LOW NOISE MICROWAVE INTEGRATED RECEIVER FOR 64 QAM DIGITAL RADIO

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ABSTRACT

64 QAM digital radio requires a very high linear operation not only in the transmitter section, but also in the receiver.
The paper presents a low noise microwave integrated receiver able to cover each CCIR radio frequencies band from 4 to 11 GHz with the linearity performances required for 64 QAM digital radio application.

1. INTRODUCTION

High capacity digital radios with multilevel modulation methods require a large dynamic operating range, therefore an automatic gain control network must be used in the microwave section of the receiver in order to guarantee the required linearity performance even during strong up fading phaenomena as often observed in many trial systems.
A low noise figure guarantees a high system gain value.
The wide instantaneous bandwidth reduces the maintenance expenses drastically decreasing the number of spare part units.
Microwave integrated circuit technology permits the reduction of the mechanical dimensions of the units.
Substantially we can say that linearity performance, low noise figure, wide instantaneous bandwidth and mechanical compactness are the main characteristics required for a modern microwave receivers line up.

2. MICROWAVE RECEIVER

Figure 1 shows the microwave receiver block diagram: it consists of a low noise amplifier with an automatic gain control (AGC) network and an image rejection mixer followed by an intermediate frequency preamplifier.

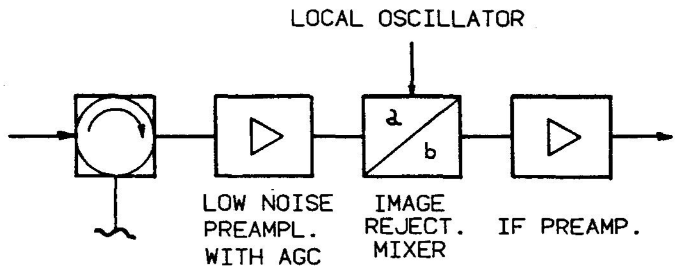

Fig. 1
Microwave receiver block diagram

2.1 Image Rejection Mixer

To avoid the band-pass filter between preamplifier and mixer, an image rejection mixer has been designed: its block diagram is shown in figure 2.

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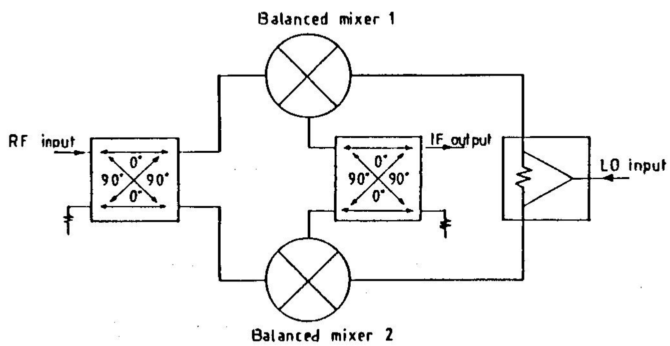
It consists of two balanced mixers and three hybrids: the first for the RF signal in quadrature, the second for the local oscillator in phase and the third for the IF signal in quadrature that combines the output of the two IF mixers.



In this way the IF output response to the RF signal is present only at one of the IF hybrid outputs while the IF output response to the image signal is present at the other IF hybrid output.
Low barrier Schottky diodes have been used for balanced mixers: a typical 10 dB noise figure has been achieved including a 2 dB 70 MHz IF preamplifier noise figure.

Fig. 2 - Image rejection mixer principle schema

2.2 Low Noise Preamplifier

With the purpose of achieving the required linearity performance together with the best noise figure of the complete receiver, a two stage low noise preamplifier with the automatic gain control has been designed.
0.3 micron gate length GaAs FET devices have been used obtaining a typical noise figure of the first stage of 1.1 dB at 6 GHz and 1.9 dB at 11 GHz.
AGC microwave network can be placed in between the two FET stages, or after them according to the block diagram of figure 3 in which, for the two different frequency range of 6 and 11 GHz, gain and noise figure are given.

