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A FET L-BAND PHASE/AMPLITUDE CONTROL MODULE

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ABSTRACT

The design and performance of a lumped element analog phase/amplitude control module at L-band is presented. This miniature phaser uses the principle of vector manipulation and employs FETs in a low power consuming passive configuration with good temperature stability.

INTRODUCTION

Electronically controllable analog phase shifters that operate by combining vectorially the amplitudes of two or more signals with different fixed phases and variable amplitudes have been described in the literature (1)(2)(3). The vector voltages are derived from power splitters,the different phases from the inherent phase difference of these splitters and/or by added phase delays. The individual vector amplitudes are varied by voltage or current controlled active or passive elements with gain or attenuation. The construction of these phasers is in distributed circuit form and occupies a relatively large circuit area. Some air- or space- borne radars that use analog phase/amplitude control modules, however, have size and weight requirements that call for a miniaturization of this vital component in conjunction with low power consumption.

This paper describes the construction and performance of a miniaturized phase/amplitude control module that operates on the principle in which three by 120deg. staggered signals of variable amplitude are vectorially combined. The key elements in the successful fabrication of the phaser are, the development of a lumped element three-way Wilkinson divider, the use of lumped element delays, and the low power consumption of passive FET variable reflective attenuators. The phaser operates in the 1050MHz to 1150MHz frequency range, is variable over 360deg. at a constant amplitude that is adjustable over a 11dB range, and occupies a circuit area of .5x.4 squ.inches.

CIRCUIT DESCRIPTION

Fig. 1 shows a block diagram of the phase/amplitude control module. It is an assembly of three basic components, a three-way in-phase power divider, necessary phase delays, and a variable amplitude element. The choice of a bilateral attenuating element and the component arrangement as shown make the entire module bilateral and symmetric. For the three vector case the individual fixed unit vectors are nominally adjusted via the phase delays to be separated by 120deg. The desired variable vector A with phase θ is contollable by the variations of two of the three vectors at a time while the third vector remains constant. The accuracy and reproducibility of selected amplitude and phase depends upon several frequency dependent amplitude and phase errors introduced by the phase shifter components. Most of these deviations are predictable and the possibility exists to include error correction in the voltage control of the attenuating elements.

THE SHUNT ATTENUATOR

The element chosen to control the amplitudes A1, A2, and A3 of the vectors is a reflective shunt attenuator that uses the gate controlled variable and temperature stable resistance of a FET in an essentially passive mode of operation (4). The evaluation a FET with a gate width of 600 μm indicated a useful resistance range from 6-Ohms to 3000-Ohms with gate voltages extending from 0-volt to near pinch-off at 6-volt. This range is sufficient to attain the full required 120deg. shift for any possible vector pair. Assuming an ideal divider/combiner performance the expected minimum loss of the phaser is about 13dB. In an actual circuit, howevever, this minimum and the dynamic range of A are being limited by circuit losses, mismatches and the finite isolation of the dividers.

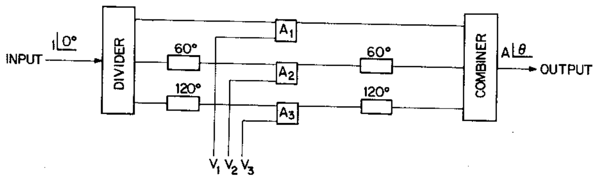

Fig.1 Block Diagram of Phase/Amplitude Control Module.

LUMPED ELEMENT THREE-WAY WILKINSON DIVIDER

The lumped element realization at L-band of a three-way Wilkinson divider is the major contributor to miniaturization. The use of spiral coils on 25mil thick alumina in a suspended substrate configuration allowed the attainment of inductance values up to 12nH, and the placement of the necessary isolation resistors in a planar arrangement on the underside of the substrate. The divider circuit is fabricated on a 0.236 x 0.40 squ. inch sub- strate which is mounted on a flange which facilitates testing of the device. Evaluation of such lumped element divider indicated a slight shift from the design frequency of 1300MHz to 1100MHz. This shift is caused by differences between calculated and realized inductance values of the spirals. The divider board also contains the two phase delays of 60deg. and 120deg. at two of the output ports,respectively. The average power split in the 1000MHz to 1200MHz freuency was 6.3dB which is 1.5dB above ideal. These excess losses are a cause of the non-optimized construction of the lumped element circuit. Isolation was in excess of 20dB and the port VSWRs were less than 1.7:1.

