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Design and Development of Varactor Tuned Microstrip Phased Array Antenna

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Abstract — This paper proposes the design of 4-element microstrip phased array antenna integrated with reflection type phase shifter loaded with the varactor diode. Steering of the main lobe is done by changing the bias voltage which leads to progressive phase-shift of phase shifter. The structure of phase shifter is based on 90^0 branch line coupler loaded with the varactor diodes used to provide the phase shifting. Feeding the quadrature hybrid reflection type phase shifter a wilkinson power divider is used. This approach of fabrication of various component can be used for large phased array for use in radar and space communication application.

Keywords- Phased Array, Patch Antenna Array, Phase Shifter, Wilkinson Power Divider, Varactor Loaded Phase Shifter, Varactor Diode.

I. INTRODUCTION

With the increase in the technology and use of Radio Frequency (RF) and the capabilities of having the steering capability and having the adaptive beam forming, it has assigned a wide use in the communication system and radar system [1-6]. Phased array system is one of the best example for these use rather having directive beam or sectoring area antenna. Modern radar systems require adaptive control of beam direction, beam shape, beam width, side-lobe level and directivity to improve the coverage and tracking resolution [5-7]. The phased array is mainly designed with the number of radiating element each connected with phase shifter. The radiation beam is formed by changing the progressive phase by changing the phase in phase shifter by changing the DC bias voltage of phase shifter, these leads to constructive and destructive interference for steering beam in the desired direction. The microwave frequencies of C band is useful in the space application in adverse weather and conditions.

In most of the antenna array the beam steering can be achieved in two ways, mechanically or electronically. In mechanically steered antenna requires mechanically rotating the antenna array. This type of steering is slow and costly when precision of steering the beam is taken into consideration. In the other way the electronically steering required no mechanical movement of the antenna array and the radiated beam is pointed in the desired direction without mechanical movement. So the electronically steering of beam has more advantage over the mechanical steering such as faster scanning rate and capability of steering the multiple beam at a time. Analoge phase shifters are one of the key component which is widely used in the phased arrays transmitters, receivers, communication system, radar systems and microwave automatic control system, to get electronics adaptive beam forming and beam steering.

Reflection type of phase shifter can be designed to achieve a wide phase shift range by connecting the varactor diode circuits at the port of the reflection devices, such as branch line couplers. Feeding the phase shifter a power distribution network is being established by Wilkinson power divider with a resistor attached to it for increasing proper isolation between the ports. Power divider feeds the reflection type phase shifter, which generated the progressive phase between the phase shifter which is connected to the patch. The beam is formed and by changing the bias voltage given to the phase shifter, gives a change in the value of the capacitance of varactor diode connected in reverse bias of reflection type phase shifter.

II. DESIGN OF PHASE SHIFTER

In the reflection type of the phase shifter a 3-dB coupler is being used usually to split the signal into two signals which are being combined to produce the output signal.

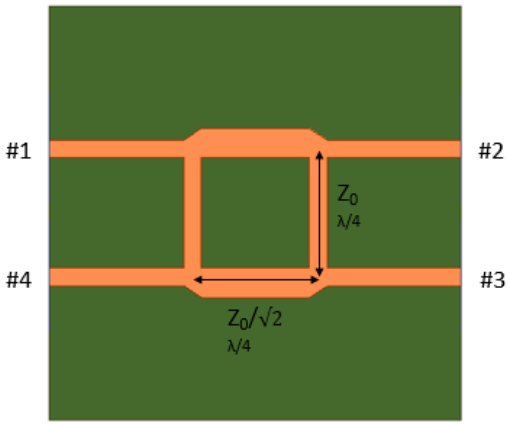

Figure 1: Schematic of Quadrature Hybrid

Figure shows the schematic of the 3-dB quadrature hybrid coupler. The input signal to port #1 is equally being divided into two signals with the phase difference of the 90^0 between the port #2 and port #3. If each of these terminal is being terminated with the reflective load with purely reactive impedance, the two reflective signal will get combine the phase to produce the output at port #4 but cancel each other at port #1. The performance of the coupler can be optimized by the varying the length and adjusting the width of the transmission line. An ideal 3-dB hybrid coupler has its S – parameters S_{21} and S_{31} with the equal amplitude and the phase difference of 90^0.

