MICROWAVE INTEGRATED CIRCUIT RECEIVERS AT MILLIMETRIC WAVELENGTHS

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ABSTRACT

This paper discusses the application of hybrid microwave integrated circuit technology using open microstrip transmission lines to the realisation of practical receivers operating on the superheterodyne principle at millimetric wavelengths.

INTRODUCTION

Microwave integrated circuit (MIC) techniques are now being accepted by the microwave systems designer as an alternative to the more conventional waveguide and coaxial approaches, and fabrication processes are becoming established for the production of MIC assemblies to meet the demand of advanced systems. The preferred design approach generally uses hybrid technology with open microstrip transmission lines, and such techniques are being applied successfully to complex receivers up to about 18 GHz[1]. Applications at higher frequencies however, present even further difficulty in design and fabrication, particularly with regard to the transmission properties of open microstrip, and the use of very low parasitic active devices.

It is the intention of this paper to show that the hybrid-open microstrip design approach can be adopted in the 26 to 90 GHz frequency region and that such techniques may be considered for ultimate production even where reproducibility is of prime importance. To provide an example of this technological approach, the main part of the paper is devoted to describing the design, fabrication and performance of a multi-circuit function receiver unit designed for operation at about 35 GHz. Application could be for airport high definition radars, vehicle headway warning devices, and other ground based radars. In addition, brief descriptions are given of an image suppression mixer and a balanced mixer for operation at about 35 GHz and 70 GHz respectively.

35 GHz RECEIVER UNIT

General description

A schematic diagram of the unit is shown in Figure 1. It contains two mixers, each with its associated amplifier. One is a low noise mixer for the signal channel, the other provides an output for automatic frequency control (a.f.c.). Both mixers are driven from a single local oscillator port. An isolator is included to increase the isolation of the local oscillator from the signal and a.f.c. channels.

The r.f. input ports are in WG22 waveguide, with transition provided to microstrip. The r.f. circuit functions are screened from the i.f./a.f.c. circuits by containing them in separate screened compartments within an aluminium alloy box of overall size about 80 × 86 × 26 mm. The r.f. circuits positioned in their box compartments are shown in Figure 2, and comprise the signal mixer, a.f.c. mixer, 3 dB power splitter and iso-circulator. These have been designed as separate circuit elements before being incorporated as separate substrates and combined by circuit links to meet the overall circuit requirement. Techniques are available which can combine these circuit elements on a single substrate if required, thus eliminating the need to provide inter-connection between the individual substrates.

The circuits are designed and constructed using advanced hybrid MIC technologies. Gold thin film microstrip transmission lines are formed on 250 μm thick silica substrates and thermo-compression bonding techniques are employed throughout for incorporating the active devices or providing substrate inter-connections/connections to the feeders.

Low parasitic gallium arsenide Schottky barrier diodes are used to provide the non-linear mixer elements[2]. The particular diode type used at this frequency has a total capacitance of about 0.05 pF. The 3 dB coupler design used to construct the balanced mixer circuit is of the rat race form.

Specialised techniques are used to provide the microstrip iso-circulator[3]. A disc of ferrite is inserted into the substrate before the thin film circuit is defined. A ferrite of high saturation megnetisation is used and a small samarium cobalt magnet in the base of the box provides the magnetic field. A miniature hybrid thin film resistor supplies the 50 ohm termination on one port of the circulator.

The i.f. and a.f.c. head amplifiers situated in their box compartment are shown in Figure 3. These employ discrete components mounted on printed circuit boards, connection through to these from the r.f. compartment is made by insulated feed-throughs. Output from these amplifiers are taken from 3 mm SMA connectors.