LUMPED ELEMENT THREE-VECTOR PHASE/AMPLITUDE MODULE

Two divider boards were fabricated and tested with the best common performance occurring in the 1050MHz to 1150MMHz frequency range. The two dividers together with the three FETs were assembled within a 1.5 x 1.5 x .6 cu.in. brass enclosure as shown in Fig.2. The circuit of the phaser alone within this enclosure occupied only an area of .5 x .4 sq.inches. The phaser could be varied over the full 360deg. range in the 1050MHz to 1150MHz frequency band. The dynamic range of adjustibility was 11dB with the minimum loss at 18dB. While the phase was varied continuously over 360deg. with a constant loss of 18dB the VSWR at any of the phase settings and at any frequency in the band was less than 1.5:1. The plot in Fig.3 shows the measured relationship between relative phase and the required gate voltages for the three FETs at 1150MHz. Fig.4 shows the transmission loss and the VSWR as a function of phase.

CONCLUSION

The successful development of an analog 360deg. phase/amplitude control in lumped form at L-band in an area of .5x.4 squ.inches indicates the feasibility of miniaturized components for present and future air- or space-borne radar applications. The use of a FET in a passive mode of operation has shown good temperature stability in a previously tested distributed two vector phaser.

ACKNOWLEDGEMENT

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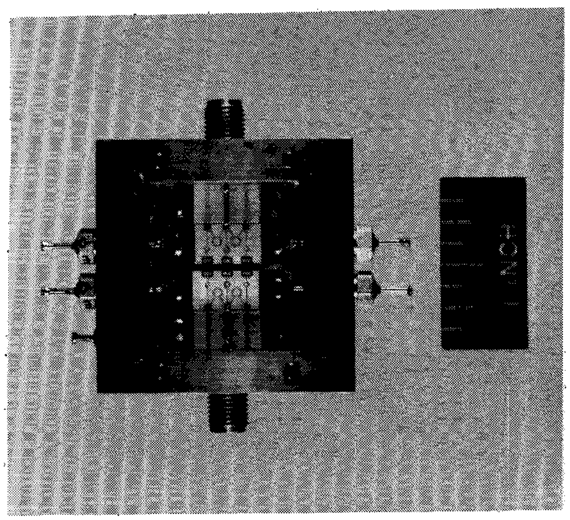

Fig.2 Photograph of Phase/Amplitude Control Module.

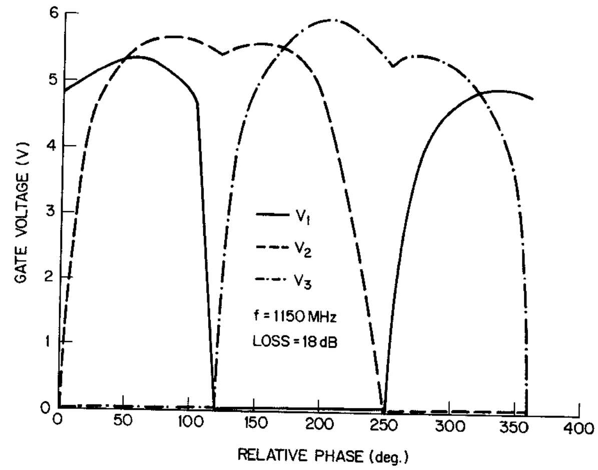

Fig.3 Three Gate Voltages as Function of Relative Output-Phase of Phase/Amplitude Control Module.

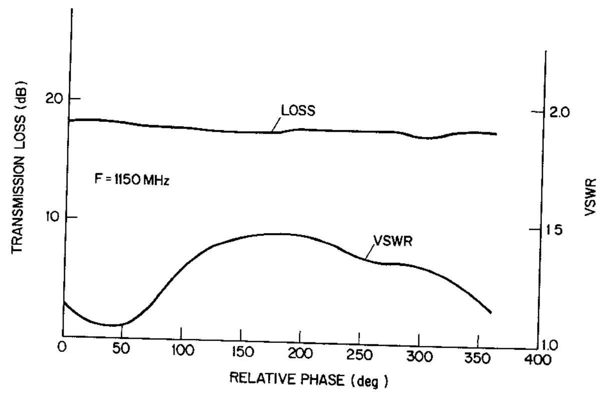

Fig.4 Output-Amplitude and VSWR as Function of Relative Output-Phase of Phase/Amplitude Control Module.