MICROWAVES IN BRAZIL: SIGNIFICANT RESEARCH AND DEVELOPMENT ACTIVITIES

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ABSTRACT

Recent microwave research and development activities in Brazil will be described in this paper. These include several programs in universities, research centers and a few in industry, in the areas of microwaves, antennas, propagation and optical communications.

Some considerations about the present situation will be presented and the prospectives for the next years will be discussed. Also some areas where international cooperation may be stimulated will be highlighted.

1. INTRODUCTION

Significant R & D work in microwaves in Brazil started in the mid 60's, simultaneously with the installation of the national terrestrial microwave links. Since then and specially due to the effort of some groups and government support, R & D programs have been growing in universities and in some research institutes. In 1976, the TELEBRÁS (Telecomunicações Brasileiras S/A) Research Center (CPqD/TELEBRÁS) was created and among other objectives, the following can be emphasized: (i) to perform R & D in several areas of telecommunications; (ii) to coordinate the support to Universities for applied research in selected areas of telecommunications; and (iii) to stimulate the installation of R & D centers in the industry and the transfer of the relevant technologies to Brazil. This scheme is naturally centralized and has shown some benefits and weaknesses. In universities most of R & D programs are supported by TELEBRÁS. Some R & D programs in microwaves are also being performed by the Navy, the Army and the Air Force at their own research institutes. R & D in microwaves in industry started very recently and it is still very limited. References [1]-[9] are an indication of the work which has been recently done in Brazil in the area of microwaves.

2. R & D ACTIVITIES IN UNIVERSITIES

This section will summarize relevant R & D activities in microwaves in Brazilian universities. These include mainly University of São Paulo (USP), Catholic University of Rio de Janeiro (PUC/RJ), University of Campinas (UNICAMP), Air Force Technological Institute (ITA) and Maua Institute of Technology (IMT). Military Institute of Engineering (IME), University of Brasília (UnB), University of Paraíba (UFPB), University of Rio Grande do Norte (UFRN) and University of Pernanbuco (UFPe) also have some microwave R & D activities. In most of these universities, a great deal of effort goes to teaching and supervision at undergraduate, M.Sc. and Ph.D. levels.

2.1 - University of São Paulo (USP)

At Microelectronics Laboratory (LME) of USP, the major R & D activities are concentrated on Microwave Hybrid Circuits, GaAs MMICS and SAW Components. Thin film technology on ceramic substrate and conventional photo-etching on soft substrates are used to develop different hybrid circuits, such as a medium power FET amplifier (at 6 GHz, with P_{out} = 5 watts and gain 13 dB), a large band (100 MHz to 4 GHz) amplifier with gain = 12 dB, LNA for the 3.7 to 4.2 GHz bandwidth (with NF < 60K and gain > 60 dB), frequency multipliers using dual gate GaAs MESFETs[1], etc...

Passive and active components for MMICs are being developed and tested separately, such as a 1 μm gate GaAs FET by the lift-off and self-alignement processes, loop inductances, interdigital and Ta_2O_5 MOM capacitors, titanium resistors, air-bridges structures, etc...

SAW components on Li Nb O_3 substrate for the 70 MHz band are also developed, such as a SAW filter for satellite reception and a convolver for applications in spread-spectrum for satellite communications[2].

2.2 - Catholic University of Rio de Janeiro(PUC/RJ)

At Center for Studies in Telecommunications (CETUC) of PUC/RJ there are three R & D groups, on microwaves, antennas and propagation. The R & D activities in microwaves are mainly theoretical studies, modelling/optimization, design, realization and characterization of hybrid active and passive circuits, using thick film technology on ceramic substrates or conventional photo-etching

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techniques on soft substrates. Significant contributions to the areas of dielectric resonator oscillators and filters[3], distributed elements analysis and synthesis, single and dual-gate GaAs MESFET mixers, etc... were demonstrated and published in international periodics.

