MIC FRONT END FOR AN I BAND MONOPULSE AIRBORNE RADAR

J.L. SOULA and Y. AMBLARD

THOMSON - CSF
AVS Division - RCM department
178, Boulevard Gabriel Péri
92240 - MALAKOFF - FRANCE

ABSTRACT

This paper describes a new way to realize a complete monopulse receiver for an airborne radar in a very compact microwave assembly ; then a unique package contains all microwave components joining aerial to IF receiver. Thin fim technique on alumina substrate is employed in each integrated RF circuit ; FET amplifiers realized in MIC techniques are used to reduce noise figure. The required and obtained electrical performances are consistent with the typical specifications of a multifunction airborne radar.

INTRODUCTION

In recent years, microwave receiver circuits of many airborne radars, used only components as mixers, LO power divider and sometimes a parametric amplifier in Σ channel.

Nowadays the required performances for a military airborne radar are more severe and imply many RF functions which are carried out into the microwave circuits.

Then it becomes necessary to design these microwave components with reduced size and weight. Waveguide transmission lines are used for the transmitter circuits due to their high power handling capability ; but other kinds of hardware as MIC are suited for receiving-microwave circuits. To the reliability point of view, all RF connectors which are source of problems have been eliminated into this design.

A new approach was followed to design a complete monopulse receiver in a very compact microwave assembly ; microwave receiver block diagram of a multifunction airborne radar is shown figure 1 ; it essentially consists of two low power microwave sub-assemblies including all receiving circuits : RF front End and Test block. Few coaxial cables are used for interconnexions between the sub-assemblies.

Among the microwave functions which are included in the RF front end, there are three low noise FET amplifiers and three sensitivity time controlled attenuators. All the functions are made with microwave integrated circuits (MIC) on alumina substrate. A special assembly technique is provided to remove and replace each component.

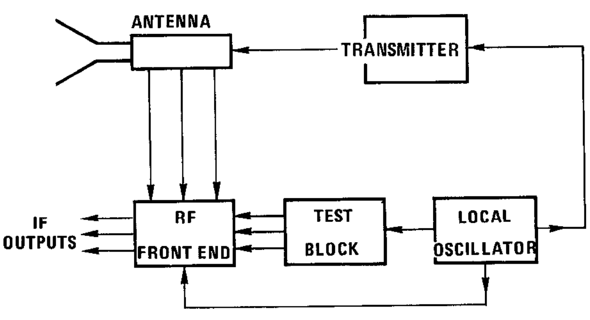

Fig 1 - Microwave Receiver Block Diagram -

RF FRONT END DESIGN

The main goal in designing this monopulse RF front end was to insert all microwave components joining antenna to IF receiver, in a unique package. Each functional component is designed apart, tested on a microwave bench with a special test Jig and assembled in the front end package by screws and bondings. If any failure happens, a component can be unscrewed and repaired at the manufacturing plant.

The reliability of such an assembly is improved due to the low number of required microwaves connectors.

Phase and amplitude tracking errors between the three channels are limited by short length lines used to join the components inside the package.

PRELIMINARY INVESTIGATIONS

For several years it has been possible to realize low power microwave components with MIC on alumina substrate. For example the following components have been developped in I band for radar applications :

- switches
- limiters
- isolators
- image rejection mixers
- varactor tuning phase shifters
- PIN diode tuning attenuators.

In these components all semi-conductor devices as varactor, shottky or PIN diodes in chip are bonded on the metallized substrate and connected by thermocompressed gold wires.

FET AMPLIFIER DESIGN

One of the most important feature of a microwave receiver for an airborne monopulse radar is noise figure.

Improved performances of receivers have been obtained in recent years with FET amplifiers ; this kind of amplifier is particulary suited to the Σ channel of such a receiver ; but typical gain and phase performances versus frequency of such an amplifier are valid for the three channels of a monopulse receiver. Finally three identical FET amplifiers were integrated in designing the three RF front end of the radar.

A low noise FET amplifier block diagram is shown figure 2 : a lower noise figure is obtained with an optimum input impedance giving a high (between 2:1 and 3:1) VSWR. A matching isolator is needed at the amplifier input and gives a small (.2 to .3 dB) noise figure increase.

