

# **A REFLECTION TYPE PHASE SHIFTER FOR INET PHASE ARRAY ANTENNA APPLICATIONS**

**Bikram Shrestha, Graduate Student**

**Jeyasingh Nithianandam Ph. D., Faculty Advisor**

**Department of Electrical and Computer Engineering, Morgan State University**

**5200 Perring Parkway, Baltimore, MD 21251**

## **ABSTRACT**

In this article we present results from modeling and simulation of a L-band reflection type phase shifter (RTPS) that provides continuous phase shift of  $0^\circ$  to  $360^\circ$ . The RTPS circuit uses a  $90^\circ$  hybrid coupler and two reflective load networks consisting of varactor diodes and inductors. Proper design of  $90^\circ$  hybrid coupler is critical in realizing maximum phase shift. The RTPS circuit implemented on a Rogers Duroid substrate is large in size. We discuss methods to reduce the size of L-band RTPS.

**Key words:** varactor diode, hybrid coupler, phase shift

## **INTRODUCTION**

Phase shifters are used widely in several RF communication systems. Currently there is significant research on various types of RF phase shifter circuits. We need L-band phase shifters that provide a maximum of  $360^\circ$  phase shift for a phased array antenna that would be used for aeronautical telemetry. We plan to use them with radiating elements of a planar antenna array for beam shaping and beam steering applications.

## DESIGN OF QUADRATURE HYBRID COUPLER FOR RTPS

Conventional hybrid couplers evenly divide incoming RF power between its two non-isolated output ports. A hybrid coupler could provide either a phase difference of  $90^\circ$  or  $180^\circ$  between RF signals at its two output ports. A schematic diagram of a hybrid coupler is shown in Fig. 1. This circuit is symmetric in shape and it uses four quarter wavelength long transmission lines at an operating frequency. The two shunt type quarter wavelength transmission lines have a characteristic impedance of 50 ohms and the two horizontal or series quarter wavelength transmission lines have a characteristic impedance of 35.35 ohm. Quarter wavelength long transmission lines in a quadrature hybrid coupler has narrow bandwidth at its operating frequency.

We used a L-band frequency of 1.8 GHz in calculating the lengths and widths of signal conductors of microstrip transmission line sections of a quadrature hybrid coupler. We used RT Duroid 3203 substrate of height 1.524 mm and a copper cladding thickness of 0.017 mm. We implemented a quadrature hybrid coupler in AWR Microwave Office software platform and evaluated its performance by simulations. We found that plots of scattering parameters as a function of frequency were as expected for the simple quadrature hybrid coupler. Next we added four asymmetric microstrip T-junctions at the four corners of the quadrature hybrid coupler circuit as shown in Fig. 2 and performed simulations. The S-parameter plots of Fig. 3 show that the hybrid coupler operates at a lower frequency of 1.652 GHz. We next implemented the quadrature hybrid coupler with four asymmetric T-junctions in Ansoft's high frequency structure simulator (HFSS) software and performed full wave finite element calculations. We varied the parameters of microstrip asymmetric T-junctions and four microstrip quarter wavelength microstrip line sections of the quadrature hybrid coupler in HFSS software. We performed optimization simulations with HFSS. The S-parameter plots of optimized quadrature hybrid coupler in Fig. 4 show that the hybrid coupler works at 1.8 GHz.

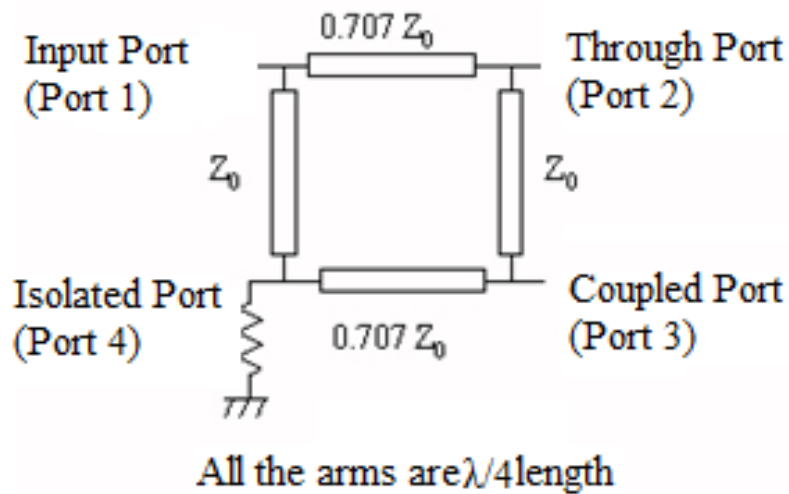


Figure 1. A schematic diagram of conventional quadrature hybrid or branch line coupler.