Performances of r.f. circuit elements

The performances at about 35 GHz, of the main separate elements in test boxes, are briefly summarised below:-

Signal balanced mixer

v.s.w.r. at l.o. and signal ports	<2.0:1
l.o. to signal isolation	>15 dB
l.o. power	5 mW
diode rectifier current	1.5 mA/diode
overall noise figure ($F_{i.f.}$ = 1.5 dB)	7 to 8 dB

Iso-circulator

insertion loss	<1.0 dB
isolation	>20 dB
v.s.w.r.	<1.3:1

Performance of complete receiver unit

The main electrical performance features are summarised by indicating typical values:-

frequency	33 to 36 GHz
overall noise figure	8 dB
intermediate frequency	60 MHz
overall receiver gain (signal channel)	16 dB
l.o. power	10 mW
signal a.f.c. and l.o. port v.s.w.r.	1.6:1
overall a.f.c. channel gain	4 dB
temperature range	-10 to $+40^{o}C$

The receiver overall noise figure as a function of frequency is shown in Figure 4.

35 GHz IMAGE SUPPRESSION MIXER

Image suppression in this mixer unit is achieved by the well established technique of feeding two mixers with signals in phase and l.o. power in quadrature. The i.f. output from the two mixers appears in quadrature, and by introducing a further 90^{o} phase shift of the correct sign, either upper or lower sideband operation can be arranged.

The r.f. circuit is shown in Figure 5. The circuit is designed and constructed using hybrid MIC techniques similar to those indicated for the previous receiver unit, with the exception that the circuit elements are produced on a single substrate, thus eliminating the need for inter-connection between separate circuit substrates. The r.f. and i.f. circuit functions are contained in separate screened compartments provided in the unit box.

The overall performance in terms of noise figure and image suppression is shown in Figure 6.

70 GHz BALANCED MIXER

A balanced mixer for operation at about 70 GHz is shown in Figure 7. Hybrid-open microstrip MIC techniques are still applied, with the gold thin film circuit produced on a 120 μm thick silica substrate, size 10 mm × 10 mm. The gallium arsenide beam lead diodes are specially produced to even further reduce their stray parasitics and their total capacitance is about 0.03 pF per diode. A conversion loss of about 8.0 dB is achieved over the frequency range of 65 GHz to 75 GHz.

CONCLUSIONS

It has been shown that practical MIC receivers can be realised at millimetric wavelengths in hybrid-open microstrip form, by the application of advanced techniques, and further progress in this direction will be possible by considering even more complex circuits.

The techniques evolved are applicable to combining many circuit elements on a single substrate, with the associated advantages already established at lower microwave frequencies. This will in turn lead to the benefits of full integration for new systems operating at frequencies above 26 GHz.

REFERENCES

1. Lancaster, N. and Oxley, T.H., 'Production of a High Reliability J(Ku)-Band Transmit-Receive Unit using Hybrid MIC Technology', INTERNEPCON UK, 1975.

2. Oxley, T.H. and Swallow, G.H., 'Beam Lead Mixer and Detector Diodes for Microwave Integrated Circuit Applications', Proc. 8th Int. Conf. on Microwave and Optical Generation and Application, Amsterdam, September, 1970.

3. Brigginshaw, P.M. and Riches, E.E., 'Development of MIC circulators from 1 to 40 GHz', IEEE Trans. on Magnetics, MAG-11, No.5, September, 1975, pp.1273-1275.

