A COMPACT, MONOLITHIC RADIOFREQUENCY DEMODULATOR - MODULATOR FOR 64-QAM DIGITAL RADIO LINKS

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ABSTRACT

The design, fabrication and performance of a GaAs monolithic radiofrequency demodulator with phase and amplitude trimming in the quadrature coupler and balanced mixers, in the 5.9-8.5 GHz range is described.

This circuit includes amplitude and phase trimming circuits, two single balanced mixers, couplers, and a quadrature phase comparator. The design is such that the same chip can be used either as a direct 64 QAM demodulator or a modulator. The small chip size is 2.7 mm x 3.65 mm.

INTRODUCTION

Telephone or data communications by means of digital modulations become the most used in radio links. Digital radio links of today require sophisticated amplitude and phase modulation techniques (QPSK, 16QAM, 64QAM, 256QAM...), to increase spectral efficiency or transmission capacity. The conventional heterodyne solution for M-QAM demodulation in digital radio equipments is being replaced by direct demodulation for system simplification and economical considerations (lower costs due to the suppression of the IF stages) [1]. One of the most complex component to achieve in a direct demodulation receiver is the demodulator. Some 6.4-7.1GHz 16QAM direct modulators and demodulators have been demonstrated in hybrid technology [1],[2],[3] or with several MMIC's [5]. Until now, only QPSK monolithic microwave modulators have been reported [6],[7].

A monolithic realization of a M-QAM demodulator takes full advantage of the very low parameter variations of active and passive components in a MMIC, especially for symmetrical designs. Besides, this technology allows wide band designs, thus providing size and cost reductions. This paper presents a monolithic realization of a demodulator, which includes elementary functions such as in-phase couplers, quadrature couplers, balanced mixers and circuits giving the possibility to adjust phases and amplitudes for a 64 QAM and higher level modulation.

CIRCUIT DESCRIPTION

The use of high level M-QAM modulation makes microwave links more sensitive to manufacturing spreads. In particular, quadrature phase error in the demodulator increases the BER (bit error ratio) of a radio link. The quadrature phase and amplitude must be electrically adjusted to meet the system requirements and to take into account the technological spreads.

The receiver requirements and the monolithic technology have led to the block diagram of the multi-level modulation demodulator-modulator (figure 1).

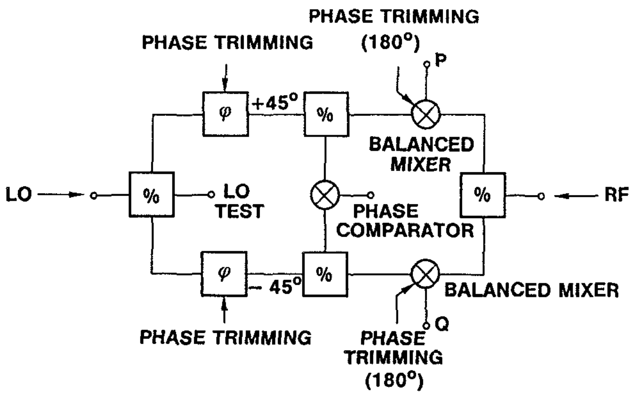

Figure 1: Block diagram of the demodulator

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In particular, it appeared convenient to add a phase comparator in order to control the quadrature phase adjustement. For the same reasons as those for the quadrature, the 0°-180° phase-shifts in the balanced mixers have to be adjustable.The circuit includes two couplers, a LO level test, a quadrature phase comparator, adjustable ±45° and ±90° phase-shift sections, and two single balanced mixers.

RF and LO signals are applied through 2 way- and 3 way- lumped element Wilkinson couplers respectively. The choice of a passive coupler for the RF port provides reciprocal operation so that the circuit can be used either as a modulator or a demodulator. The adjustable ±45° and ±90° phase-shifts are realized with high-pass and low-pass "pi" networks using the variable capacitance of MESFET's connected as varactors. The quadrature phase comparator is actually designed as a balanced mixer where the input signals applied are at the same frequency. This balanced mixer was implemented using a monolithic approach of the rat-race hybrid [4].

Schottky diodes were selected as the non linear element for the mixers and the quadrature phase comparator. First, they do not need DC bias circuitry, which implies zero DC power consumption for the whole demodulator. Second, the low number of active components leads to a good yield and small electrical spreads. Third, the diodes exhibit a lower noise figure than single-gate or dual-gate MESFETs below 10 MHz.