Recently, two areas of activities, (a) the modelling and design of GaAs MMICs and (b) the microwave performance of laser diodes[4] and photodetectors for high capacity optical communication systems became of special interest.

The research activities of the antenna group at CETUC are related with the development of antennas to be used in satellite communications systems, fulfilling the current needs and observing future trends of the National Telecommunications Network. The present emphasis lies on the following: - Asymptotic and numerical analysis of reflector antennas; - Synthesis of off-set dual-shaped reflector antennas[5]; - Numerical analysis of corrugated feeds[6]; - Radome analysis and synthesis.

A substantial amount of the Radio Propagation Group's effort is currently being directed toward the study of multipath effects on digital radio links. In addition to measurements on existing links, on going work involves analog and digital simulation, as well as modelling and theoretical calculations.

Long-term statistics of rainfall rate and attenuation due to rain in different terrestrial line-of-sight links have also been obtained. Recently, radiometric measuments have been initiated at three sites (Rio de Janeiro, Belém and Manaus). Attenuation due to rain in slant path in the 13 GHz frequency band, as well as the gain resulting from the use of space diversity will be investigated. This program is performed in cooperation with the Communications Research Centre, Ottawa, Canada.

2.3 - University of Campinas (UNICAMP)

At the Microwave and Optics Department (DMO) of UNICAMP the main R & D activities in microwaves are concentrated on integrated circuits, planar structures and antennas. More recently, an effort on Coherent Optical Communication was initiated through the installation of a research laboratory in this area, supported by a Federal Research Agency (FINEP) and TELEBRÁS.

The work done or in progress includes the development of microwave circuits, such as: oscillators, amplifiers, mixers, filters, couplers, phase shifters, ferrite devices, delay lines, limiters, circuits using PIN, Gunn and avalanche diodes, semiconductors lasers, etc. Computer programs for the design, analysis and synthesis of microwave integrated circuits were also developed. A major effort, still in progress, includes the characterization of propagation in structures, particularly planar structures (striplines, microstriplines and finlines) on isotropic or anisotropic substrates. This effort includes also studies on multilayer planar or cylindrical printed antennas and radio propagation in layered media[7].

The objective of the effort on optical communications is to achieve technical competence in the area and to look for future applications in long distance communications as well as in high capacity local area networks. The immediate effort consists in developing simulated homodyne and heterodyne communication systems with optical fibers. A local - oscillator using a high stability semiconductor laser should be developed in an immediate future, followed by the setting of an optical PLL and coherent and heterodyne optical link systems[8].

2.4 - Air Force Technological Istitute (ITA)

The major R & D activities in microwave at ITA are in the fields of acousto-optics, electro-optics, SAW devices, microstrip antennas, fiber optics and ferrite devices.

In the area of acousto optic devices the major interest is the utilization of quartz crystals, which are easily available in Brazil, for implementing both tunable filters and optical modulators. The experimental results so far obtained involve device design fabrication and characterization (e.g. measurement of diffraction efficiency and Bragg angles).

In the area of microstrip antennas theoretical and experimental results include the effect of both the electric and magnetic anisotropies of the substrate and the measurement of the radiation pattern of some antennas which will be used by the Brazilian Air Force.

The research in fiber optics is concentrated in fiber optics data transmission and optical fiber sensors, and in the area of ferrite devices a relevant work includes phase-shifters and YIG tuners.

2.5 - Mauá Institute of Technology (IMT)

At Mauá Institute of Technology (IMT), most of the R & D activities are in the area of industrial applications of microwaves. The two major fields of interest are measurement techniques (specially of the dielectric properties of solids and liquids) and high power devices and processes (for microwave dielectric heating, drying, cooking for cereals and food).

Other activities include the development of different components, waveguides, antenna measurements and electromagnetic interference measurements.

