals, Inc. Microwave Opt Technol Lett 51: 942–944, 2009.

Abstract—This work investigates the use of Koch Island patch elements to design frequency selective surface (FSS) band stop filters that reflect X- or Ku-band signals. To control the FSS resonant frequency and -10 dB bandwidth, we modify the shape of Koch Island patch elements adjusting the fractal parameters, iteration factor, and iteration number. The electromagnetic (EM) behavior is described as a function of the element shapes and the permittivity of the dielectric substrate. A FSS parametric analysis is accomplished through the use of the Ansoft Designer™ software. The obtained EM-data is utilized for training a multilayer perceptrons (MLP) artificial neural network to achieve the FSS modeling task. Experimental and simulated results are obtained to validate the developed MLP model. VC 2009 Wiley Periodicals, Inc. Microwave Opt Technol Lett 51: 3014–3019, 2009.


Abstract—This work presents a new fast and accurate electromagnetic (EM) optimization technique blending the Particle Swarm Optimization (PSO) algorithm and a Multilayer Perceptrons (MLP) Artificial Neural Network (ANN). The proposed technique was applied for optimal design of Koch fractal Frequency Selective Surface (FSS) with desired stop-band filter specification. Initially, a full-wave parametric analysis was carried out for accurate EM-characterization of FSS filters. From obtained EM-dataset, a MLP network was trained with the first-order Resilient Backpropagation (RPROP) algorithm. The developed MLP model for FSS synthesis was used for efficient evaluation of cost function in PSO iterations. The advantages in the optimal design of FSS through the PSO-ANN technique were discussed in terms of convergence and computational cost. Two optimized FSS prototypes were built and measured. The accuracy of the proposed optimization technique was verified through the excellent agreement obtained by means of comparisons between theoretical and experimental results.

Figure 5. Measured and simulated results for the transmission coefficient of a Koch fractal FSS with level 2 and iteration factor 5. Dielectric substrate: $\varepsilon_r = 4.4$ and $h = 1.6$ mm.


Abstract—Numerical and experimental investigations are presented for a dual-band frequency selective surface (FSS) with perfectly conducting rectangular patch elements. In the first step two single-band FSS screens were designed to obtain resonant frequencies at 9.5 GHz and
10.5 GHz, each one with about 1.5 GHz bandwidth at -3 dB. In the second step these single FSS screens were cascaded and separated by an air gap layer to achieve a dual-band response. The Moment Method is used to analyze the structures single band. After this, a numerical cascading technique is used to analyze the effect of the air gap between the cascading structures. Numerical and measured results were compared and a good agreement was obtained.

Figure 6. Measured and simulated results for the transmission coefficient of coupled Koch fractal FSS. Structure 1 has fractal level 1 and structure 2 has fractal level 2. The air gap spacing is 10 mm.


Figure 7. Measured and simulated results for the transmission coefficient of a Koch fractal FSS with level 2 and iteration factor 5. Dielectric substrate: $\varepsilon_r = 4.4$ and $h = 1.6$ mm.
Also, the following doctoral dissertation and master’s theses were approved:


2.2 Planning of WiMax networks -- Propagation models and measurements.

2.2.1 Development of propagation models for WiMAX applications

The telecommunications industry has experienced recent changes, due to increasing quest for access to digital services for data, video and multimedia, particularly using the mobile phone networks. Recently in Brazil, mobile operators are upgrading their networks to third generations systems (3G) providing to users broadband services such as video conferencing, Internet, digital TV and more. These new networks that provide mobility and high data rates has allowed the development of new market concepts. Currently the market is focused on the expansion of WiMAX technology, which is gaining increasingly the market for mobile voice and data. In Brazil, the commercial interest for this technology appears to the first award of licenses in the 3.5 GHz band. As a consequence a lot of work has been done in the development techniques and methods to predict the path loss.
In this work a genetic algorithm (GA’s) was developed in order to optimize the prediction of the propagation loss at 3.5 GHz, thus enabling an estimate of the signal closer to reality to avoid significant errors in planning and implementing wireless communication system at this frequency.

