THE DEVELOPMENT OF MICROWAVE COMPONENTS FOR EARTH STATION RECEIVER

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ABSTRACT

This paper outlines the Microwave Group activities at the Microelectronics Laboratory (LME-University of São Paulo) the development of microwave devices for a Satellite Earth Station Receiver over the 3.7 to 4.2 GHz band.

Introduction

A National Satellite Programme has been sponsored by the TELEBRÁS Research and Development Centre (CPqD) in Brazil, aiming the development of appropriate technology to increase the present-day number of earth stations.

Two different receivers are being carried out: one for television signal reception and another one for multi-channel (up to 1800 voice channels) telephone signal reception.

The Microwave Group contribution to the programme comprises the design and manufacture of the RF prototype modules for both receivers.

System Description

The receiver scheme adopted is based upon the Intelsat IV earth station configuration[1]. Figure 1 shows a block diagram of the microwave signal processing section. The dashed contour detaches the blocks under the Microwave Group's responsibility.

The 10 m diameter antenna to be used, requires a 100°K noise temperature amplifier, with 50 dB minimum gain[2]. The signal power is equally divided into four receiver subsystems and a down-conversion process from 4.0 GHz to 70 MHz is performed in two steps, at each receiver. Firstly, the FM carrier is down-converted into 1112.5 MHz, amplified and filtered. Subsequently, the carrier is converted into 70 MHz and passed through an additional amplification stage. The first local oscillator (LO) is a voltage controlled oscillator operating over the frequency band from 1.20 GHz to 1.33 GHz, phase locked by a crystal reference signal and frequency multiplied by four. Channel selection is accomplished by tuning the LO frequency at 1112.5 MHz above the incoming carrier.

The most important considerations taken into account in the design philosophy were: circuit compactness, good electrical performance, easiness of reproduction, rapid realization and low-cost.

Thin-film microstrip technology was largely employed in order to meet reliability and high capability of circuit integration requirements. TaN, Ni-Cr and Au thin-film layers were sucessively deposited on 25 mil thick, 99.5% pure alumina substrates by DC cathode sputtering, in the circuitry fabrication process. This method permits direct implementation of thin film tantalum nitride resistors, whenever required in the circuit design.

Microwave Modules

Low - Noise Preamplifier

This element situated near the antenna, is composed of a waveguide-to-stripline transition , an isolator, a low-noise stage (gain= 10 dB, noise figure = 2.5 dB) and a high gain stage (gain = 40.0 dB), as shown in figures 2 and 3.

In order to minimize losses, the isolator and the waveguide-to-stripline transition were implemented in air-dielectric stripline technique[3].