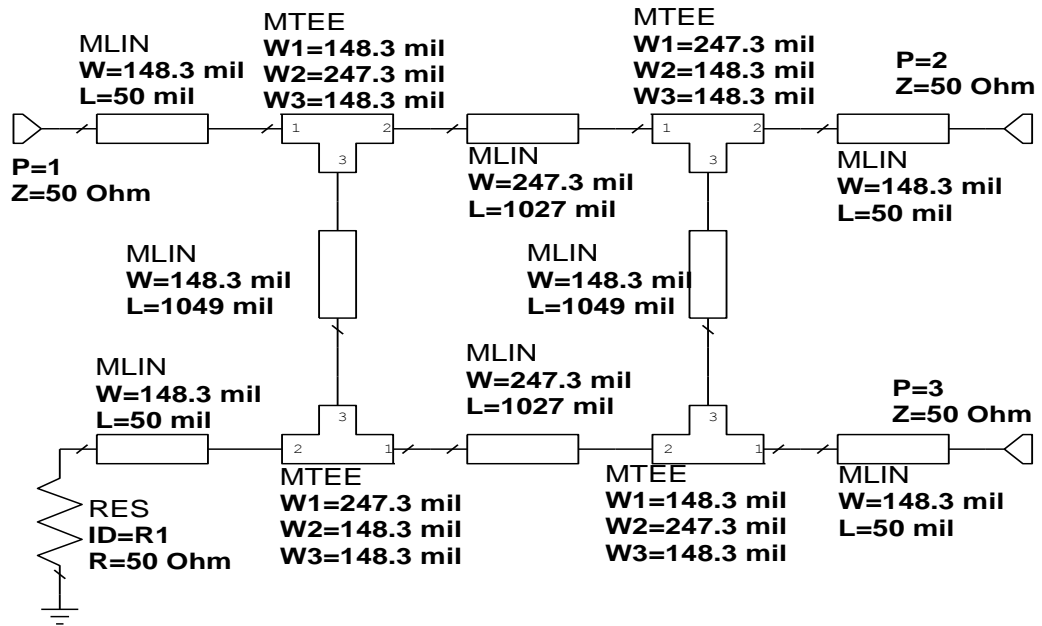


Figure 2. A diagram of quadrature hybrid coupler with four T-junctions in Microwave office