![Measurement routes in the UFRN campus.](image)

**Figure 9.** Measurement routes in the UFRN campus.

![Measured and simulated results for the propagation path loss.](image)

**Figure 10.** Measured and simulated results for the propagation path loss.

### 2.2.2 Wireless communication

The following master’s theses were approved:


Abstract—This dissertation has the purpose to present a portable device named PlugData MG100G, equipper with a cellular module, to analyze the radiofrequency coverage in a GSM network situated in João Pessoa city, state of Paraíba, at four distinct regions. The equipment, originally, was developed to be used in fixed environments, so it was adapted so that it could be used in conditions of mobility. From the Mobile Measurement Reports (MMRs) RF coverage and the handover process are analyzer. The MMRs enable the identification of the serving cell and the list of the closest neighboring cell monitored by the mobile. This works analyses only data referents to the serving cell and the two closest neighboring cells. Inter-cell and intra-cell
handovers are identified. The frequency planning and quality of service offered by the network related to the regions are discussed as well.


Abstract—Since its advent, wavelet coding has been recognized as a promising technique for digital transmission over wireless communication environments, especially due to its low decoding complexity and good performance over multipath fading. However, this technique generates not-equiprobable symbols, and consequently the performance gains from these systems are influenced significantly by their modulation schemes. In this work, it is proposed a design methodology to obtain sub-optimum modulation schemes for wavelet systems over Rayleigh fading channels. In this context, novels signal constellations and quantization schemes are obtained via genetic algorithm and mathematical tools. Numerical results obtained from simulations show that the wavelet-coded systems derived here have very good performance characteristics over fading channels.

Events

• I Workshop on Wireless Communication
  Belém, PA, December 2008.

• II Workshop on Wireless Communication

• III Workshop on Wireless Communication
  Belo Horizonte, MG, June 2009.

• IV Workshop on Wireless Communication
  Natal, RN, April 2010.

• V Workshop on Wireless Communication
  Vila Velha, ES, August 2010.
Conclusion

The main activities developed in the INCT-CSF in the biennial 2009-2010 were described.

Quantitative and qualitative features were presented, emphasizing the activities involving graduate students, the development of research activities that will contribute to the national development and the cooperation with the telecommunication industry, telecommunication operators, as well as governmental agencies and institutions.

It should be mentioned that, despite the fact that the developed activities have been described by each one of the research groups and institutions, the whole work was developed with the knowledge, approval and mostly in cooperation among researchers of different laboratories.

This is a consequence of a compromise of the INCT-CSF of planning the project activities in a participative way, including the organization of meetings in a regular basis. In fact, we organized five workshops, three of them including students and researchers, with oral presentations (Belem and Natal), one in order to evaluate and plan the project activities (Belo Horizonte) and the last one in Vila Velha, during the MOMAG Symposium, open to all the conference participants.

The excellent relationship among the INCT-CSF researchers could be verified by the joint development of several research activities that resulted in the publication of several papers in technical journals and conference proceedings, co-authored by members of different INCT-CSF research groups. This cooperation was extended to the joint advisory activity for several students of the INCT-CSF groups, as well as in the participation of several PhD committees.

Another important contribution for this excellent cooperation activity came from the measurement campaigns. Five measurement campaigns were conducted in São Paulo, Rio de Janeiro, Belo Horizonte, Belem and Natal. It should be mentioned that these campaigns were developed with the participation of researchers of different universities. In the campaigns developed in São Paulo and Belo Horizonte we had also the support of the National Institute of Metrology (INMETRO), including the mobile reception unit and technical staff.

Several measurement equipments are being bought to prepare the INCT-CSF mobile reception units that will be used in the future measurement campaigns. The opportunity of using the INMETRO mobile reception unit was unique in improving knowledge and skills.

The main difficulty is related to the administration of INCT-CSF. It is really very hard to handle the INCST-CSF budget without having a good infrastructure. Nevertheless, the experience in the last two years was very important and now we are able to handle these issues in a better way. Particularly, the UFRN administration has given positive signs with respect to use its administrative units.

The continuity of the INCT-CSF Project is imperative. Since the beginning, it has been very motivating for the students and researchers. In fact, we believe that its formation was a very successful initiative.

For 2011 and beyond, we are expecting a faster development for this project with an increase of the cooperation among the researchers, the graduation of our students, the development of research works that will contribute to the national development and the cooperation with the telecommunication industry, telecommunication operators, as well as governmental agencies and institutions. Particularly we are planning to extend the INCT-CFS international activities.