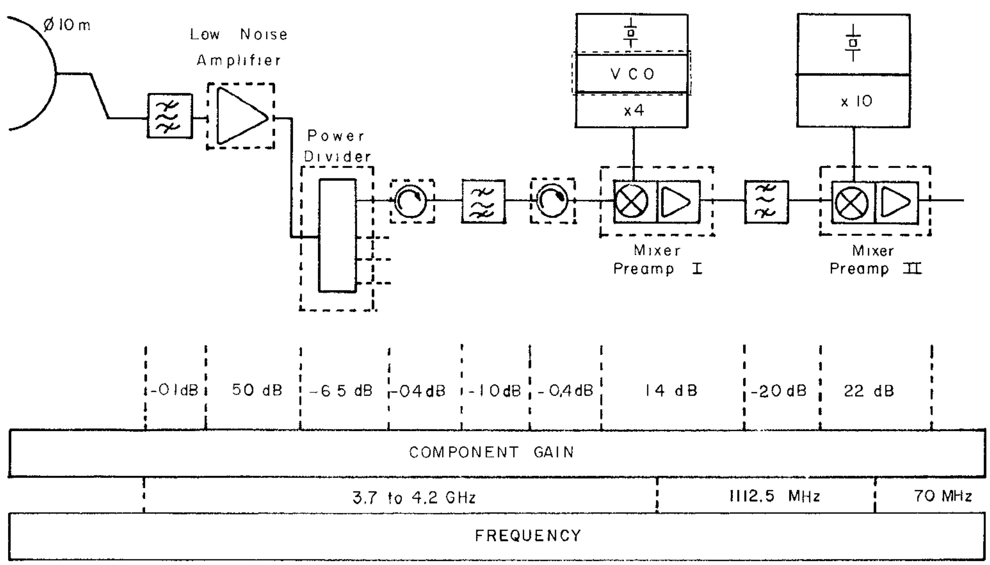

Figure 1 - Receiver Block Diagram

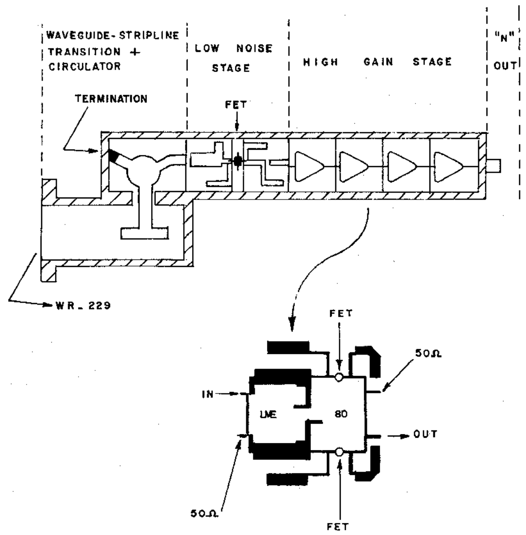

Figure 2 - Cross Sectional View of the Low - Noise Preamplifier

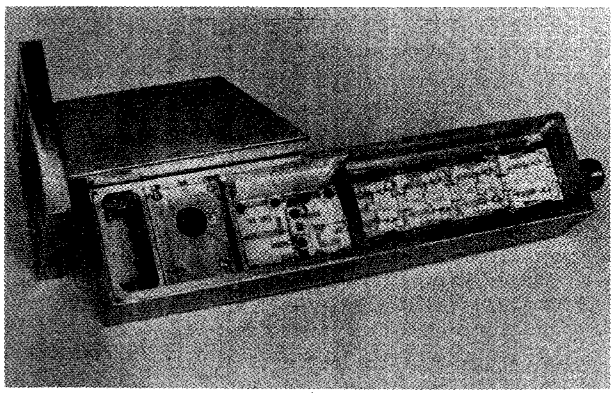

Figure 3 - Photo of the Low-Noise Preamplifier

In the amplifier low-noise stage, a NEC 38806 FET provides the suitable noise figure and linearity characteristics required for the amplication[4]. The input and output impedance matching circuits were designed upon published noise and S-parameters[4].

The high gain stage combines four balanced amplifier blocks, employing Plessey GAT4 FETs. The printed circuit version of a single block is shown in figure 2 inset. The balanced configuration was selected in order to guarantee good VSWR characteristic associated with non-degraded in-band ripple.

In all stages MIS (metal-insulator-semiconductor) capacitors, manufactured in this Lab in unpackaged chip form, were used for DC block purposes.

The first experimental prototype presented 50 dB gain with a maximum noise figure of 3.0 dB and about + 15 dBm linear output power (at 1 dB gain compression).

The total noise performance was affected by the circulator insertion losses (0.5 dB) and the rather excessive noise figure (4.5 dB) of the high gain stage. These characteristics are to be improved in the next optimized circuit.

Power Divider

The four-way power divider, used to distribute the LNA output signal, consists of two-way split - tee divider cells combined in a single structure. It was constructed by using conventional printed circuit technology on soft substrate (Diclad 522T). The input and output connectors are N female type, adapted for microstrip line.

The unit offers 6 dB power split, less than 0.5 dB insertion loss and more than 22 dB isolation between ports.

Mixer Preamplifiers

Single-balanced configuration for the mixer circuits were considered to meet the requirements of cost and performance.

The structure incorporates a "Miley" type hybrid, selected for its high bandwidth and ease of manufacture in thin-film technique. HP-5082-2229 Schottky diodes in the beam lead form were employed as the mixing elements.

First Mixer-Preamplifier Module

Figure 4 shows the 4.0 GHz mixer-preamp circuit photomask. The IF and LO traps were designed based upon a notch filter and a low pass filter schemes respectively.

The IF signals generated at each diode were added by means of a "Wilkinson" type combiner. As a result, isolation is obtained between the diodes and IF impedance matching becomes easier. The DC return was realized by using a 1 mil gold wire lumped choke.

The IF output from the mixer is fed into a two-stage 1112.5 MHz preamplifier, presenting a 22 dB gain and 2.5 dB noise figure. Both stages were built with bipolar transistors in chip form(type HP-35820A) suitably biased for low-noise and high dynamic range achievements.

The performance characteristics of the mixer - preamplifier module include 14 $\pm$ 0.5 dB conversion gain within the receiver band, 11 dB SSB noise figure and $\pm$ 0.2 dB in-band ripple over any 36 MHz segment.

