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MMIC BASED MODULES FOR COMMERCIAL SATELLITE APPLICATION

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ABSTRACT

In the last years the satellite applications see a strong increase in the space hardware demands mainly for commercial communication services like Fixed Service (FSS), Broadcasting Service (BSS) and Mobile Service (MSS). The design of radiofrequency, microwave and millimeter wave equipment and electonics has been deeply modified in order to allow the space companies to compete in the commercial market keeping high equipment performances but at low recurring costs and with very short lead-times.

The paper will focus the design and development of a set of building blocks and functions using MMIC technology for on-board satellite application. Basic building blocks, like MMIC low noise amplifier, medium power amplifier, variable gain amplifier, flatness corrector, are used in different integrated functions including LNA, Front End, Receiver, downconverter and channel amplifiers. A short highlight of each function will be provided together with some details on the MMIC performances and hybrid technology.

1. INTRODUCTION

Present satellite applications, mainly for commercial communication services, demand for reduction of dimension and weight, lower recurring costs, improved reliability and high performances. The number of satellites to be built in the next years is growing and an impressive reduction in the typical lead-time to built the space hardware is also required to succesfully compete in the worldwide market.

In this scenario the evolution of microwave engineering and technologies is a key element to find a competitive answers to the market needs. The possibility to integrate complex microwave function like Low Noise Amplifiers, Front Ends, Receivers, Downconverters and Channel amplifiers plays a key role and it became possible with the introduction in the flight production of integrated technologies like GaAs MMIC, ASIC, Multi-Chip Module and Low Temperature Cofirig Ceramic.

Alenia Aerospazio is widely using MMIC technology in the production of space hardware mainly for commercial satellite application. As stated in the abstract different modules have been developed for the satellite working in Ku band (13.5-14.5 GHz, 17-18 GHz) and are in development for future systems using the Ka band frequencies (29-31 GHz, 18.5-21.5 GHz).

The functions include Low Noise Amplifier and Integrated Front End sections for Tracking, Command and Ranging subsystem, LNA for communication repeaters, FSS and BSS Communication receivers, Channel Amplifiers. Two well proven and settled foundry processes have been used with very good result in terms of overall yield in the flight production:

- low noise 0.25 um pseudomorphic HEMT based
- low pinch-off general purpose MESFET based with 0.5 um gate length

2. LNAs and FRONT ENDs

A fully integrated Ku band front end has been developed to perfom the frequency downconversion from the received up-link signal to the IF (140 MHz). The hybrid has been designed making use of two different chips (LNA) working in the 14 and 18 GHz band. After having been filtered the received signal is routed to a three stage MMIC LNA.Each chip is realised with the PHEMT process and employs two stage self biased configuration with inductive source feedback on the first stage in order to achieve optimum noise figure associated to good input VSWR. An image reject mixer while rejecting the image frequency and the noise at the same frequency, performs the frequency conversion down to the IF. It has been realised with chip and wire tecnology using beam lead diodes. Minimun gain of 28 dB are achieved in the flight production over a large statistic and image rejection figure of 25 dB is achieved.