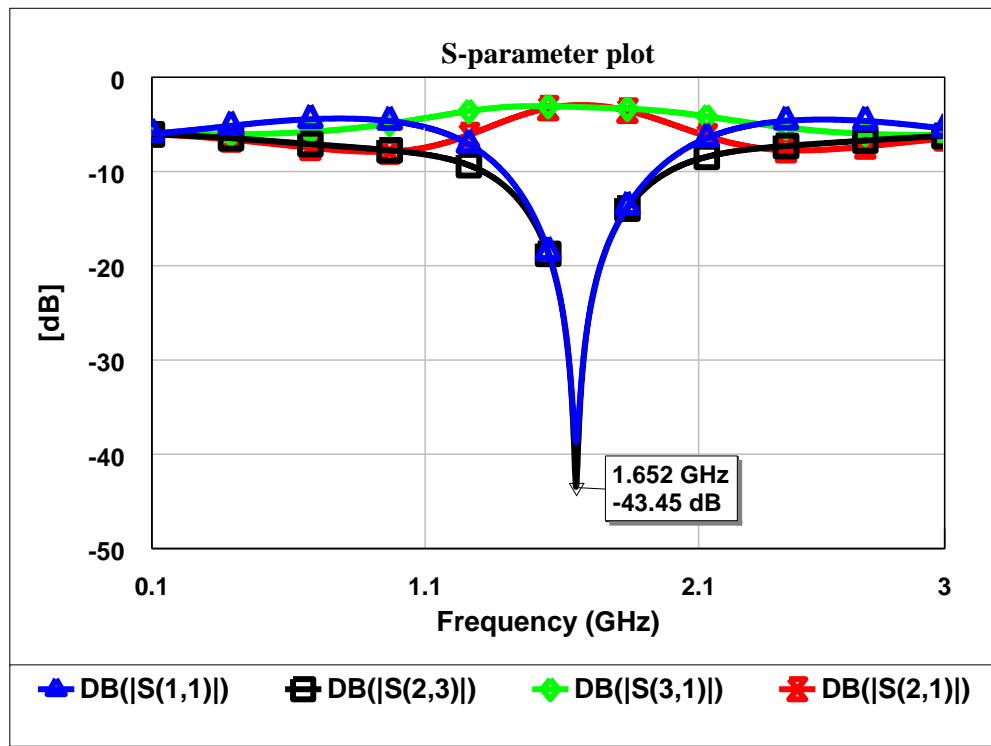


Figure 3. A plot of S-parameters of branchline coupler of figure 2 in Microwave Office and the

branchline coupler operates at 1.652 GHz instead of 1.8 GHz.

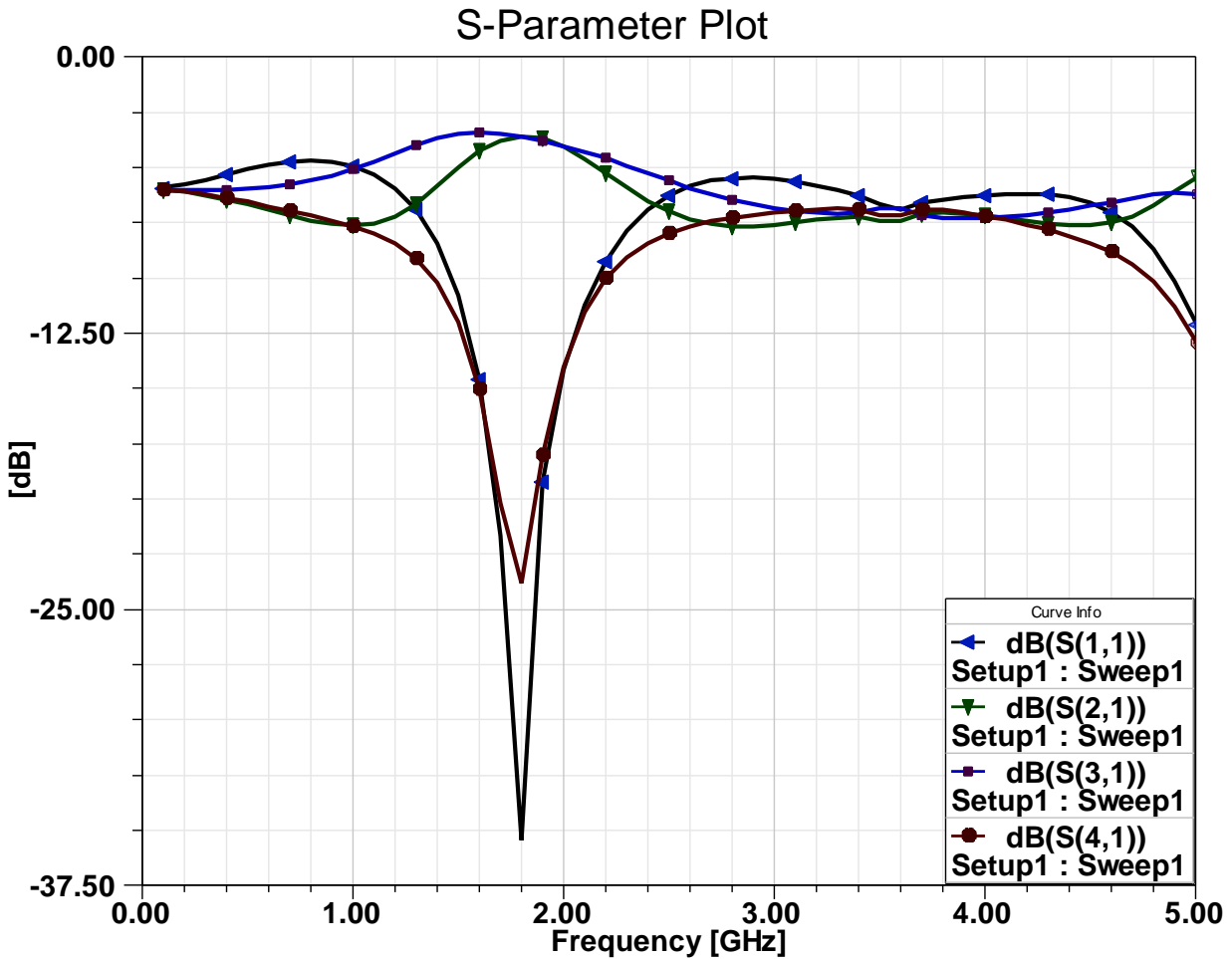


Figure 4. A plot of S-parameters of branch line coupler obtained from HFSS simulations.