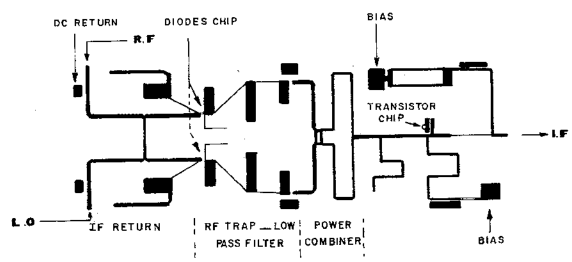

Figure 4 - Photomask of First Mixer-Preamp I

Second Mixer-Preamplifier Module

Figure 5 shows the 1.1 GHz mixer-preamp circuit photomask.

The mixer beats the 1112.5 MHz IF carrier with a local oscillator, in order to produce the 70 MHz carrier. The LO and IF traps were accomplished by means of $\lambda/4$ open-ended and short-ended stubs, respectively.

The assembly includes a three-stage preamplifer with 30.0 dB gain and 4.0 dB noise figure.

The transistor chips (FUJITSU FJ 201X) were employed in a resistive feedback configuration,envisaging a wide-band amplification.

This module features a conversion gain of 22 dB, SSB noise figure of 11 dB and an output power of + 5 dBm (1 dB gain compression point), with + 20 dBm intercept point.

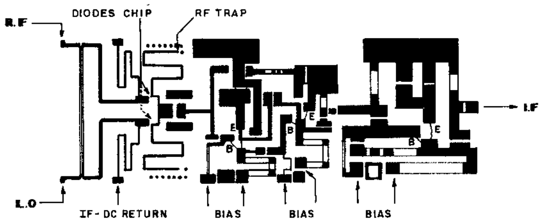

Figure 5 - Photomask of First Mixer-preamp II

Figure 6 shows a photograph of both mixer-preamps

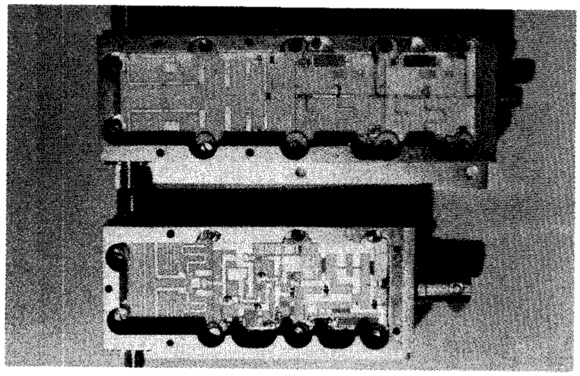

Figure 6 - Photo of Mixer-Preamps I/II

Voltage Controlled Oscillator

A varactor-tuned transistor oscillator was designed to operate over the 1.20 to 1.33 GHz frequency range. The bipolar transistor (HP series 21) used in this circuit,was mounted in common base configuration with inductive series feedback provided by a short-ended transmission line.

A varactor diode chip (MA 45000) loaded line serves as a tunable resonator coupled to the emitter. A schematic of this component is shown in figure 7.

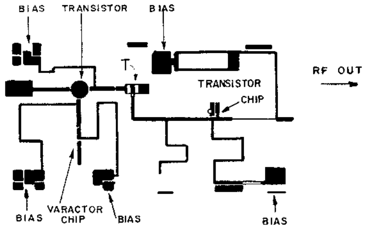

Figure 7 - Voltage Controlled Oscillator

In order to improve load isolation, a 10 dB "T" attenuator cascaded with a buffer amplifier was integrated to the circuit. The amplifier is of the type used in the first down-converter module, adjusted to give + 10 dBm output power. Figure 8 is a photograph of the final prototype.

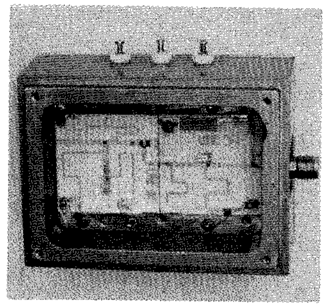

Figure 8 - Photo of VCO prototype

Conclusions

The microwave modules described above have been assembled together with components constructed in other national universities and industries, resulting in a complete TV receiver station. It has been operating successfully at TELEBRÁS - CPqD at Campinas - São Paulo, Brazil since October 1980. The performance characteristics obtained prove the components to be suitable for TV signal down-conversion purposes.

Current efforts are now directed towards the improvement of the down-converter's gain flatness, the noise characteristics and circuit compactness, aiming the suitability of the components for use in a public telephony station.

Acknowledgement

This work has been carried out with the support of TELEBRÁS Research and Development Center. The authors would like to thank Mr. A. Flacker for providing the metalized alumina, Miss D. Consoni for manuscript revision,and Mr. M. Saito for assistance during the course of this work.

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