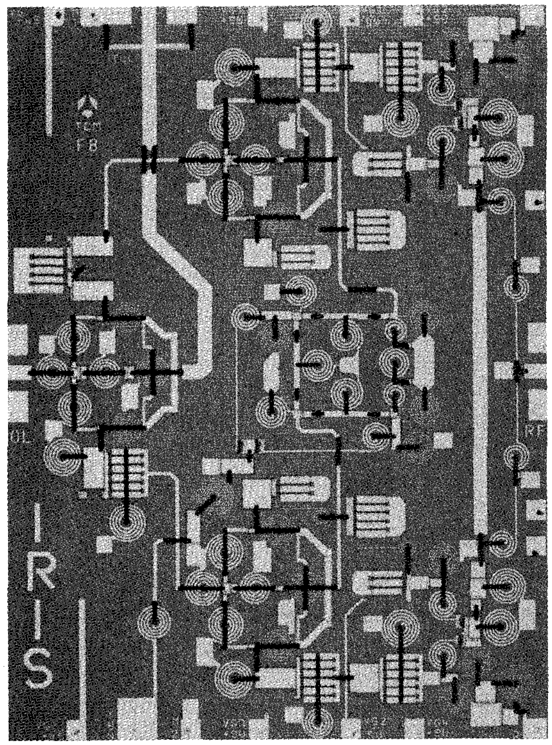

Figure 2: Photograph of the demodulator-modulator

CIRCUIT LAYOUT AND FABRICATION PROCESS

The layout was carried out with special care to preserve the symmetry of the sub-block functions and thus to achieve amplitude and phase balances. The circuit, of small dimensions 2.7 x 3.65 mm^2, is composed of 68 inductors, 68 capacitors, 46 via-holes, 121 air-bridges, 6 diodes of 64μm total gate width (figure 2). The total gate width for the MESFETs is 6.75 mm, but these MESFETs work with a zero drain voltage.

The circuits have been fabricated at THOMSON Composants Microondes Foundry with its standard LN05 process. The main LN05 process features are TiPtAu 0.5μm gate length MESFETs and diodes, implanted and metallic resistors, Si_3N_4 overlay capacitors, spiral inductors, air bridges and via-holes through 100μm thick wafer.

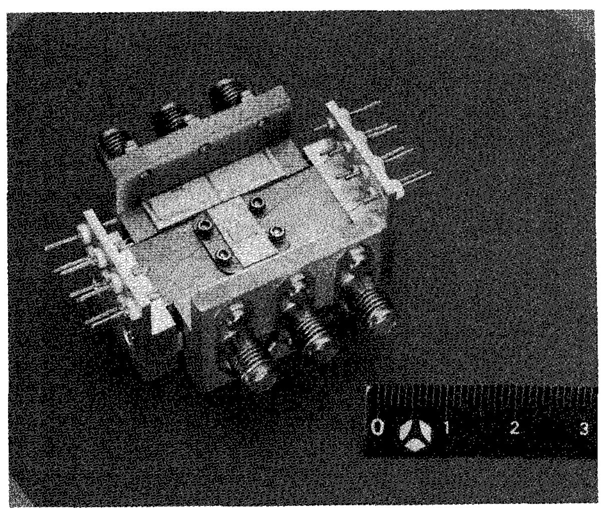

Figure 3: Photograph of the circuit in its test fixture

PERFORMANCES

This circuit has been measured in a digital radio link over the 6.4-7.1 GHz range as a 64 QAM and 16 QAM demodulator. A photograph of the demodulator mounted in its test fixture is presented figure 3.

The figure 4 shows a 64 QAM constellation obtained at 6.8 GHz, for a data transmission rate of 140 Mbit/s. The quadrature phase error measured is lower than 0.5°.

The quadrature phase error varies linearly with each trimming voltage, when the other trimming voltages are fixed (figure 5). These linear variations of the quadrature phase error allow simple control laws of the trimming voltages.

During these measurements, the linear response of DC voltage detected at the output of the phase comparator was recorded (figure 6).

The quadrature phase error variation is lower than ±1.5° all over the 6.4 GHz - 7.1 GHz range for a quadrature phase adjusted at 6.8 GHz.