### REFLECTION TYPE PHASE SHIFTER DESIGN

A reflection type phase shifter (RTPS) circuit that provides a continuous phase shift of  $180^\circ$  at a L-band frequency was reported in reference [1]. The RTPS in reference [1] uses a quadrature hybrid coupler and a pair of reflective loads. Each reflective load consists of an inductor connected in parallel to two varactor diodes in an "anti-series" configuration [1]. We made improvements to the RTPS reported in reference [1] by incorporating a radial stub network to provide DC bias voltages to four Infineon BB833 varactor diodes and a quadrature coupler designed with HFSS simulations. A shunt connected radial stub network with a 60 mil thick R03203 substrate implemented in Microwave Office software is shown in Fig. 5.

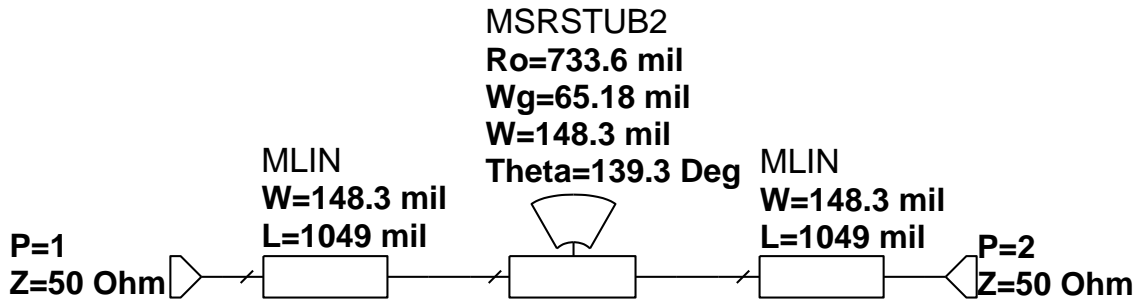


Figure 5. A shunt connected radial stub for providing DC bias voltages to varactor diodes.

We performed simulation of the shunt connected radial stub with Microwave Office software. The scattering parameters and input impedance as a function of frequency for the radial stub are shown in Fig. 6 and Fig. 7 respectively. We find that the shunt connected radial stubs provides high input impedance values to RF signals and they would essentially isolate the DC voltage source from RF signals in our RTPS circuit.

