MILLIMETER-WAVE MONOLITHIC BALANCED BPSK MODULATOR USING A MINIATURISED BACKWARD-WAVE COUPLER

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Abstract

A miniature parallel-coupled microstrip coupler has been realised at millimeter-wave frequency using capacitor compensation at the ends. The coupler has been used in a very compact BPSK modulator as an example of application. The balanced modulator employs reflection-type topology and measures 0.7 x 0.9 mm excluding RF-on-wafer probe pads.

I. Introduction

VSAT transmitters have adopted direct carrier modulation to cut down cost in their microwave transmitters where the cost is actually concentrated [1,2]. If a conventional microwave mixer is used to perform frequency translation from a low IF to the carrier frequency it would be impossible to remove the unwanted sidebands. To upconvert the modulated signal to the transmission frequency a transmitter requires series of an IF modulator, mixers, filters and amplifiers. So for mm-wave applications, where size and cost remains a major factor restricting the widespread use of wireless systems, direct carrier modulation is a potentially important solution.

A known technique in direct carrier modulation is to employ a balanced reflection topology using four Lange couplers with FETs as switches on the coupled and direct ports [3,4,5]. At high frequencies the intrinsic parasitics of the FET switch becomes the dominating factor. These are series inductance and resistance in the ON-state, and the shunt capacitance in the OFF-state. So the BPSK constellation is far from ideal and it is very difficult to tune out these parasitic in a wideband design without using a balancing technique. In such a modulator the dimensions of the chip mainly depend on the size and the shape of the coupler. At high frequencies Lange couplers are difficult to meander due to the complex behaviour of the four fingers around the corners. In this paper a very compact parallel-coupled microstrip coupler employing two polymide capacitors at the ends has been realised and successfully measured to be used in a miniature BPSK modulator.

II. Coupler design and measurement

The quadrature directional coupler consists of two parallel-coupled microstrip transmission lines which are separated by 5 µm. Simulations on *em* (Sonnet Software) were performed on 95-µm-long subsections and included all the various dielectric layers. The simulated sections were then cascaded on Touchstone™ to obtain the overall response. Microstrip directional

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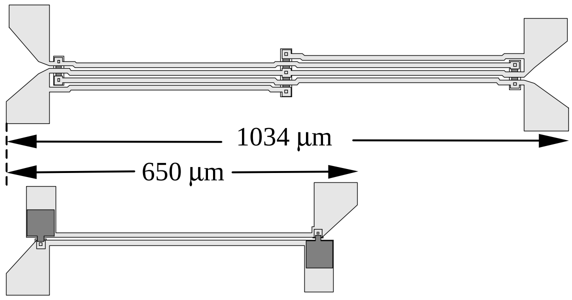
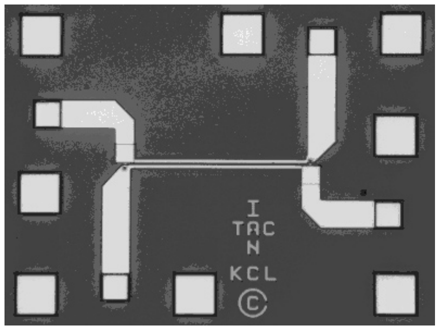
couplers suffer from poor directivity because of inhomogeneous dielectric. Hence the odd and even modes excited in the coupled region have different phase velocities and wavelengths. To compensate this inequality polymide capacitors at the ends of the coupled region have been included [6,7] and then the overall circuit on Touchstone has been optimised. The top metal layer M3 and the bottom layer M2 are used to form the plates of the capacitor and the plates are separated with 1.4 µm thick polymide. Fig. 1 shows the comparison between the layouts of standard Lange coupler and the new miniature coupler at the centre frequency of 30 GHz. It measures 0.85 x 1.1 mm including the 50 Ω feed lines and RF-on-wafer probe pads. The coupler itself has a coupled length of 470 µm is much smaller than the overall layout and it has the potential for meandering to obtain even more compact layout. The coupled two transmission lines are 10 µm wide and the measured performance is shown in Fig. 2. The miniature coupler is well matched with good amplitude and phase response.



a)



b)

Fig. 1 a) Comparison between the layouts of Lange coupler and miniaturised coupler, b) Photograph of the coupler

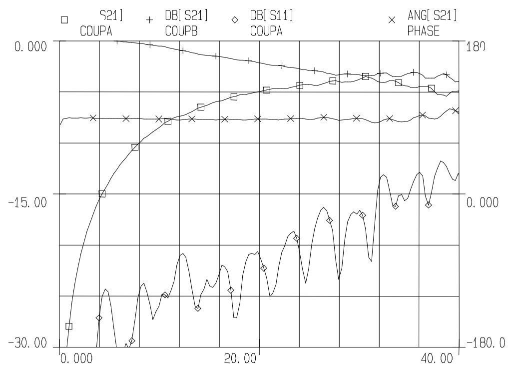


Fig. 2 Measured performance of the miniature coupler

III. The balanced modulator and design

Single ended modulators are limited in performance at high frequency due to the parasitics of the switching elements. The use of balanced modulator can reduce these effects and a typical configuration employs two single ended modulators in push-pull fashion which are combined by a pair of couplers. The input signal is effectively split in a balun, the modulating baseband signal is split into a pair of complimentary signals and the outputs from each branch are combined in-phase. The combined output is the vector sum of the two transmission coefficients. Since one branch is ON and the other OFF, or vice versa, the response is now totally symmetrical if the balun is ideal. Since baluns are difficult to implement on MMICs two miniature parallel-coupled couplers are used to obtain the 180 degree operation. One coupler is placed at the input and one at the output similar to the balanced amplifiers, as shown in Fig. 3. Each arm is fed with complimentary baseband signals and the output is directly opposite the input.