A reflection type of phase shifter based on the quadrature hybrid is shown in the Fig.

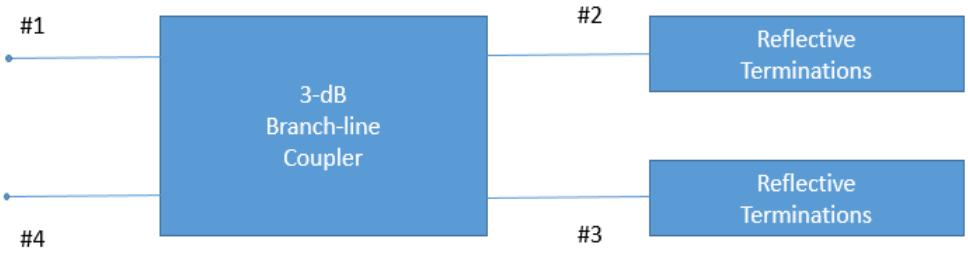

Figure 2: Schematic of Reflection type Phase Shifter.

III. DESIGN OF REFLECTION TYPE PHASE SHIFTER

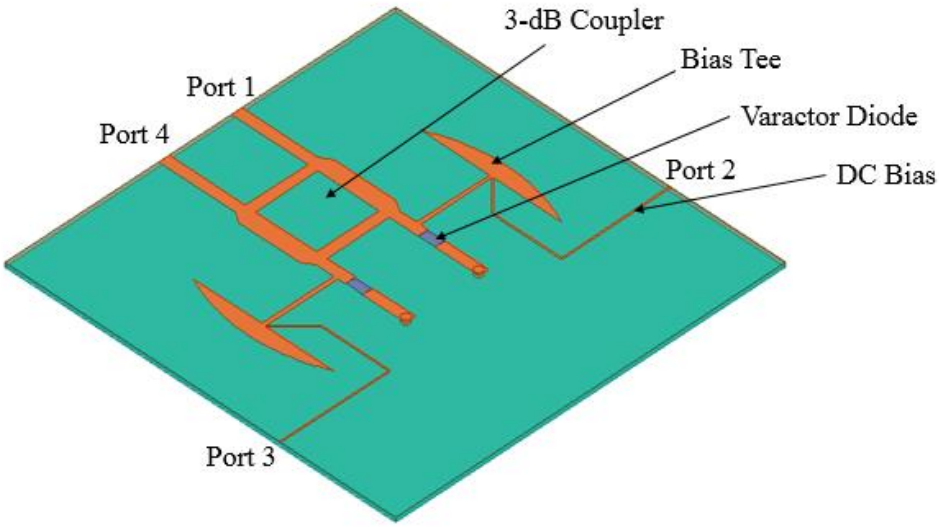

Figure 3: Schematic of Varactor Loaded Reflection type Phase Shifter

The design of the phase shifter is shown in the figure. It consists of a 3-dB coupler with reflection function unit. The input signal in the port#1 is being equally divided due to the coupler in the port #2 and port #3 having the same amplitude and the phase difference of 90^0 between them. Now by ending the two terminal #2 and #3 by the same varactor diode the signal will get reflected in the same phase. Due to the reflection of the signals by termination with the varactor diode the signal will recombine in the coupler, which will give output at port #4 and due to 180^0 out of phase difference due to port #1, which is input port, the signals will get cancelled to each other.

By changing the applied reverse bias voltage of the varactor diode, the phase and amplitude of the reflected signal due to change in the capacitance offered by changing the reverse bias voltage of the varactor diode.
A bias tee is required to be designed and attached to the 3-dB coupler to achieve the isolation between RF and DC biasing voltage lines given to the diode. The substrate used in the phase shifter is Roger RO (3003) having the relative permittivity of 3 and relative permeability 1 with the loss tangent of 0.0013.