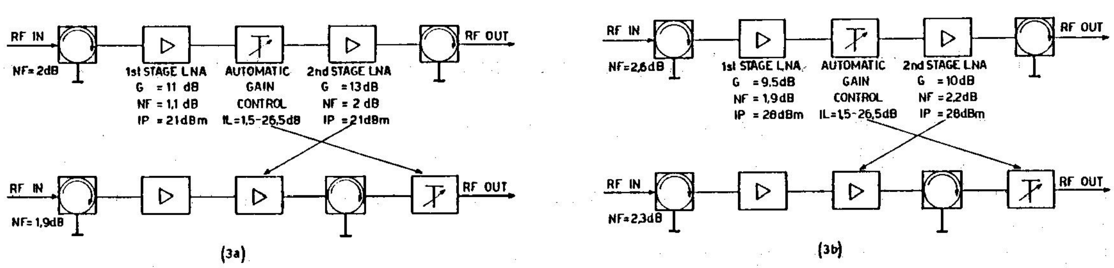


Fig. 3 - Preamplifier with AGC block diagram
3 a): 6 GHz arrangements 3 b): 11 GHz arrangements

Figure 4 shows a third order intermodulation level versus input power for the two different solutions in the 6 and 11 GHz frequency range.
It can be see that the best compromise between noise figure and third order intermodulation level is to choose, for the 6 GHz, AGC network in between the two FET stages and for the 11 GHz after them.

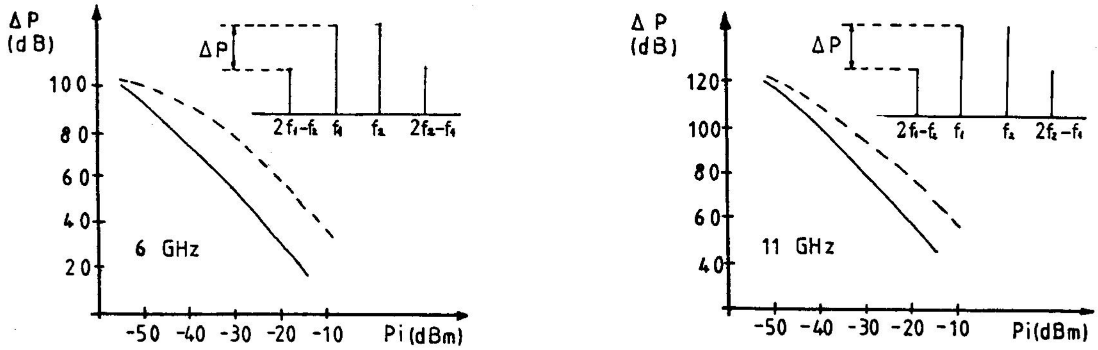


Fig. 4 - Third Order Intermodulation Level Versus Input Power in the 6 and 11 GHz Frequency Range
- **dotted lines: with AGC network between the two FET stages**
- **continuous lines: with AGC network after the two FET stages**

2.3 Automatic Gain Control Network

The automatic gain control network consists of a parallel type PIN diodes attenuator in a balanced or single configuration as shown in figure 5.