GEC-Marconi's H40 pHEMT process was employed for the design. This offers 0.25 µm AlGaAs/InGaAs HEMTs fabricated on 3 inch diameter wafers of 100 µm thickness. The Cold-FETs are 2 x 60 µm and all the other circuit elements such as thin film resistors, capacitors, microstrip lines were modelled using either the library elements or *em.* The miniature couplers are further meandered to save space and gain even more compact layout.

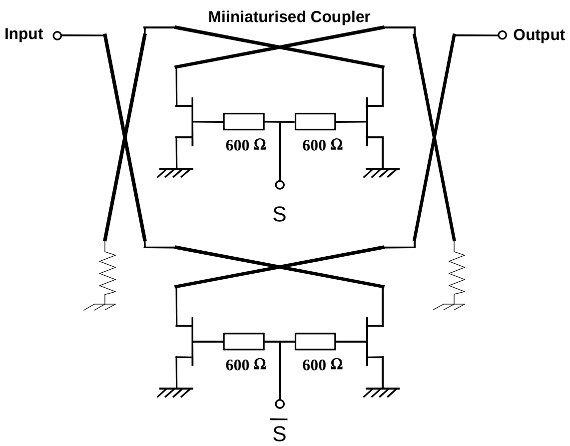


Fig.3 Balanced BPSK modulator circuit

IV. Modulator results

The photograph of the BPSK modulator measuring 1.1 x 0.9 mm is shown in Fig. 4. The circuit's frequency response and the static constellation were measured using a Cascade prober and HP8510B network analyser. For the practical demonstration a PC with DAC card was used to create pseudorandom sequence and then generate the analogue control voltages. As an example measurement Fig. 4 and Fig. 5 shows the amplitude, phase and output spectrum of 30 GHz BPSK signal measured on an HP8562 spectrum generator respectively. The measured results can be fine tuned by controlling the DC bias level under computer control to obtain better response.

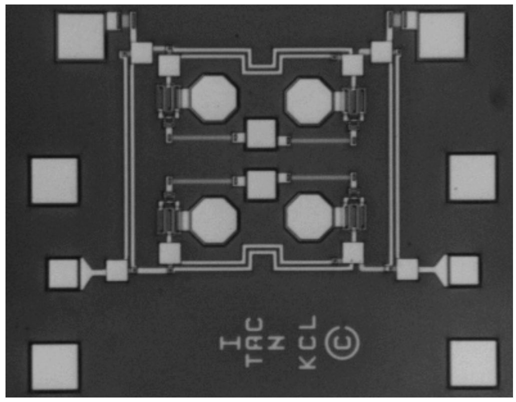


Fig. 4 Photograph of the BPSK modulator

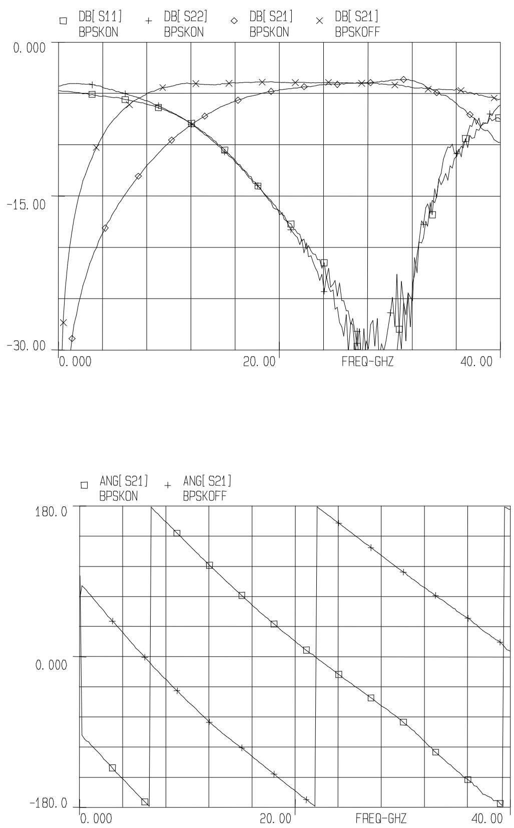


Fig. 5 Measured performance of the modulator

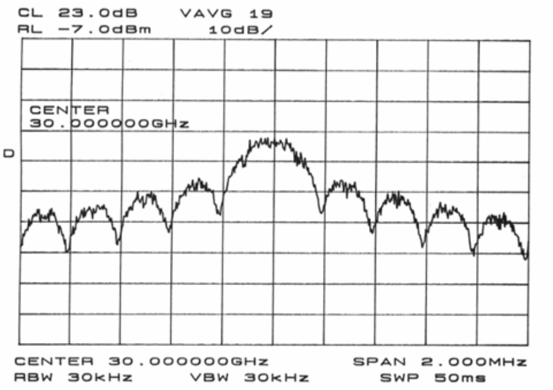


Fig. 6 Measured output spectrum of 30 GHz BPSK signal

The Cold-FETs in the modulator are operated at zero drain bias and the complimentary signals on the gates are used to change the state of the switch. Hence the power consumption is very low.

V. Conclusion

A miniaturised quadrature parallel-coupled microstrip coupler has been successfully realised and tested. Capacitor compensation technique is adopted for the inhomogeneous dielectric (part dielectric substrate, partly air) to account for the different phase velocities and wavelength in the coupled region. A further use of such coupler has been demonstrated in a very compact direct carrier BPSK modulator.

Acknowledgements

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