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# A NOVEL DESIGN FOR A MMIC 180 DEGREE PHASE SHIFTER

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## ABSTRACT

A novel circuit topology is discussed for the design of a 180 degree phase shifter. The approach expliots the dual nature of the tee and pi configurations of the lowpass and highpass filter topologies. The resulting configuration requires fewer elements than conventional switched filter approaches and does not require complementary control voltages.

## A NOVEL DESIGN

### Introduction

There are several techniques for the design of a fixed 180 degree microwave phase shifter such as switching between arms in a microstrip rat race coupler, switched delay lines, phase dispersive Schiffman sections, etc. In a MMIC, most of these structures are far too large to be practically employed except at millimeter-wave frequencies. One conventional approach for the 180 degree phase shifter is to switch between phase lead and phase lag networks employing primarily lumped components. This paper describes a new topology requiring fewer elements and a single control voltage.

### Conventional Approach

Canonic highpass and lowpass filter structures provide 90 degrees of phase lead and lag respectively and are often used for phase shift applications. Figure 1 shows the schematic of a conventional highpass/lowpass 180 degree phase shifter. Either a tee or pi configuration can be selected for either structure. Typically, a highpass tee and a lowpass pi are selected to minimize the area by employing the least number of space consuming inductors.

The conventional approach requires complementary signals from the driving circuit so that one set of switching elements can be placed in a low impedance state and the other set in an high impedance state simultaneously.

### New Topology

A new approach is shown in Figure 2 which exploits the dual nature of the canonic highpass and lowpass structures by changing the topology of the network using switching elements. When the switching elements are in the low impedance state, the circuit becomes a highpass pi network. In the high impedance state, the network forms a lowpass tee network. This topology requires only a single control signal halving the complexity of the switch driver. Additionally, the number of phase shifting components is reduced to only two inductors and two capacitors.

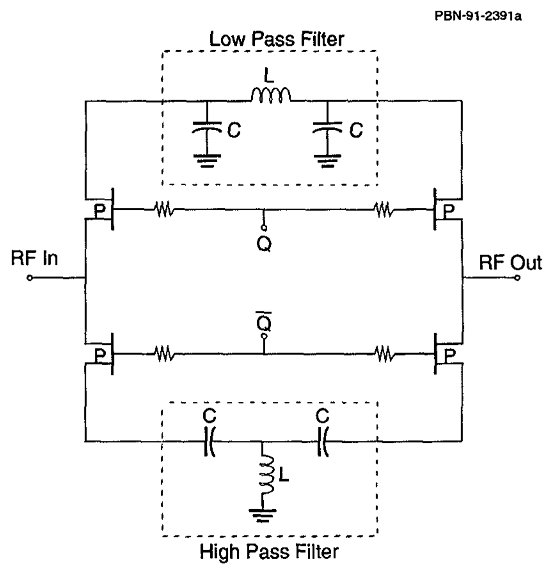


Figure 1. Schematic of Conventional Topology Phase Shifter.

Figure 3 shows a comparison of the relative size of the new topology phase shifter versus the more conventional approach. There are two additional FETs in each design for use as an attenuator. Note that the conventional approach has a set of redundant pads for ease of interconnection. Even considering the area used by these extra pads, the size reduction of the new topology is significant. This is primarily due to the elimination of two capacitors, one bonding pad and its associated bias resistors.

Figure 4 compares the phase balance of the conventional and switched approaches. The 10 degree phase bandwidth of both designs is approximately 550 MHz. Figure 5 compares the amplitude balance indicating that the new topology bandwidth is somewhat narrower than the conventional approach.