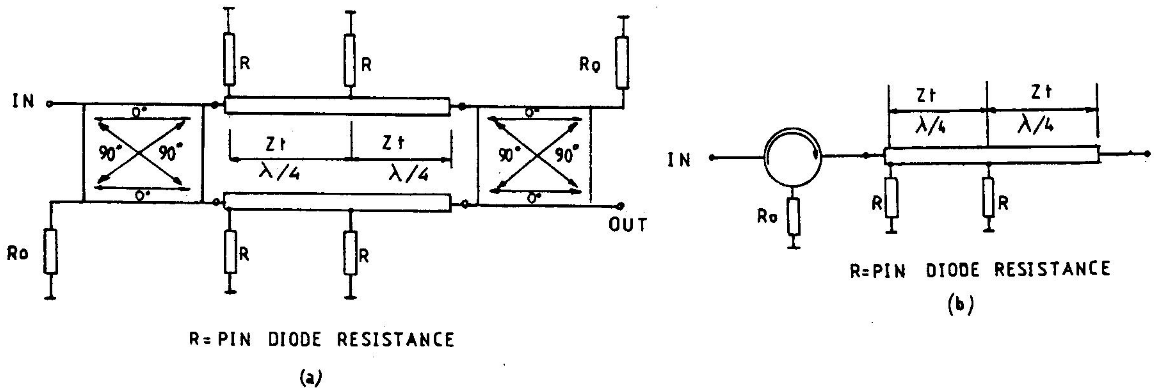


Fig. 5 - Balanced (a) and single (b) Configuration PIN diode attenuator

Parallel type configuration has been choosen because, increasing the attenuation, PIN diode current increases: that minimizes the intermodulation distortion introduced by the diode itself at a high input power level.
The circuit has been designed in order to obtain a high dynamic range attenuation with lower PIN diode current variation with respect to the commonly used PIN diode attenuators. This has been achieved by means of admittance step (*) in the transmission line when PIN diodes are located.
Figure 6 shows a parallel type circuit schema.

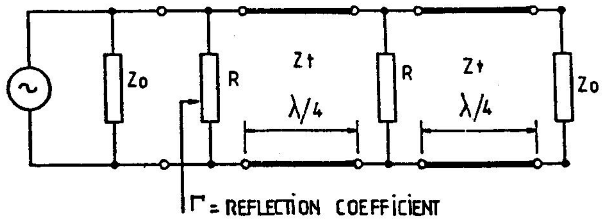


Fig. 6

Parallel type PIN Diode Attenuator Circuit Schema

(*) Italian patent application N.22923 A/85

It can be shown that the attenuation of this kind of circuit is given by:

$$A\ [dB] = 10 \log_{10} \left[\frac{\dfrac{1}{\dfrac{Zt^2}{R} + Zo}}{\dfrac{1}{\dfrac{Zt^2}{R} + Zo} + \dfrac{1}{R}} \cdot (1 - |\Gamma|^2) \; \frac{1}{1 + \dfrac{Zt^2}{R.Zo}} \right]$$

with:

$$\Gamma = \frac{\dfrac{1}{Zo} - \dfrac{1}{R} - \dfrac{1}{\dfrac{Zt^2}{R} + Zo}}{\dfrac{1}{Zo} + \dfrac{1}{R} + \dfrac{1}{\dfrac{Zt^2}{R} + Zo}}$$

where:

R = PIN diode resistance
Zt = Transmission line impedance
Zo = Input/Output characteristic impedance

Figure 7 shows the attenuation versus Zt with Zo = 50 Ω, parameter: PIN diode resistance.

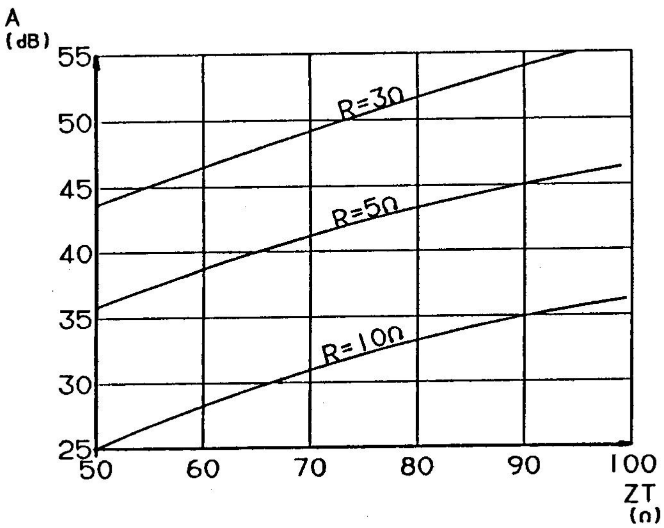


Fig. 7

Attenuation Versus Z_T for PIN Diode Resistance different values

3. MIC REALIZATION

All the microwave circuits are microstrip designed. High purity alumina substrates 25 mils thick have been used and the circuits are manufactured in thin film technology with Ti, Pd, Au metal conductor system which is resistant to environmental corrosion, solderable, thermobondable, accepts thermal cycling for stabilization of tantalum nitride resistors, and maintains good end-of-life conductivity.