Results of this circuit operating as a modulator will also be presented.

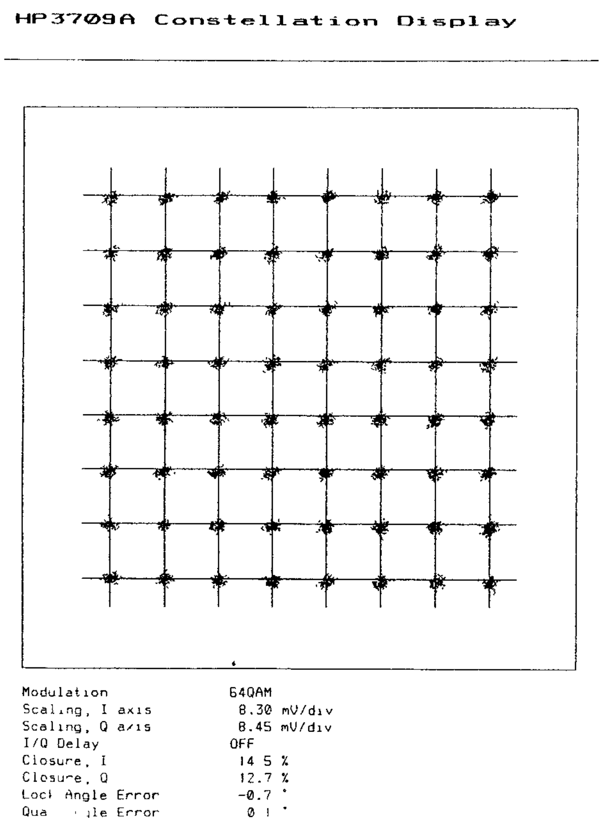

Figure 4: 64 QAM constellation at 6.8 GHz

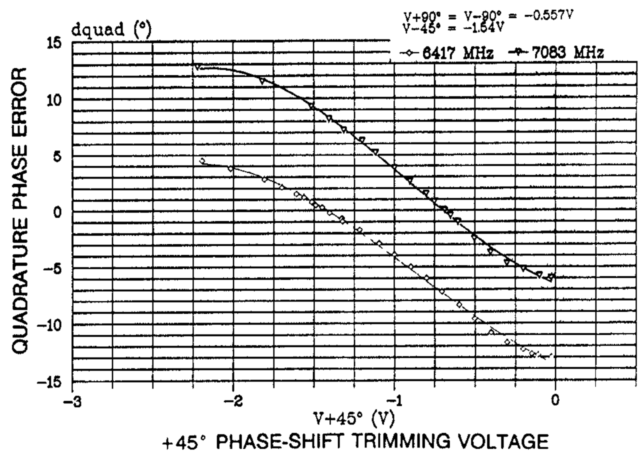

Figure 5: Variation of quadrature phase error with quadrature trimming voltage (+45° phase-shift section voltage here)

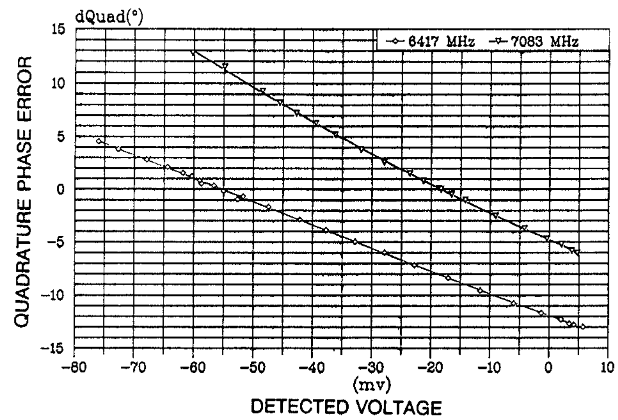

Figure 6: Variations of quadrature phase error vs detected voltage of the phase comparator, when the trimming voltage of the +45° phase-shift section varies from 0V to -2V

CONCLUSION

A single chip monolithic 64 QAM demodulator-modulator with phase and amplitude trimming, and with a quadrature phase test has been developed in the 5.9-8.5 GHz range. The high performances achieved allow its integration into future radio link equipments.

This design demonstrates the ability offered by the MMIC technology to achieve high performance circuits with a high level of integration and low DC power supply.

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