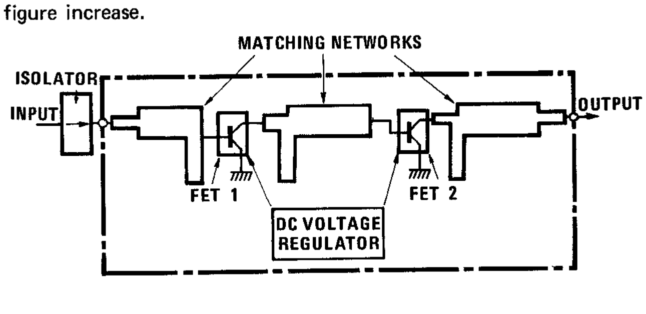

Fig 2 - Two Stages Fet Amplifier Diagram -

Microwave transistors of each amplifier are biased via a DC regulator circuit which is installed close by the microwave circuit.

Electrical performances of a typical two stages FET amplifier are presented in the 9, 9.6 GHz frequency band, see figure 3.

Gallium arsenide FETs employed here are NEC 244.06 pattern ; these packaged devices were chosen for their low noise figure in I band and their high reliability in an airborne environment.

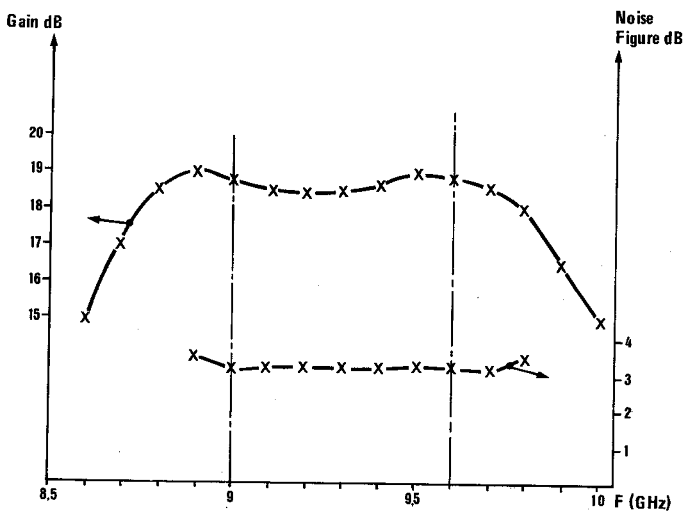

Fig 3 - Fet Amplifier Electrical Performances -

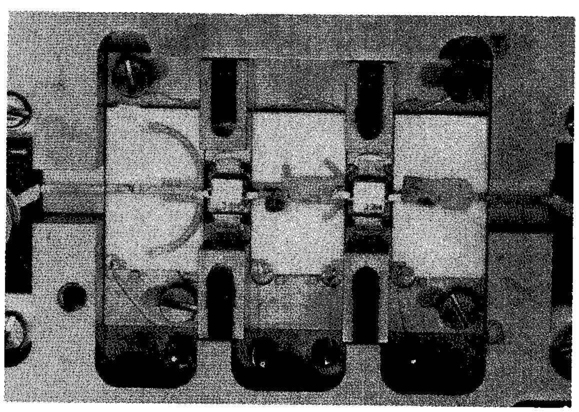

Fig 4 - Two Stages Fet Amplifier -

MIC TECHNOLOGY (figure 5)

All the components which are included in this three channel receiver are achieved with the following technique :

- the substrate material is 99,5% purity alumina which is 0,63 mm thick, with nichrome, copper and gold depositions
- each fundamental element with its photoetched conductive lines on the substrate and all bonded devices is soldered on a titanium carrier plate which is screwed into a cell. All the cells are milled in the alumnium material of the front end box
- the connections between each element in the cells are 50 ohms printed lines which are etched on a small substrate ; these substrates are bonded into grooves which are milled in the intersections isolating walls

Such a technique has a double advantage :

- before the final assembly it is possible to test each element of circuit in a test jig where the conditions of operation are reproducible
- it is easy to remove the failure element and to insert a new one with new bondings on input and output parts only.