Requirements for precise fine lines and small spaces (50 µm) are presently well met by selective plating the gold directly onto the Pd barrier layer using positive photoresist sprayed on as thickly as the final gold. Figures 8 and 9 shown respectively 6 GHz on 11 GHz receiver pictures.

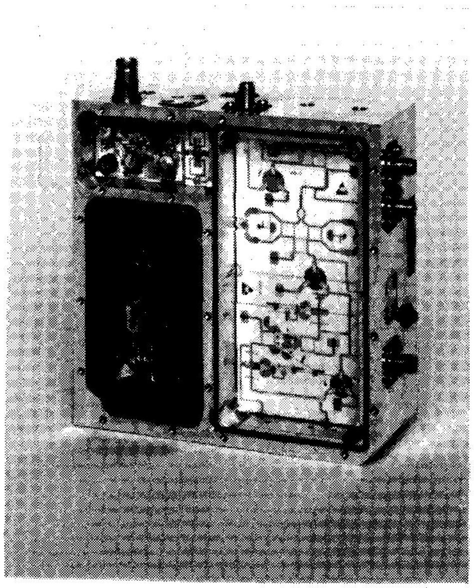


Fig. 8 - 6 GHz Receiver

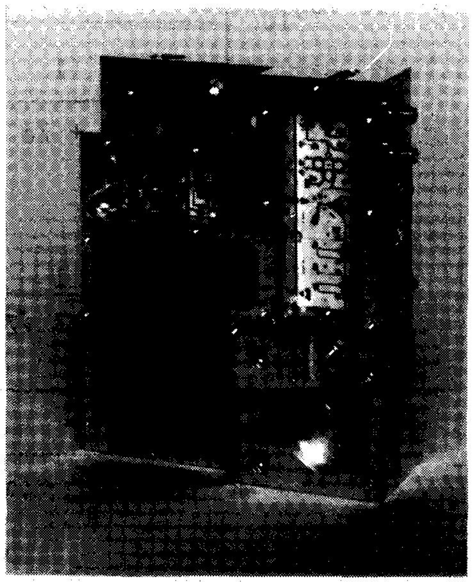


Fig. 9 - 11 GHz Receiver

4. OVERALL MICROWAVE RECEIVER EXPERIMENTAL RESULTS AND SYSTEM PERFORMANCES

Figure 10 shows a measured overall microwave receiver noise figure for different receivers, designed in different frequency ranges. Figure 11 shows third order intermodulation product levels measured at maximum input power level.

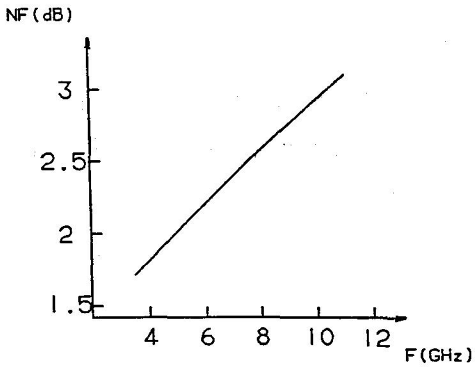


Fig. 10 - Typical overall microwave receiver noise figure versus frequency

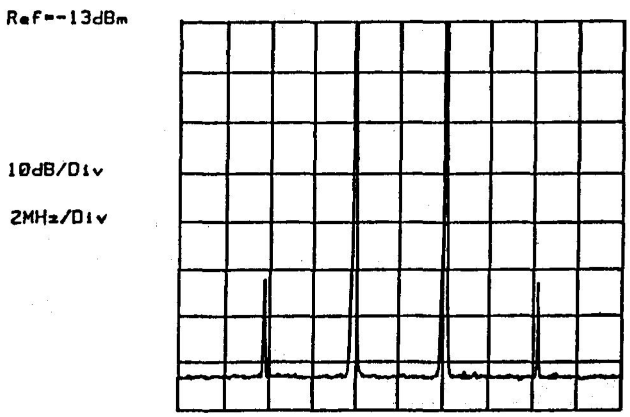


Fig. 11 - Typical third order intermodulation product at maximum input power level

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