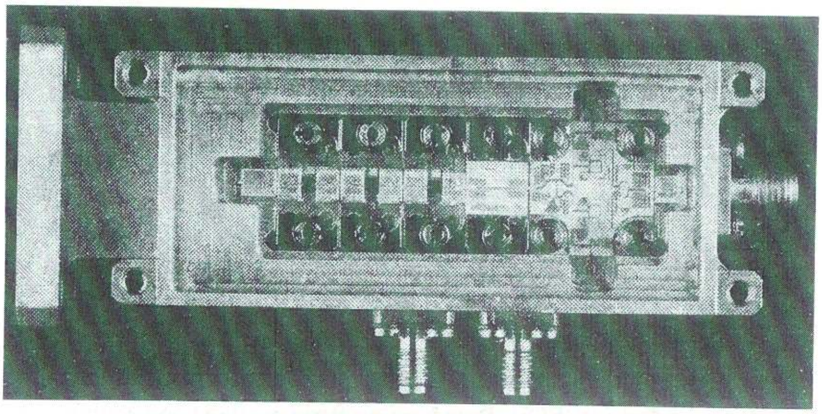

Figure 2.1 - Ku Band Front End Hybrid

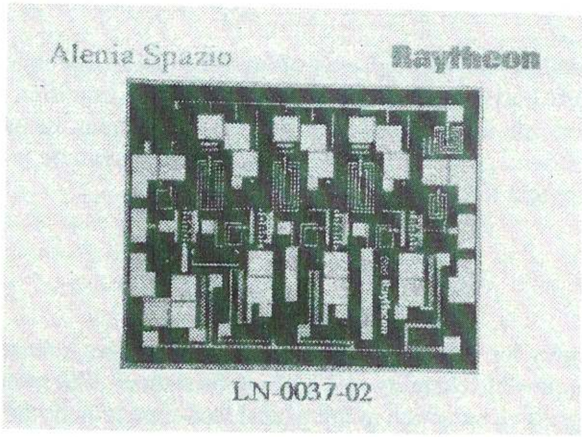

Figure 2.2 PHEMT Ku MMIC Low Noise Amplifier

The same LNA building block have been used to realise a fully integrated LNA function for communication payloads in Ku band as well as in Ka band. The low noise amplifier is composed of a hybrid MIC using discrete HEMT chips, followed by a cascade of monolithic LNAs and variable attenuators. The HMIC LNA first stage is a single ended amplifier whose input network is optimised for noise figure performance, whereas the input return loss is guaranteed by a very low loss WR62, WR51 or WR34 waveguide isolator external to the hermetic module. The devices are state-of-the-art low noise HEMTs. The LNA is composed of three self-biased HEMT stages, designed as source feedback amplifiers to simultaneously guarantee noise figure and return loss performance. The analog attenuator design is based on a broadband extended T design. This approach was chosen because of its minimal VSWR variation and flat gain response over the attenuation range. Since dual voltages are needed to drive the attenuator a low current driving circuit has been also incorporated on the chip. The microwave section is conceived as a macrohybrid with MMICs brazed on open carriers, as result of a tradeoff between the needs of miniaturization and production yield. A command and control section provides the command and telemetry management, the thermal compensation and the gain control. It is realised as a multichip module using a thick film multilayer substrate.

3. FSS/BSS RECEIVERS

The communication receiver for FSS or BSS applications provides low noise amplification and downconversion of signals in a portion of the frequency range 12.7-14.7 GHz or 17 - 18 GHz down to 10.7-12.7 GHz, by means of a net subtraction of an internally generated Local Oscillator frequency.

A hybrid hermetic module mostly MMIC based has been designed to integrate the low noise, the mixer and the IF circuits. The low noise amplifier section uses exactly the same architecture and circuits described before but is followed in this design by a microstrip filter, providing the proper image frequency rejection so as to avoid any detectable contribution of the image band noise to the receiver noise figure.

A hybrid single balanced mixer using beamlead GaAs Schottky diodes converts the RF signal from the frequency range 12.7-14.7 GHz or 17-18 GHz down to 10.7-12.7 GHz, providing 35 dB typical RF/IF isolation plus strong rejection of even or odd LO harmonics (potentially falling into the IF band), depending on the selected configuration.

A bandpass filter is the first element of the IF section, providing suppression of out-of band mixing products: two identical filters realised in microstrip are used in a wideband balanced configuration to implement an absorptive filter, thus avoiding reactive loading of the mixer IF port for unwanted frequency products, which can affect the flatness. The rest of the IF section is composed of a cascade of different MMIC circuits which provide the required gain and gain control dynamic. The first gain stage is an MMIC LNA as the one above described: the large passband of the MMIC allows use on the IF section as well, in order for it to have negligible contribution to the overall noise figure. The MESFET process has been used for the MMICs following in the IF chain.

