New Results on MMIC Six-Port's used in Ka Band Direct Conversion Receivers

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Abstract — **New results obtained on two Ka Band Monolithic Microwave Integrated Circuit (MMIC) six-port junction circuits realized in GaAs PHEMT technology at TriQuint Texas Foundry are presented in this paper. Comparative results of simulated and measured S parameters are shown for both designs. The proposed MMIC six-port circuit is used to realize the QPSK demodulator of a Ka band direct conversion receiver.**

I. INTRODUCTION

In the past 30 years six-port junctions have been utilized in the microwave field for low cost measurements of complex impedance or phase. New six-port junctions have been developed at Poly-Grames Research Center and used to realize Direct Conversion Receivers. This new six-port hardware receiver is proposed as a robust, low cost receiver for use in wide Ka-band wireless mass market QPSK communications.

A six-port circuit is described having four arms whose output signals are a function of two RF input signals. Complex impedance or phase measurements can be obtained by simple power or voltage magnitude measurements at the four side arms [1].

The six-port circuit has been utilized in principal as low-cost alternative to the Network Analyzer. A number of six-ports has been designed to perform measurements of reflection coefficients [2]-[4].

The six-port can be also designed to perform accurate phase difference measurements between two RF signals. If one signal is the reference signal and the second one is a QPSK modulated signal, a QPSK demodulator can be realized. Excellent demodulation results have been obtained in six-port direct conversion receivers [5]-[9].

The excellent results obtained with a Monolithic Hybrid Microwave Integrated Circuit (MHMIC) distributed parameter six-port junction [8] had a determinant role to provide a MMIC implementation of this direct digital receiver architecture. Two different six-port circuits have been fabricated on 100 μm substrate at TriQuint Texas Foundry using 0.25 μm GaAs PHEMT Technology. Results of simulated and measured S parameter are presented in this paper for both designs of the MMIC circuits.

II. SIX PORT OPERATING PRINCIPLE

Fig.1 shows the topology of a six-port module composed of a six-port junction and four power detectors. This junction is specially designed to perform phase measurements. The phase difference between the two RF input signals can be obtained using power measurements at the four six-port outputs.

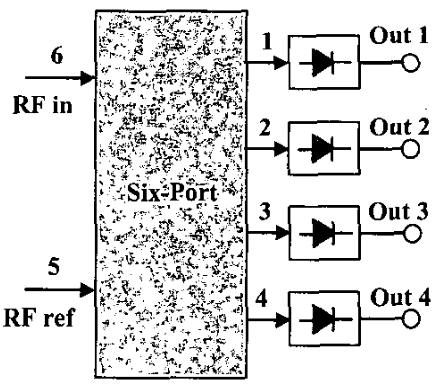

Fig.1. The block diagram of the six-port module

If the two input signals have the same amplitude a, the power of the output signals can be written as :

$$P_i = K|a|^2 \left| \exp\left[j\left(\frac{\pi}{4} + \varphi_{IN} - \varphi_{REF} \right) \right] - q_i \right|^2 \quad (1)$$

where K is a constant and q_i are the "q" points of the six-port junction presented in Fig. 2.

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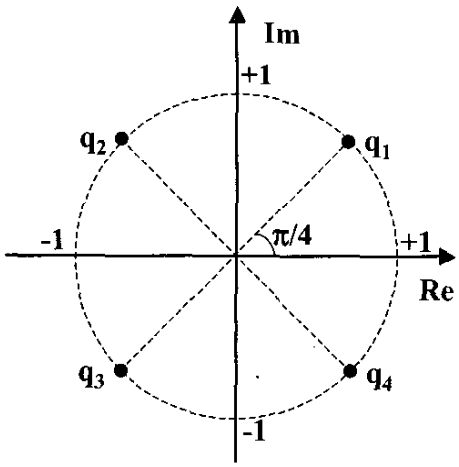

Fig.2. The q_i points of the proposed six-port junction

III. THE SIX PORT DESIGN

The six-port circuit is composed of three 90° hybrid couplers and a Wilkinson power divider. Four RF power detectors are connected to the outputs.

Fig. 3 shows the layout of a distributed parameter power detector used in the six-port design. The power detector is realized using an integrated Schottky diode (H2 on the circuit layout). In order to obtain a good return loss at the central frequency a matching network connected to the diode input and a quarter wave length stub connected to the output were used.

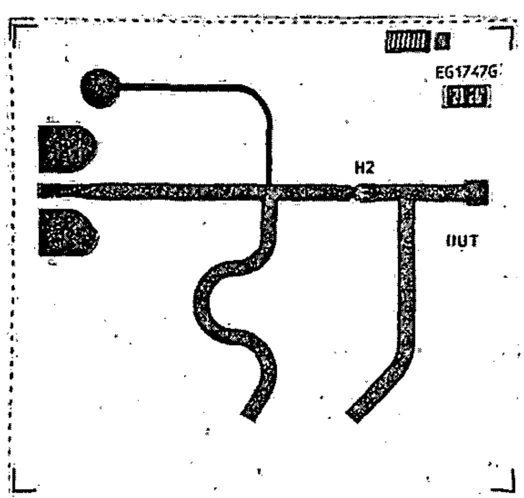

Fig.3. Photograph of the distributed elements power detector

The lay-out of the first six-port design is presented in Fig. 4. The six-port junction is placed in the middle of the circuit layout. Four RF power detectors are connected to the six-port outputs. Transitions to coplanar were used for the RF inputs to facilitate RF measurements.