3. R & D ACTIVITIES IN RESEARCH CENTERS

The significant R & D activities in microwaves in research centers in Brazil are performed specially at CPqD-TELEBRÁS (Telecomunicações Brasileiras S/A R & D Center) in Campinas, São Paulo, at INPE (Space Research Institute) in São José dos Campos, at IPD-CTA (Air Force Research Institute) also in São José dos Campos, at IPqM (Navy Research Institute) and IPD/CTEx (Army R & D Institute), both in Rio de Janeiro.

3.1 - TELEBRÁS Research and Development Center (CPqD).

The CPqD activities in microwaves, antennas and optical communications will be now summarized.

The basic aim of CPqD activities in microwave circuits is to provide devices for the radio equipment of the Brazilian Telecommunication System. Under this concept, CPqD has been involved in the development of design techniques and fabrication processes for microwave devices.

Several circuits in the "S", "C" and "X"-band have been developed, such as microwave low-noise/medium-power amplifiers; mixers; oscillators (PLL and D. R. O.); frequency multipliers; filters; circulators; isolators and others. These components have been used to develop Up and Down Converters complying with INTELSAT specifications, a low-cost professional TV signal receiver and a 2-GHz digital radio.

Also CPqD has already developed band-pass filters and delay line oscillators utilizing SAW techniques.

The TELEBRÁS R & D Center is endowed with facilities wich allow for designing and manufacturing thin and thick film technology hybrid circuits and microwave circuits on soft substrates. For the coming years, CPqD intends to increase its efforts in miniature MICs and GaAs MMICs.

The CPqD Antenna Group has as one of its main tasks the development of earth station antennas for the Brazilian Satellite Telecommunication System. The undergoing research and the software package presently available enable the design of microwave components for reflector antenna feed chains, as well as reflector surface synthesis for axially symmetric antennas compatible with CCIR and FCC requirements.

A software package specially developed for the analysis of circular corrugated structures and coupling between corrugated and smooth wall waveguides has been successfully utilized in the design of wideband corrugated horns, low return loss mode converters for widely separated frequency bands, and wideband diplexers [9] for four port feeds operationg with frequency reuse. Presently a series of four and two port feeds is being developed for C band (Rx: 3.625 - 4.2 GHz / Tx: 5.850 - 6.425 GHz) circular and linear polarization operation. The four port feed chain consists of a pair of multihole corrugated directional couplers which can be connected to a dual-depth corrugated horn for operation throughout the extended band (3.4 - 4.2 GHz/5.850 - 6.775GHz) allocated by Warc'79.

For reflector design, computational tools are available for single and double reflector antenna analysis and synthesis. Secondary effects such as scattering by struts are taken into account and second order diffraction effects are analysed by GTD. Near field horn-subreflector interactions are also considered and the resulting antenna scattering field patterns are efficiently calculated by sampling technique. Double reflector 6.0 and 4.5 meter earth station antennas for C band operation compatible with CCIR Rec. 580-1 were designed and have been industrialized.

Efforts are now being made towards developing the necessary theoretical tools for the design and analysis of simple and double reflector offset antennas and for satellite on-board antenna design. Alternatives for the fully corrugated horn with compatible performance are also being investigated in order to reduce manufacturing costs.

The TELEBRÁS Optical Communications Program aims at mastering the technologies related to equipments and systems and to manufacturing processes of optical fibers and opto-electronic components considered to be of critical importance for telecommunications in Brazil.

The main achievements of the Program were:

a) ELO-34 and ELO-TV
The first one is an optical interface unit designed to transmit a 34 Mbit/s signal on a multimode fiber, in the 850 nm spectral region, making it possible to install optical links up to of 15 km of distance between repeaters. The second is an equipment designed to transmit a TV signal, being used in the interconnection of TV signal generation/distribution centers and local TV stations.

b) Optical fibers and opto-electronic devices.
In this segment of the Program, CPqD developed low loss optical fibers (multimode and singlemode) and high reliability GaAlAs lasers (over 1000.000 hours of operational life expectancy) manufacturing processes.