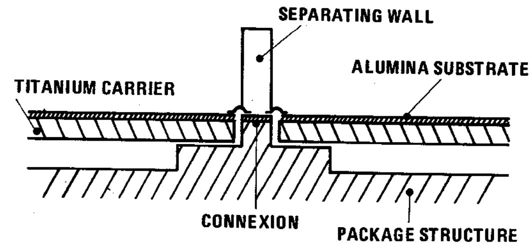

Fig 5 - Connexion Between Two Differents Components -

RF FRONT END BLOCK DIAGRAM (figure 6)

To protect the input FET of each amplifier from high power parasitic microwave signals coming from the transmitter leakage or any external source, a TR diode switch and a passive diode limiter are introduced in front of each channel.

On Σ channel these protector devices are made in waveguide.

Following the FET amplifiers are variable attenuators with a sensitivity time control feature ; in a radar application the STC mode can be introduced at such time as a target is well discernible ; increasing attenuation is then introduced as the target return increases, preventing receiver saturation.

Then on the output of the attenuators are three image rejection mixers ; their intrinseque noise figure is less than 8 dB.

A three way power devider including three varactor diode controlled phase shifters delivers the local oscillator signal to each mixer.

The reverse side of the main box contains IF preamplifiers, DC voltage regulators for FETS and switches and attenuators drivers.

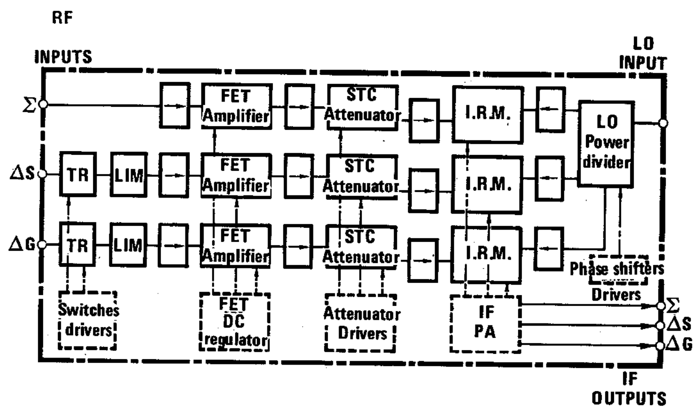

Fig 6 - RF Front End Block Diagram -

RF PERFORMANCES

RF performances of the three channel MIC receiver are shown figure 7 :

Over all Σ channel noise figure :	3.8 dB (typical)
Phase tracking between channels :	⩾ 5°
Gain tracking between channels :	⩽ 0.5 dB
STC attenuation :	> 50 dB
Maximum input peak power :	< 1 KW
Phase shifter control range :	⩾ 100°

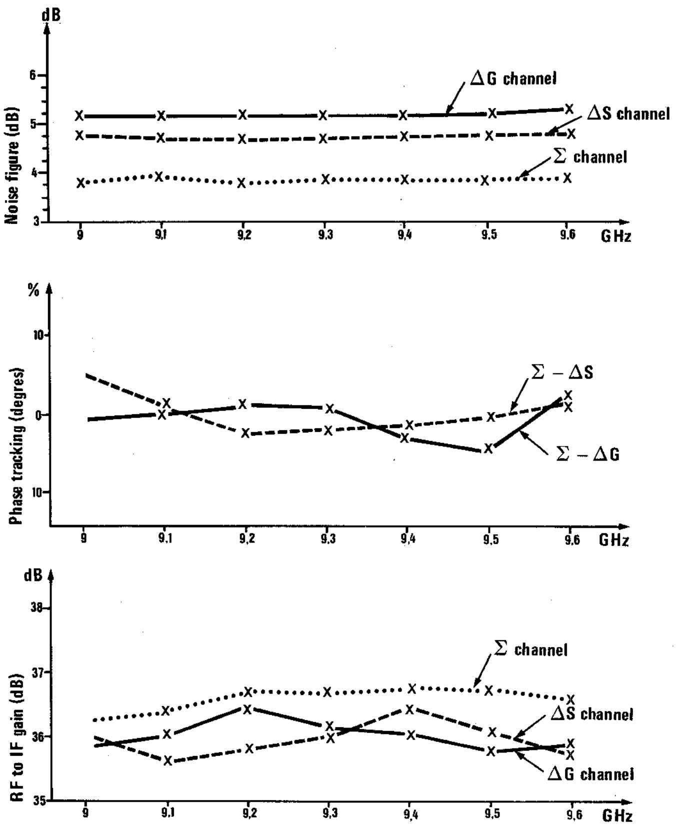

Fig 7 - I Band RF Front End Performances -

TEST BLOCK

An other subassembly has been designed with the same technique, to provide the built in test capability of the receiver ; it essentially consists of a single side band generator with three amplitude and phase balanced outputs.