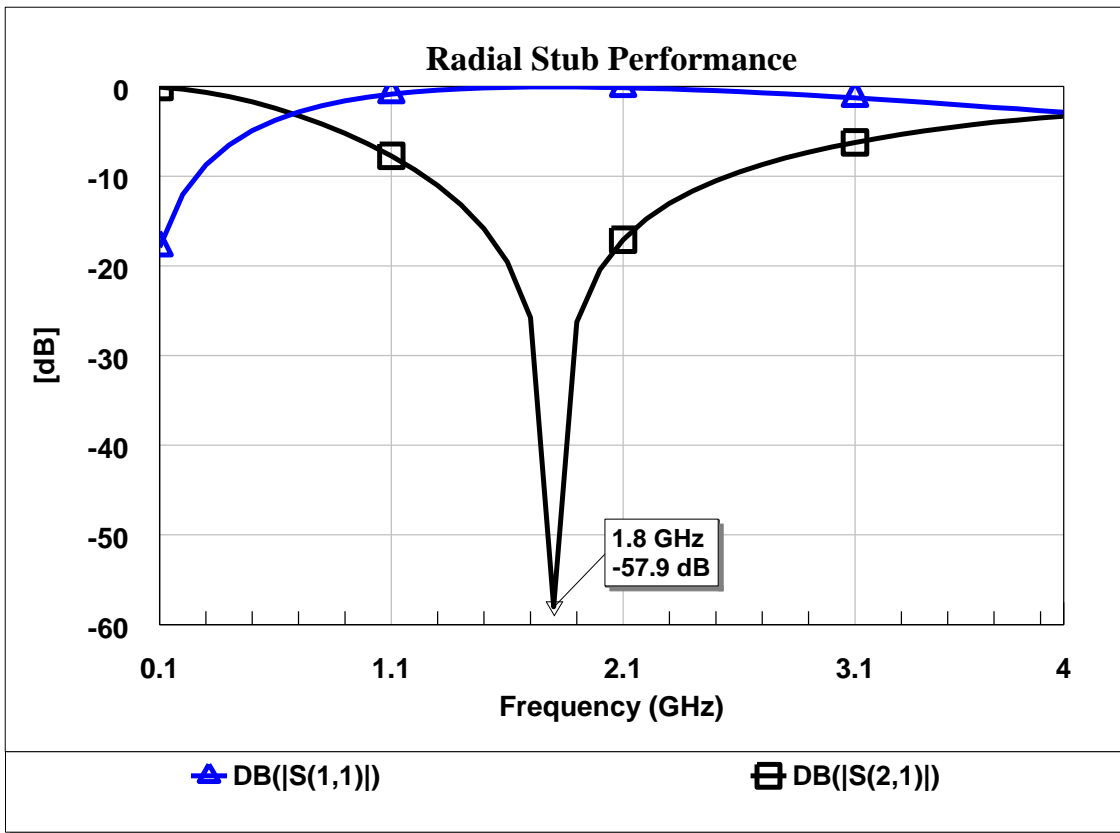


Figure 6. A plot of scattering parameters of a radial stub as a function of frequency.

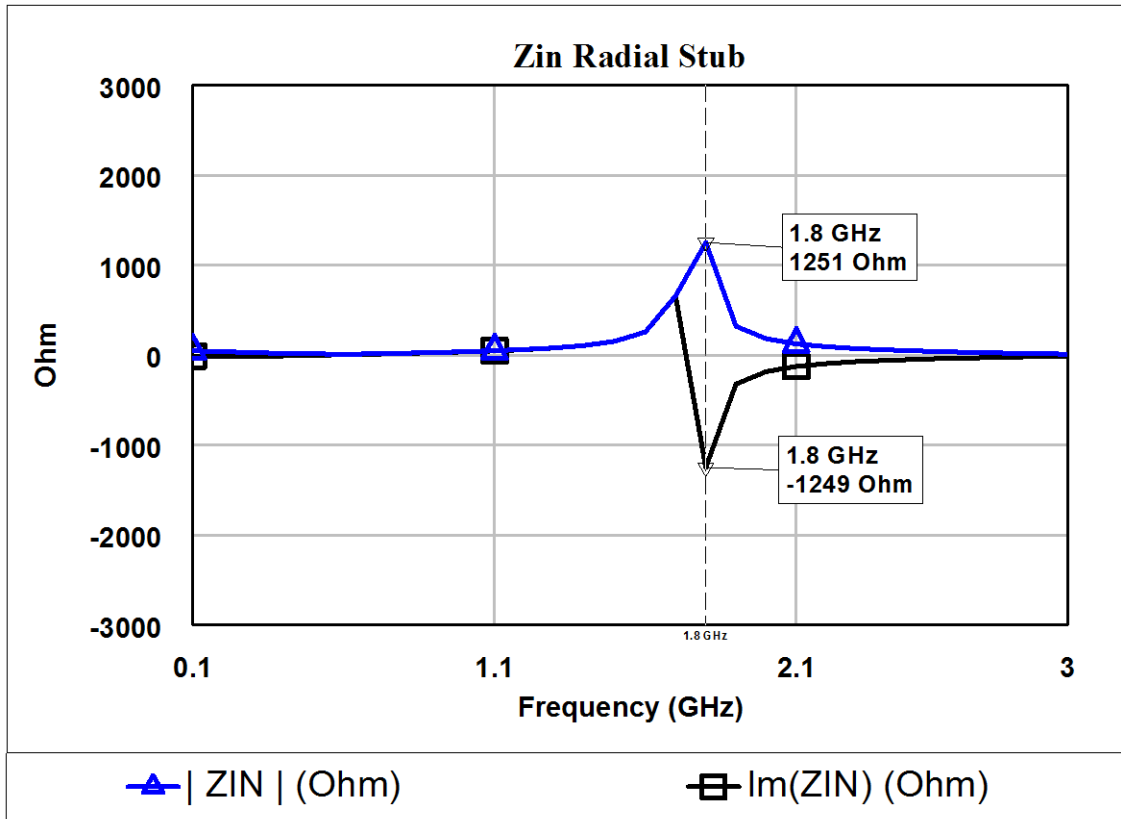


Figure 7. Real and imaginary parts of input impedance of a radial stub.