CPqD is currently carrying out the development of the ELO-434 equipment, which is designed to transmit 4 digital signals, 34 Mbit/s each, on a siglemode fiber, to be applied in high capacity and long distance links. The development of higher capacity systems (over 1Gbit/s) is under study. InGaAsP lasers and LEDS to operate in the 1300nm region, and InGaAs PIN photodetectors, are in final development stage. Lasers to operate in the 1550 nm region, photodetectors with internal gain and optical modulators built on $LiNbO_3$ substrates are also under development. Activities in the areas of integrated optoelectronic devices and halide fibers are being planned.

Up to the present all optical fiber links in the Brazilian Telecommunication System resulted from technology developed by CPqD. In order to reach this goal, in addition to the products and activities mentioned above, CPqD, in a joint program with local industries, has further developed multi-fiber cables, accessories, tools and instruments necessary for the installation, operation and maintenance of such systems.

3.2 - Space Research Center (INPE)

Microwave R/D activites at the Space Research Center in São José dos Campos, mainly consist of (a) development of on-board subsystems for environmental data collection satellites, and (b) applications to remote sensing.

The on-board subsystems being developed are intended for the first and second satellites of the Brazilian Space Mission. This Mission includes the development, construction, launch and operation of two types of satellites: the first one for data collection of environmental data provided by

platforms, the second one for remote sensing of the earth. The main items being developed are: a data collection transponder, which receives signals at 400 MHz, and retransmits them at 2.2GHz to an earth station for processing and dissemination; an S-band TT & C transponder; helicoidal antennas for these transponders; a 10W X-band amplifier.

In the area of applications to remote sensing, microwave techniques are used for the development of measuring methods for soil parameters like humidity. The effectiveness of X-band radiometry is being investigated.

4. R & D IN INDUSTRY

Microwave activities in Brazilian industry are basically concentrated on development and manufacturing, with some efforts on research in specific areas.

Among the main companies one can mention: Sul America Teleinformática (SAT), NEC do Brasil, Control, Equitel, Telemulti, Mapra, Avibrás, Amplimatic, Harald/Brasilsat, Elebra, SID/Telecom, Microline, Engesa and Celta. The main pruducts developed by SAT are 6 and 8 GHz TX/RX (1800 channels) equipment, 5 GHz Digital TX/RX (140Mbits/s), 6 GHz Amplifiers, VHF/UHF (160 MHz to 1.5 GHz) TX/RX equipment. The products developed by NEC are down/up - converters, LNAs and digital/analog microwave transceivers from 2 to 8 GHz. The main products developed by Control are attenuators, power dividers, amplifiers and filters, mainly for 4/6 GHz TX/RX earth stations. Equitel is participating in the development of a digital radio system (140 Mbits/s) at 4/6 and 8 GHz bands. At Telemulti, the major developments are in digital and analog TX/RX at UHF and SHF. Microline developed products such as isolators, power dividers and combiners, RF-multiplexers and coaxial lightning arrestors. Celta developed one/two octave directional couplers (100 MHz to 12 GHz), 100W attenuators and loads, as well as log-periodic VHF/UHF antennas.

Antennas for terrestrial microwaves and earth station satellites are produced by MAPRA, AVIBRÁS, AMPLIMATIC and HARALD/BRASILSAT.

Optical fiber is produced by ABC/Xtal. Elebra, SID/Telecom, Engesa and Avibrás are also able to produce it. Optical fiber equipments are produced by NEC do Brasil, ABC/Xtal, Telemulti and Elebra. The optical cables are produced by Pirelli do Brasil and Marsicano.

5. CONCLUSIONS

This paper has reviewed the relevant R & D programs in microwaves, antennas, propagation and optical communications in Brazil. As a conclusion, it can be mentioned that significant work is under way in some universities and research centers, and that in industry R & D activities started recently and are still very limited. As the needs for telecommunication services and equipments are increasing rapidly, Brazilian researchers and engineers have been working hard to increase R & D activities. This task is not easy, specially in experimental programs, partly due to difficulties in buying foreign laboratory equipment and materials. International cooperation has already shown significant results and must be stimulated.

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