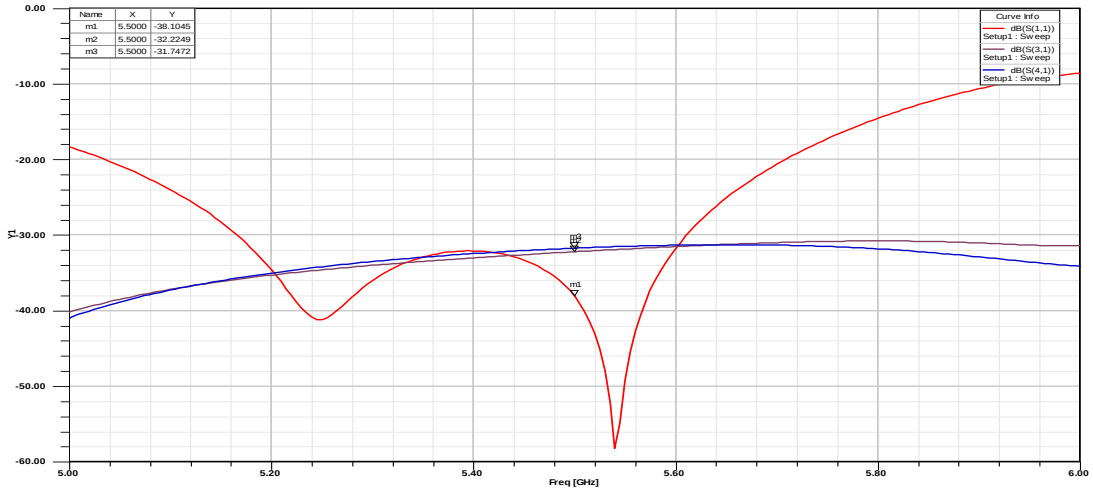

Figure 4: S-Parameters of Quadrature Hybrid Phase Shifter

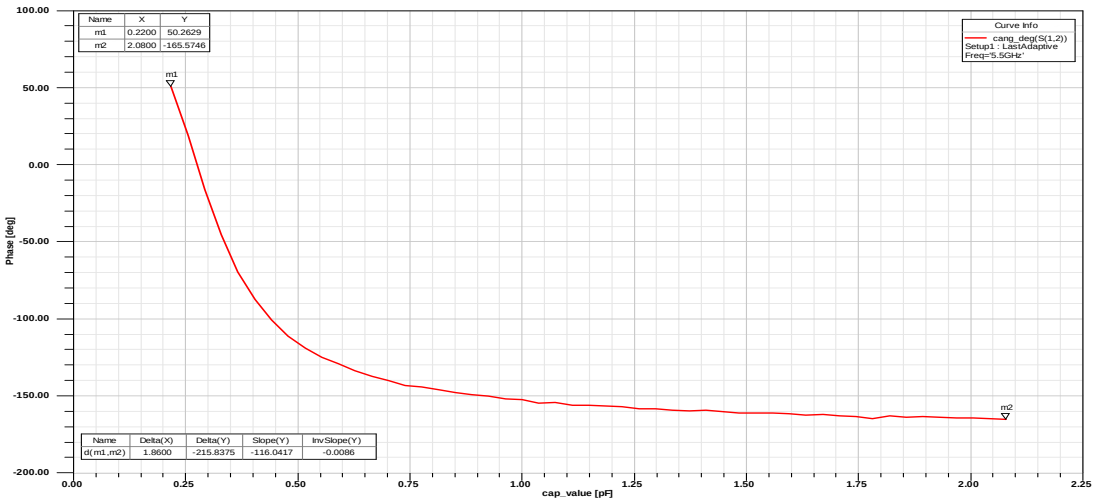

Figure 5: Phase vs. Capacitance of Quadrature Hybrid Phase Shifter

The return loss (S_{11}) of the quadrature hybrid phase shifter is-38.10 dB, S_{31} and S_{41} are -32.22 dB and -31.74 dB respectively.
Changing the value of the capacitance of the varactor diode connected in the reverse bias of the reflection type phase shifter from 0.22pF to 2.08pF, the phase shift generated is -215^0.
A bias tee is attached with quadrature hybrid coupler for the purpose of isolation between RF and DC port. The isolation of bias tee is -39.8 dB and return loss of -40.1 dB.
For increasing phase shift of the reflection type phase shifter for increasing the scanning of array antenna, four varactor diode configuration of the phase shifter has used. By increasing the number of the varactor diode the amount of the phase shift is being increased.