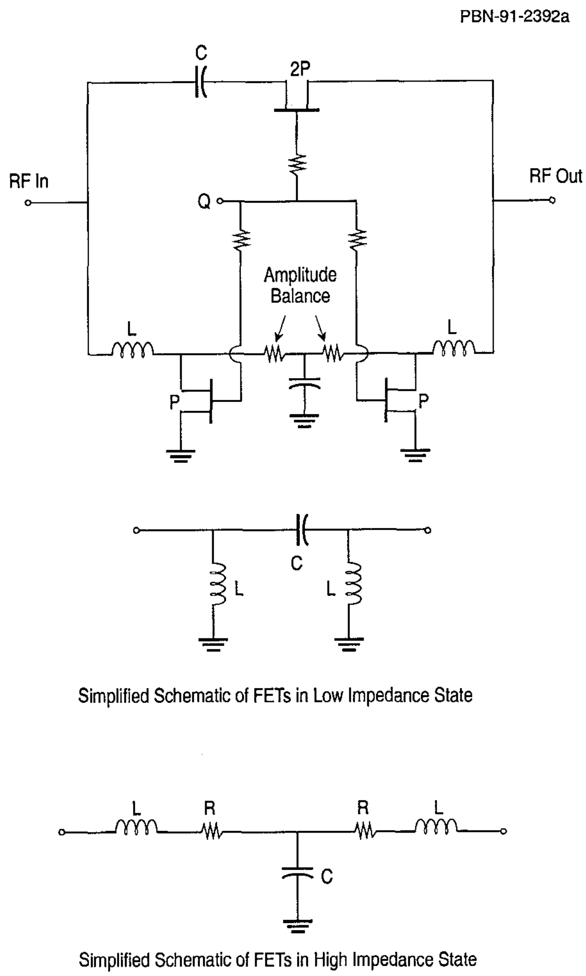


Figure 2. Schematic of New Topology Phase Shifter.

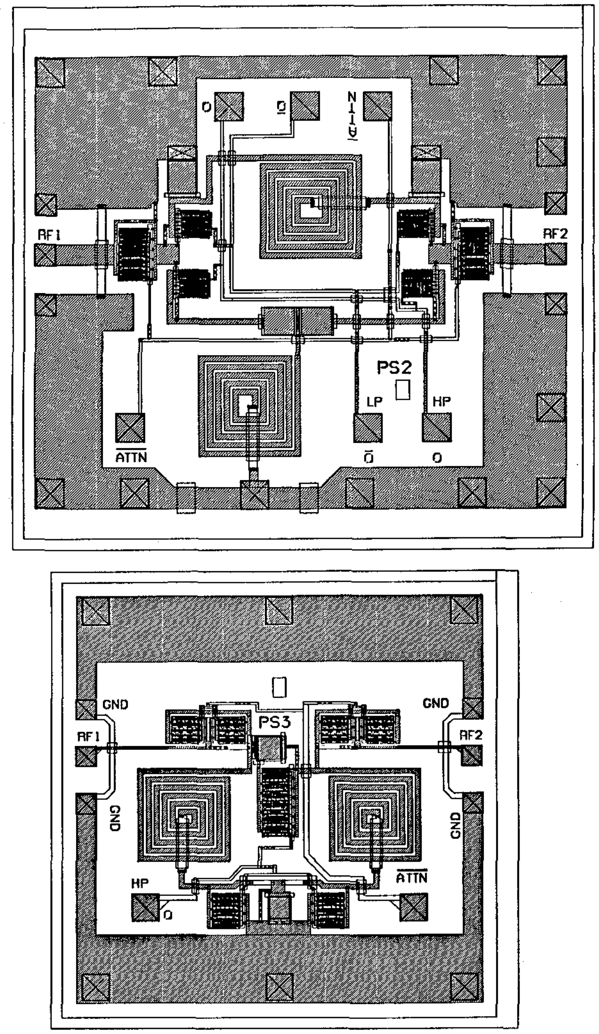


Figure 3. Comparison of New and Conventional Phase Shifter Size.