It contains one SSB modulator, three varactors controlled phase shifters and three PIN diode controlled attenuators to balance phase and amplitude on the three outputs.

CONCLUSION

A three channel monopulse microwave receiver has been realized in a very compact package, with reduced size and weight, and a better reliability. This unique front end includes all microwave components for signal processing from antenna ot IF preamplifier outputs.

Such an assembly has been tested with a complete monopulse radar antenna and has given the required RF performances,for instance :

Phase tracking between channels : $\leqslant 5^{0}$

Gain tracking between channels : $\leqslant$ 0,5 dB.

These performances are consistent with the typical specifications of a multifunction airborne radar.

REFERENCES

1 – Ga AS FETs Market and Technology Review (Microwave J, February 1978 p. 22 - 31)
2 – Microwave transmission lines impedance data p. 112 - 114
3 – S parameters... Circuits analysis and design (Application Note 95 - Hewlett Packard)
4 – H A Hans : Representation of noise in linear two parts (PIRE, vol 48, january 1960, p. 69 - 74)

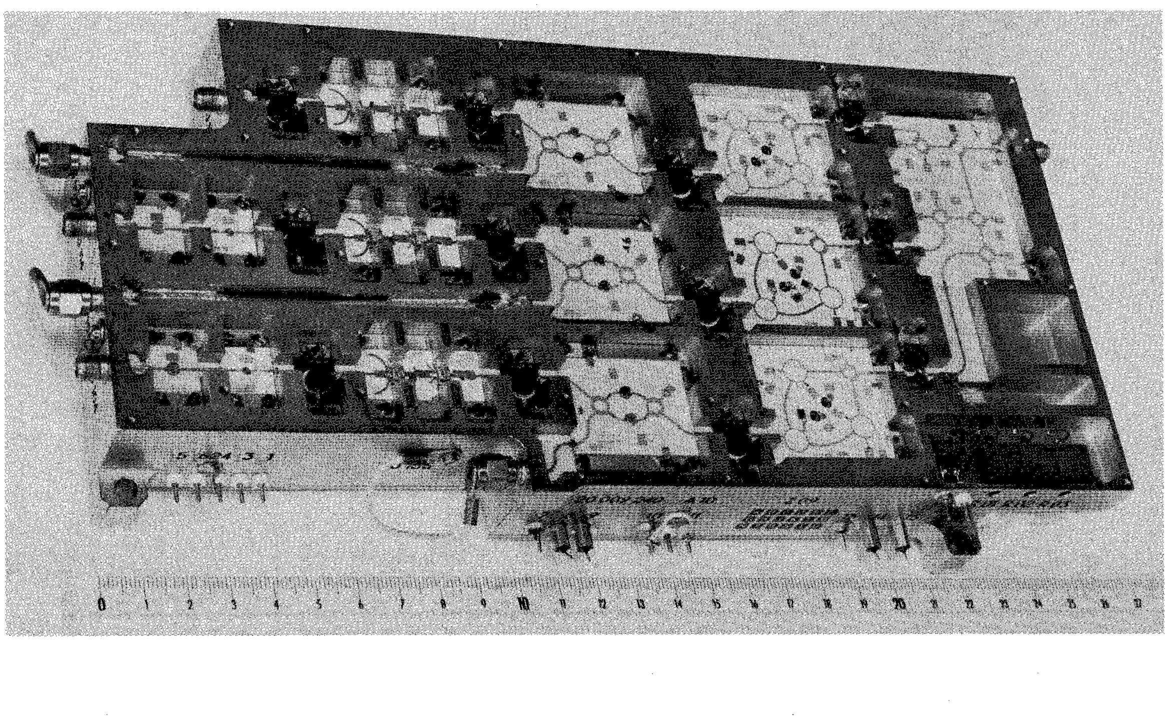

Fig 8 - M.I.C. Side View Of The RF Front End -