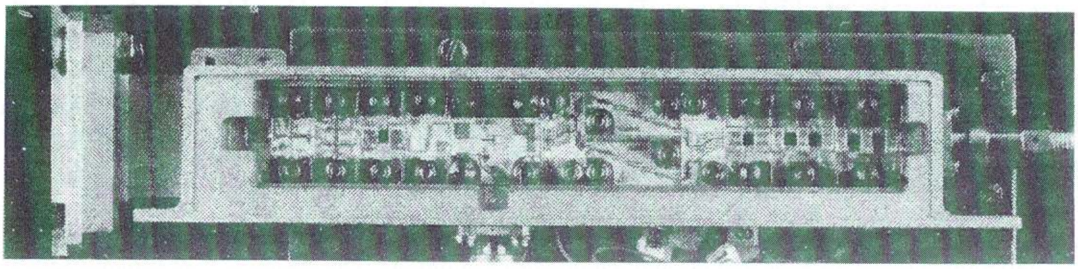

Figure 3.1 FSS/BSS Receiver Microwave Module

The Flatness Corrector (*FC*) circuit gives the possibility to control the gain slope variation consequent to the complete system assembling and possible slope variations over temperature. It allows to obtain both positive and negative slope control. The gain control block is the *VGA* (Variable Gain Amplifier) which is composed of three self-biased stages of amplification with an embedded analog attenuator, allowing compensation of gain drift over temperature of the complete assembly. The analog attenuator design was based on a broadband extended T configuration using cold FETs. This approach was chosen because of its minimal VSWR variation and flat gain response over the attenuation range. A Medium Power Amplifier (*MPA*) is used as the output stage in order to have higher output level and better linearity. The circuit design is single-ended and consists of a two stage amplifier. Output FET gate periphery was selected to achieve a 32 dBm third order intercept point while keeping the channel temperature below 110 °C when in maximum environmental temperature.

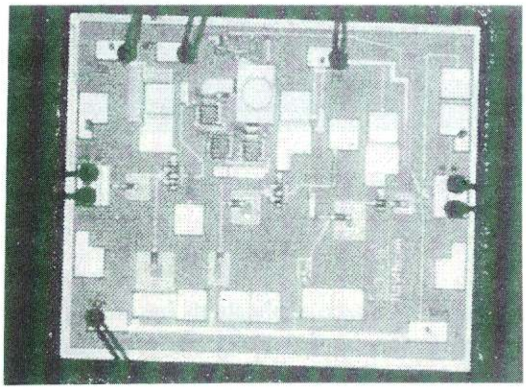

Figure 3.2 MESFET Variable Gain Amplifier

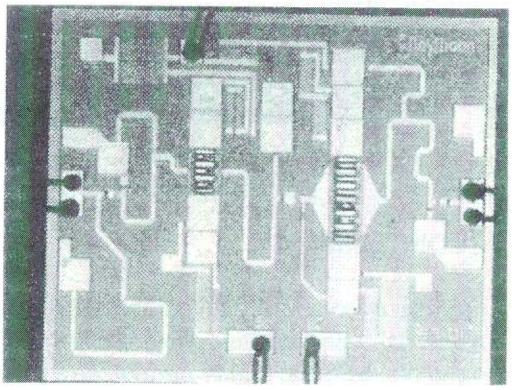

Figure 3.3 MESFET Medium Power Amplifier

All the hardware presented in this paper working in Ku band is flying in a number of satellites where Alenia Aerospazio had the responsability at equipment and/or at system level. The Ka band hardware will enter late this year in the flight production to be embarked in Ka payloads starting from the next year.