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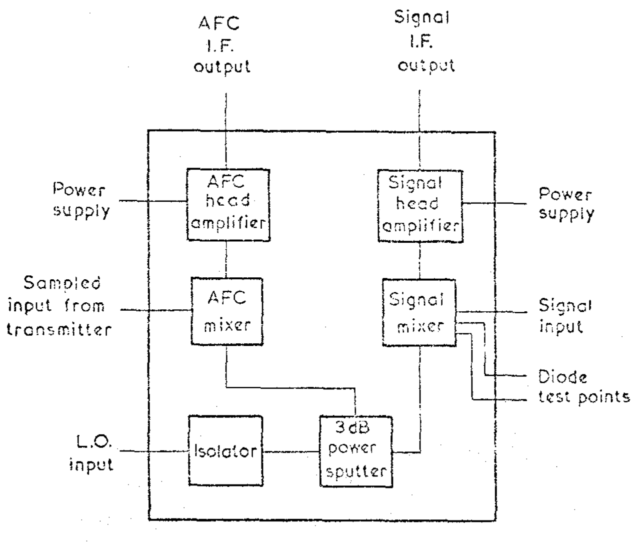
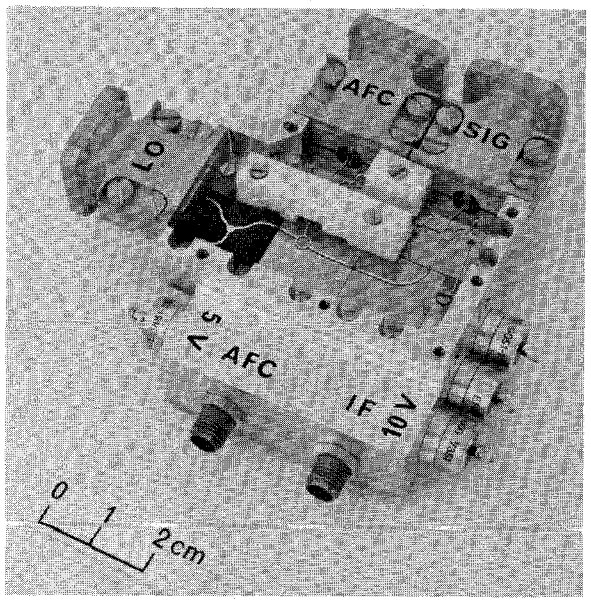
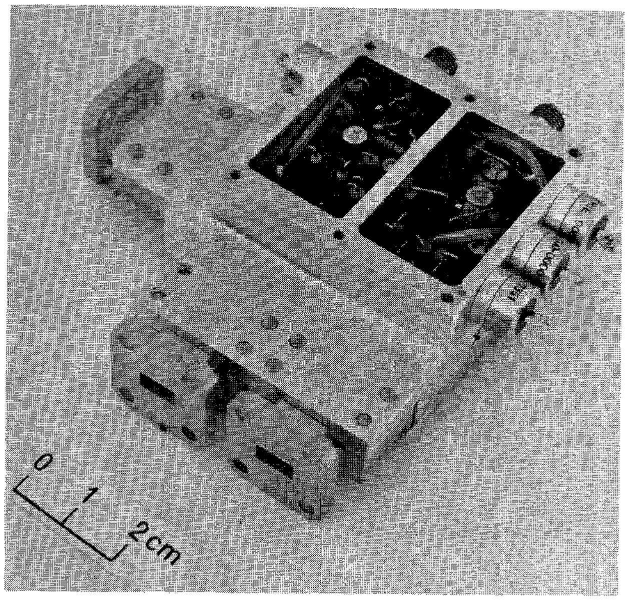


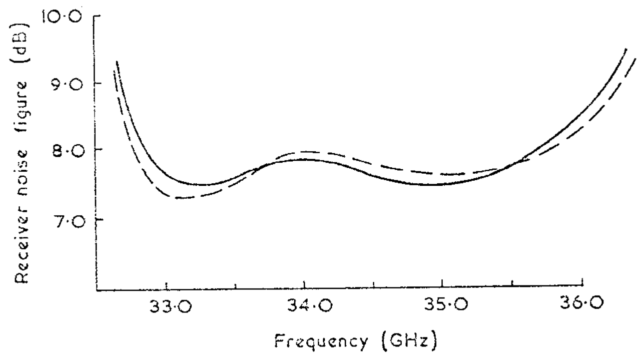
1. Block diagram of 35 GHz receiver unit.