The RTPS circuit of reference [1] with our improvements to DC bias circuit and quadrature hybrid coupler was implemented in Microwave Office and it is shown in Fig. 8. We performed simulations of improved RTPS circuit with Microwave Office and Fig. 9 shows transmission phase of RTPS circuit as a function of control voltage applied to the Infineon BB833 varactor diodes at 1.8 GHz. Our simulation results show that we could obtain a continuous phase shift from 0 to nearly 360° with the improved RTPS circuit.

## CONCLUSION

A continuous phase shift of 0° to nearly 360° could be obtained by making improvements to a RTPS circuit that uses varactor diodes in an "anti-series" configuration. The RTPS was fabricated on a RO3203 substrate and it was large in size due to the radial stub bias network. We propose to use a spiral transformer based quadrature hybrid coupler [2] in place of conventional hybrid coupler to reduce the size of RTPS. We also propose to use RF MEMS varactors instead of Infineon BB 857 varactor diodes in future.

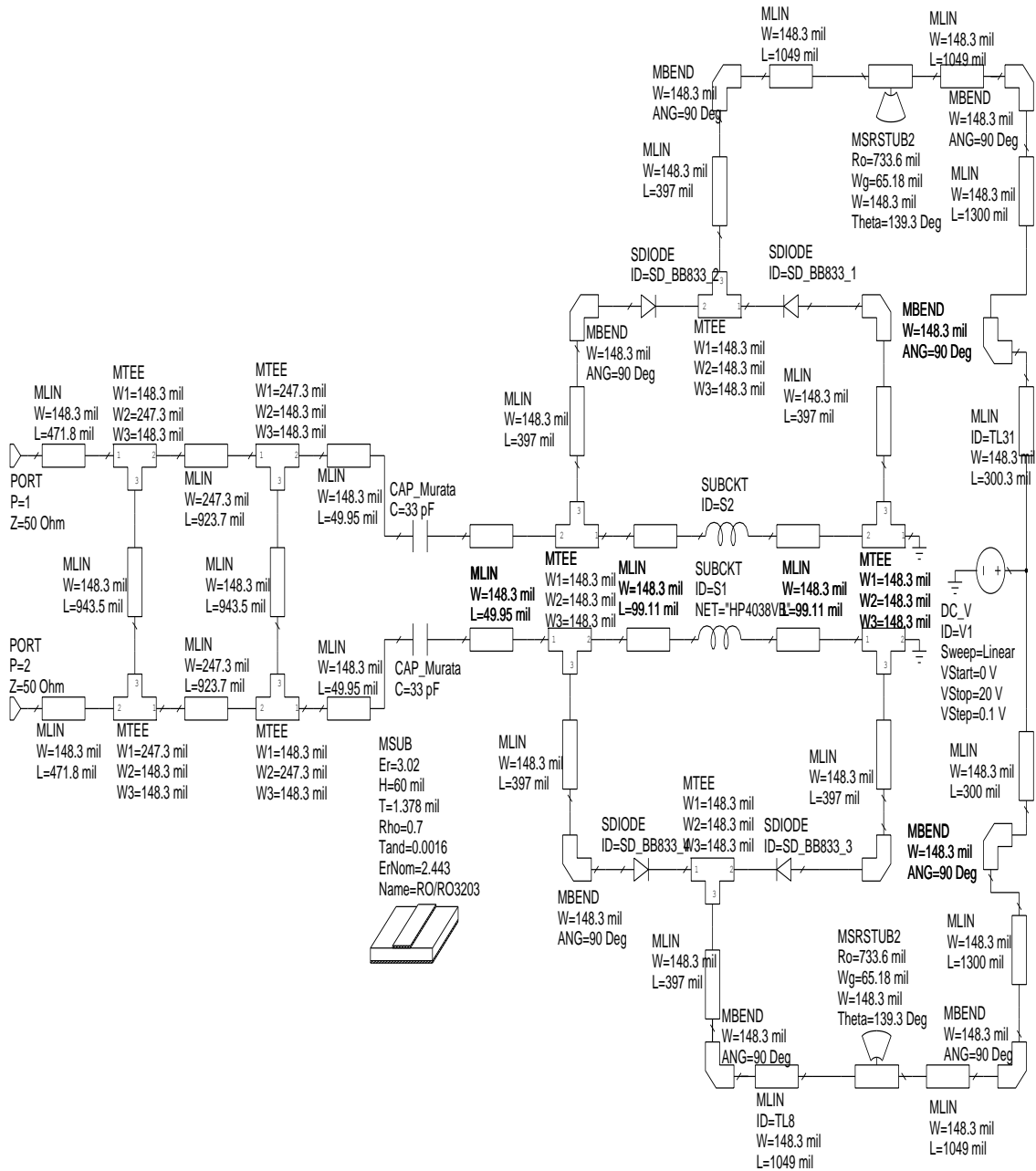


Figure 8. A reflection type phase shifter circuit in Microwave Office software platform.

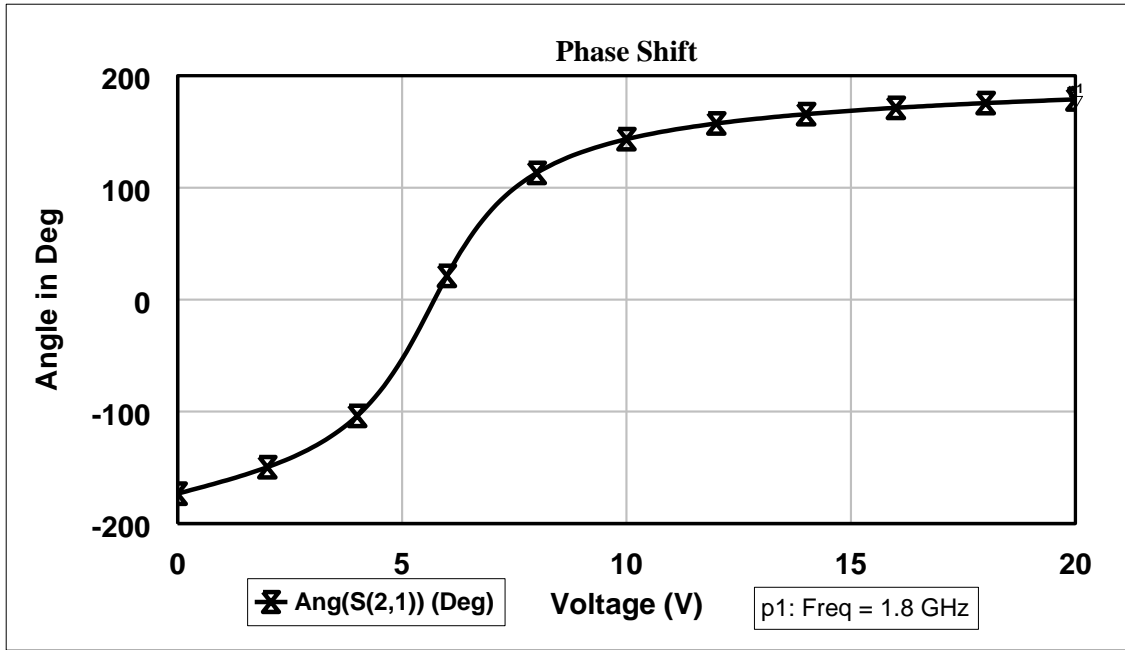


Figure 9. Simulated transmission phase of RTPS as a function of control voltage to diodes.

### ACKNOWLEDGEMENTS

The authors would like to thank the Test Resource Management Center (TRMC) Test Capabilities Development (TCD) technical development of T & E Resource Contract number SR 20091527 for support of this INET program research.

### REFERENCES

1. Keerti, A; Xiang, J and Pham, A.V, "High power linearized RF phase shifter using anti-series diodes", IEEE Transactions on Microwave and Wireless Components Letters, Volume 16, No.4, 2006, pp. 200 - 202.
2. Shibata, K; Hatori, K; Tokumitsu, Y and Komizo, H, "Microstrip spiral directional coupler", IEEE Transactions on Microwave Theory and Techniques, Volume 29, No.7, 1981, pp. 680-689.