4. CHANNEL AMPLIFIER

The Channel amplifier provides amplification of a Ku band signal (10.7 to 12.75 GHz) allowing selection of either gain (10 to 60 dB, Fixed Gain Mode) or output level (-10 dBm to +4/+6 dBm, Automatic Level Control Mode) in discrete steps by means of an external command. If the ALC mode is enabled the output level is kept constant by the loop which compensates the input dynamic range. ALC function may be inhibited for FG operation. Temperature compensation is implemented to guarantee gain stability.The CAMP is composed of two sections: the microwave section, fully MMIC based, and the command and control section.

The microwave section is fully MMIC based in order to achieve the best performances in terms of reduced weight and integration factor. It is composed of eight MMICs brazed on open carriers and integrated in a single hybrid hemetically sealed. A mass lower than 50 grams is achieved with impressive reduction in the tuning effort with respect to a more traditional approach using discrete FET devices. The basic building blocks is a Variable Gain Amplifier (VGA). The MMIC designed to work in the bandwidth 10.7-12.7 GHz, provides the amplification function in conjunction with gain control function. It's composed of three self-biased stages of amplification with an embedded analog attenuator. The analog attenuator is based on a broadband T design. A self aligned gate medium power low noise MESFET process with a gate lenght of 0.5 μm is used. Each stage gives a typical gain of 14 dB over 2 GHz bandwidth (10.7-12.7 GHz) in combination with a gain control range of about 20 dB.

A Flatness Corrector (FC) MMIC has been designed in order to control over the full bandwidth the channel slope and to recover slope variation at different gain settings and temperature conditions. The design is conceptually simple and allows to obtain both positive and negative slope control; a notch filter is realized and by means of the external control voltage it is possible to control the Q factor and the resonant frequency.

The control section is realised making use of MCM technology and provides the command and telemetry management, the thermal compensation and the gain/level linearisation. A MCM hybrid integrates CMOS digital ASIC and analog building blocks (TRs, OpAmps) achieving a considerable integration factor.

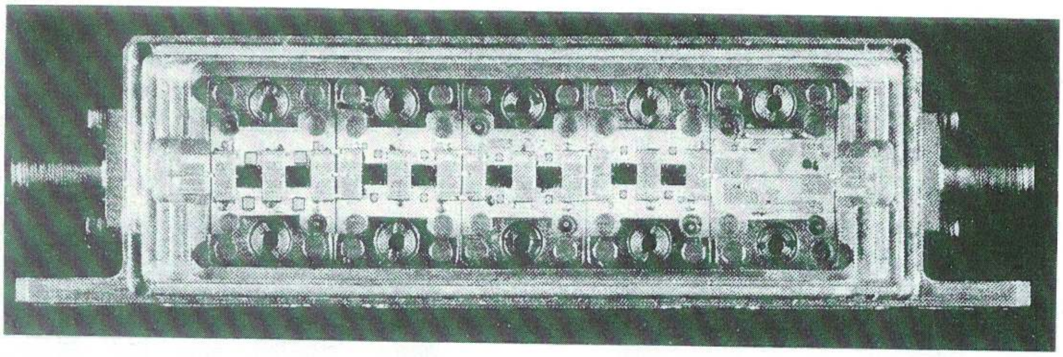

Figure 4.1 Channel Amplifier Microwave Hybrid

5. CONCLUSIONS

In this paper an overview of the latest technology in the microwave domain for space applications has been presented. The commercial telecommunication satellite application is a driving factor in the design miniaturisation and technologies like MMICs, highly integrated Hybrid Microwave Integrated Circuits, MultiChip Module and advanced packaging are now massively used in the space hardware production. The trend is impressive in terms of weight, dimensions and recurring cost reduction.

Next generation units will integrate the microwave MMIC functions and video/control function in a single macrohybrid making use of low temperatute ceramic cofiring technology in order to reduce of a factor two the weight now achieved in modules like the channel amplifier or the communication receiver. The MMIC design team is working with european and american foundries to develop complete families of MMIC in Ka band (30/20 GHz) as well as advanced functions in Ku bandwidth. The complete set of units for advanced Ka band satellite repeaters will be qualified and available for flight production starting from the second quarter of 1998.