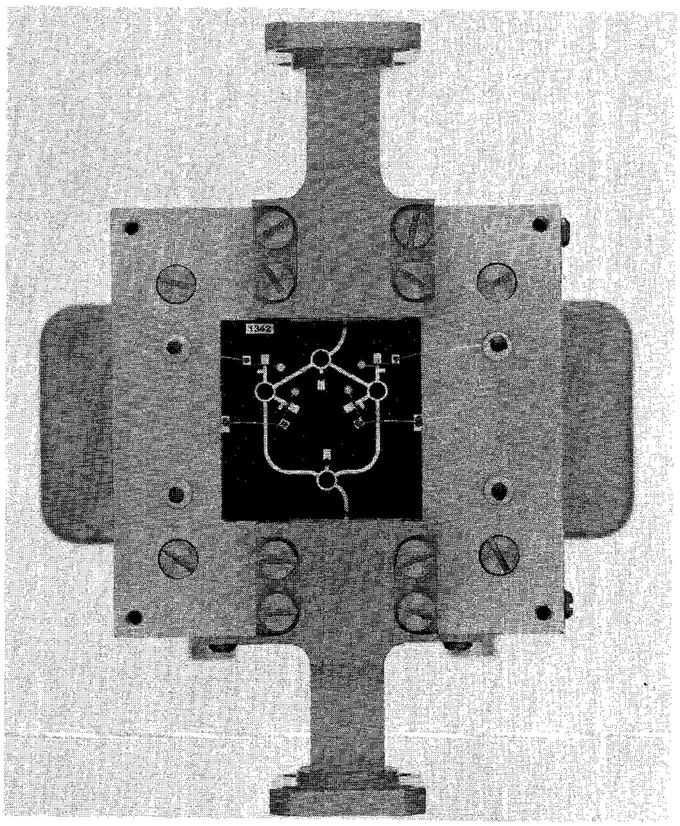
2. MIC receiver unit (top view).



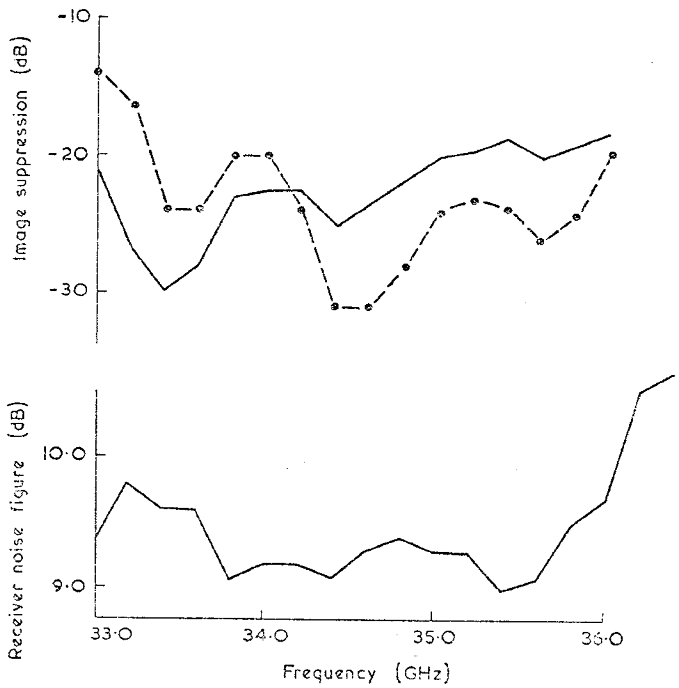
3. MIC receiver unit (bottom view).



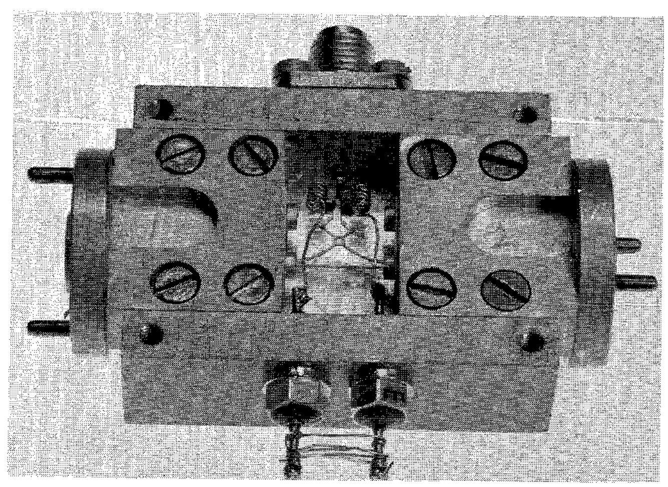
4. MIC receiver unit - overall noise figure as a function of frequency (signal channel).
(legend —— 10 mW l.o. power: - - - 15 mW l.o. power)



5. Image suppression mixer, r.f. circuit.



6. Performance of image suppression mixer.
(legend —— upper sideband accepted,
·---·---· lower sideband accepted)



7. 70 GHz balanced mixer.