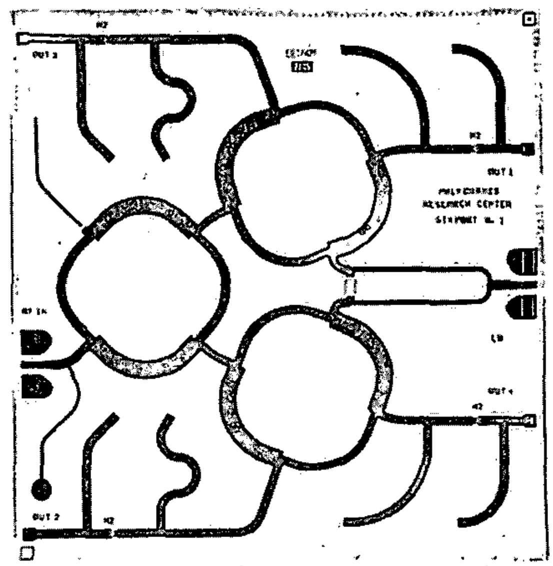

Fig.4. Photograph of the first design of the MMIC six-port module (size 4x4 mm)

In order to reduce the size of the coupler, high impedance transmission lines and shunt capacitors (about *200 fF) connected to its ports were used. Fig. 5 shows the* photograph of the new 90° hybrid coupler.

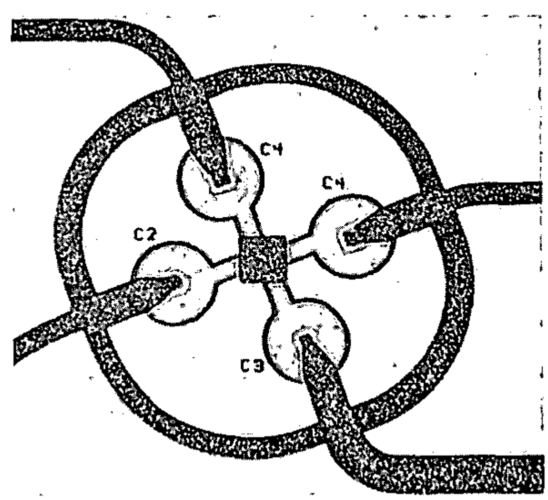

Fig.5. Photograph of the new 90° hybrid coupler

The diameter of the 90° hybrid coupler is 600 μm compared to 1300 μm in the distributed parameter MMIC design.

The lay-out of this second six-port design, reduced in size, is presented in Fig. 6. The matching networks are realized using transmission lines and shunt capacitors .

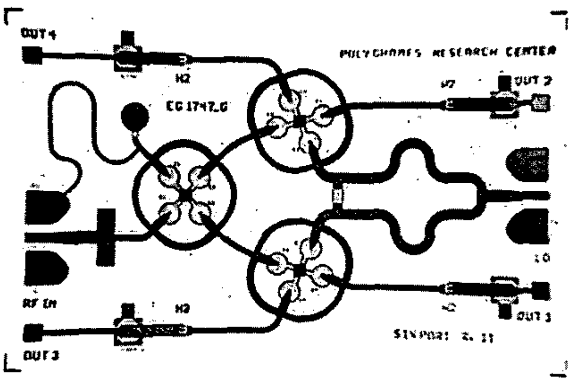

Fig.6. Photograph of the second design of the MMIC six-port module (size 2x3 mm)

IV. Test Results

S parameters measurements of the RF power detectors (Fig. 3) used in the distributed parameter six-port design were performed. The measurement results indicate a 1.75 GHz shift between simulated (27 GHz) and measured (28.75 GHz) central frequencies, as shown in Fig. 7. Therefore the central frequency of the first design of the MMIC six-port module was also shifted.

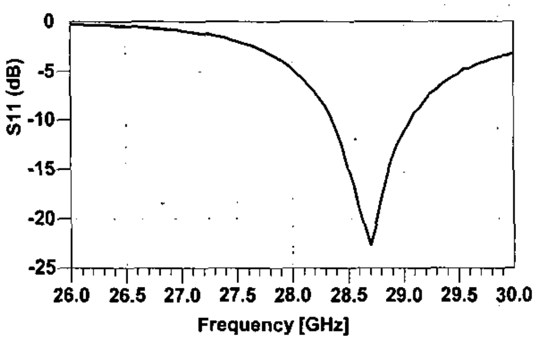

Fig.7. Measured return loss for the distributed elements RF power detector

Fig. 8 shows the simulated results of return loss at both LO (S55) and RF (S66) input ports and their isolation (S56), for the distributed parameters six-port circuit. The central frequency is 27 GHz and excellent simulation results were obtained.