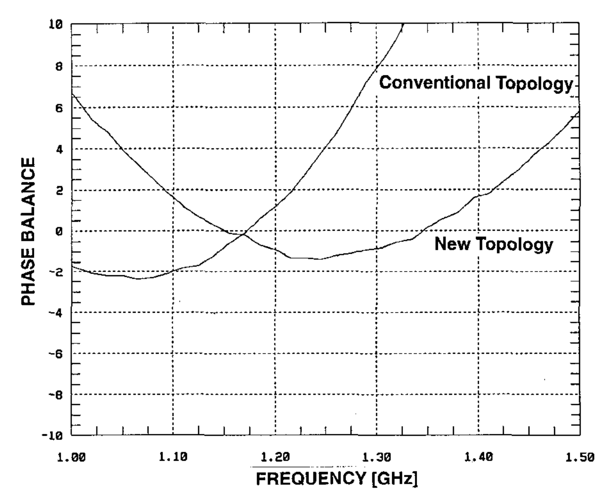


Figure 4. Measured Data Comparison of Phase Shifter - Phase Balance.

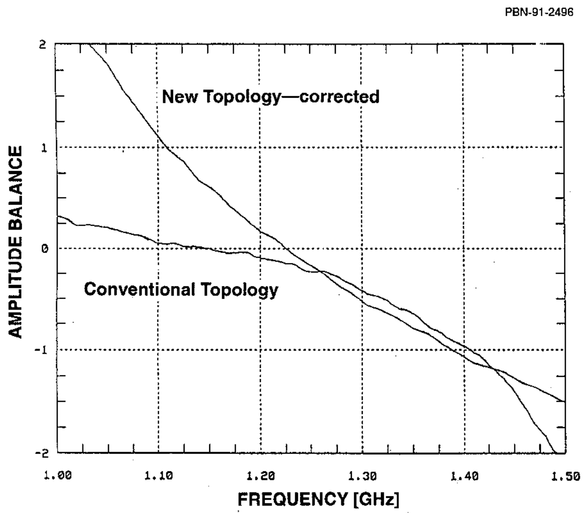


Figure 5. Measured Data Comparison of Phase Shifter - Amplitude Balance.

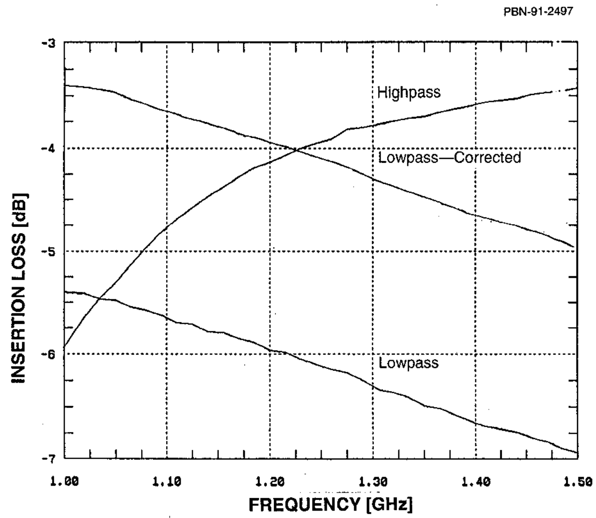


Figure 6. Insertion Loss of Phase Shifter in HP, LP, and LP-corrected States.

The phase shifter contains an amplitude balancing resistor in the lowpass side to permit exact adjustment of amplitude balance in the different phase states. For the first fabrication of this device, the value of the resistor was in error which resulted in excessive loss in the lowpass state. By reducing the resistor to its proper value, the lowpass loss can be analytically corrected to its proper value. This comparison is shown in Figure 6. The measured loss for this circuit in L-band is approximately 4.5 dB. As previously mentioned, the circuit shown includes a variable attenuator which accounts for a significant percentage of the insertion loss. Additionally, the FETs used were from a relatively new process and were not optimum for use as switches.

## Conclusions

A new topology for a 180 degree phase shifter has been designed and reduced to practice. The new approach has somewhat less bandwidth of amplitude balance than conventional approaches. However, it requires fewer components and a single control voltage. This may make it a more desirable design alternative under certain circumstances. It has been realized herein using MESFETs, however, the concept is equally applicable to other switching components such as PIN diodes with potentially improved loss performance.

## Acknowledgements

The vast amount of data associated with the measurements of the phase shifters was collected by Mr. Michael Niedzwiecki. The design of the mask was performed by Mr. Alfredo Ruiz.

## References

Garver, R., Microwave Diode Control Devices, Artech House, Dedham, MA, 1978, pp. 202.