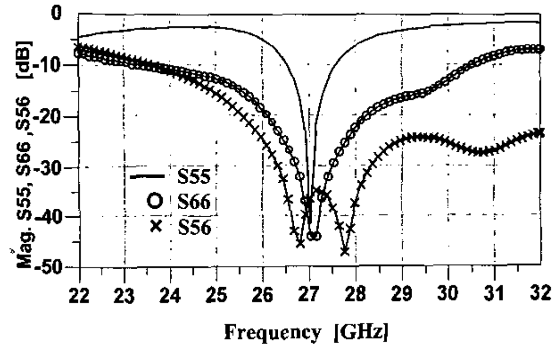

Fig.8. Simulated return loss and isolation at input RF ports for the distributed parameter design of the MMIC six-port module.

Fig. 9 shows the measured return loss at RF input port (S66) and the isolation between input ports (S56). The measured central frequency is about 28 GHz. At 29 GHz (marker1) –25 dB was obtained for S56 and –20 dB for S66 (5 dB/division in the photo). Practically the same curve shapes were obtained for both simulated and the measured results.

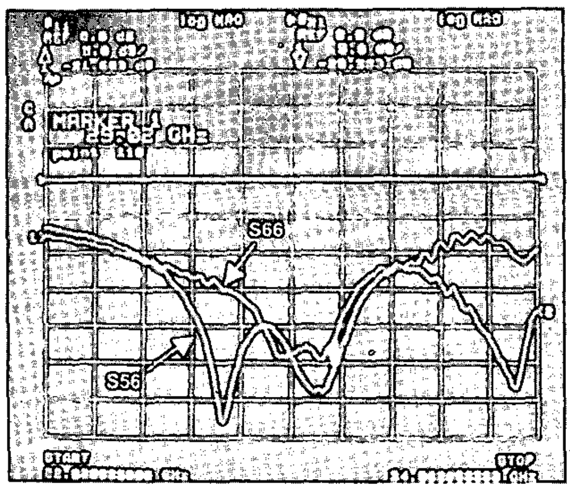

Fig.9. Measured return loss and isolation at input RF ports for the distributed parameter design of the MMIC six-port module.

Fig. 10 shows the simulated results for return loss at both LO (S55) and RF (S66) input ports and their isolation (S56), for the second design of the six-port circuit. The simulated central frequency is also 27 GHz and excellent results were obtained.

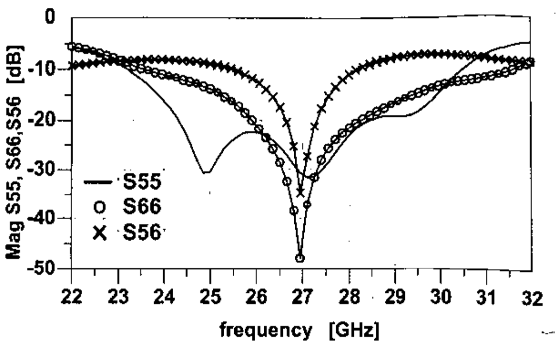

Fig.10. Simulated return loss and isolation at input RF ports for the reduced size design of the MMIC six-port module.

Fig. 11 shows the measured return loss at RF input port (S66) and isolation between the two input ports (S56). The measured central frequency is 27.5 GHz . At 27.75 GHz (marker1) –20 dB were obtained for both curves (5dB /division in the photo).

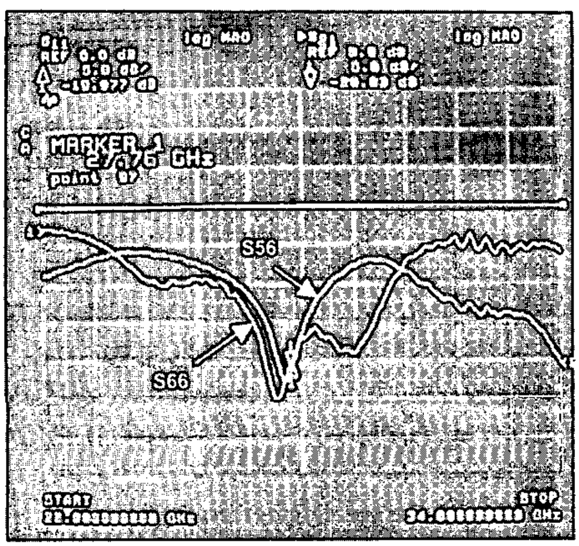

Fig.11. Measured return loss and isolation at input RF ports for the reduced size design of the MMIC six-port module.

V. Conclusions

New results on MMIC six-ports used in Ka Band Direct Conversion Receivers were presented. The six-port circuits were integrated in 0.25 μm GaAs PHEMT Technology at TriQuint Semiconductor Foundry.

The distributed parameter MMIC six-port circuit (4x4 mm) has very good S parameter results. The reduced size six-port circuit is smaller (40% of the distributed parameter six-port circuit size), but also presents good S parameter results, in the operating frequency band.

Acknowledgements

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