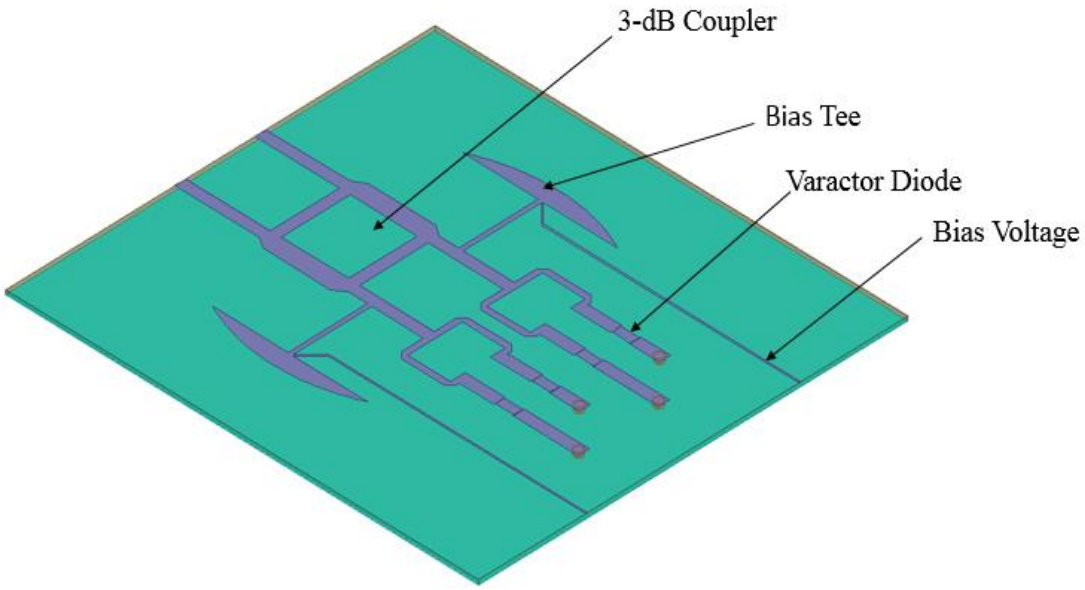

Figure 6: Schematic of Four Varactor Loaded Reflection type Phase Shifter

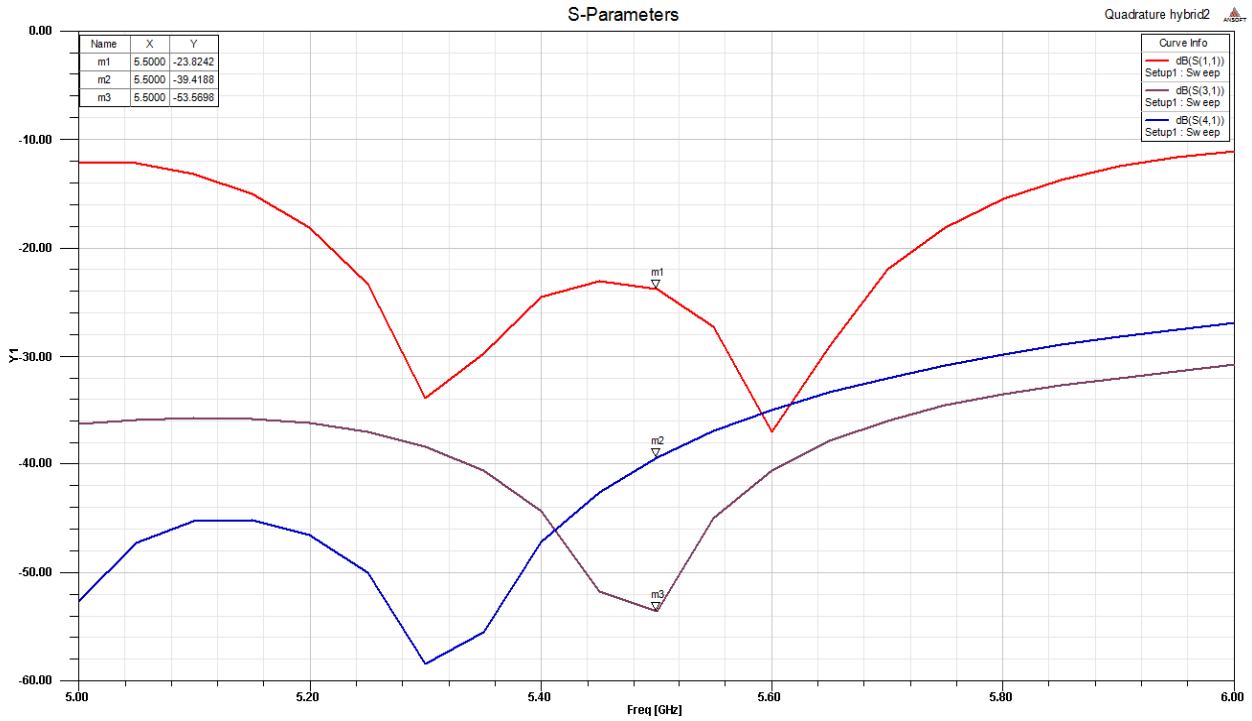

Figure 7: S -parameter Four Varactor Loaded Reflection type Phase Shifter

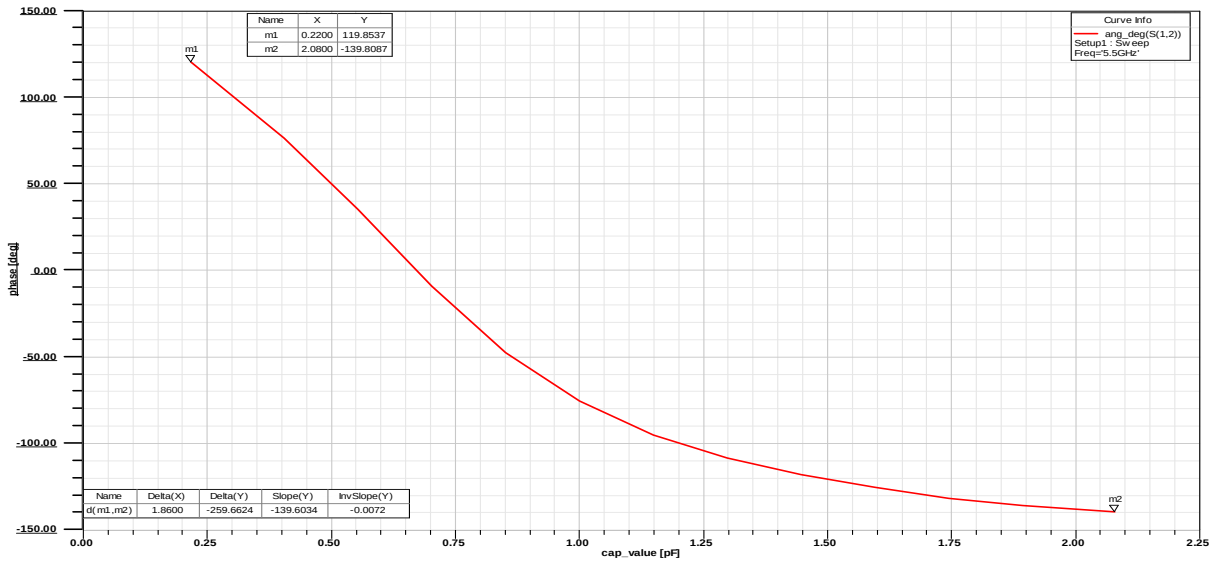

Figure 8: Phase vs. Capacitance of Four Varactor Loaded Reflection type Phase Shifter

The return loss (S_{11}) of four varactor loaded quadrature hybrid phase shifter is-23.82 dB, S_{31} and S_{41} are -39.41 dB and -53.56 dB respectively. The phase shift generated by the four varactor loaded quadrature hybrid phase shifter is -259.66^0.

IV. FOUR ELEMENT LINEAR PROBE FED MICROSTRIP ARRAY ANTENNA INTEGRATED WITH REFLECTION TYPE PHASE SHIFTER

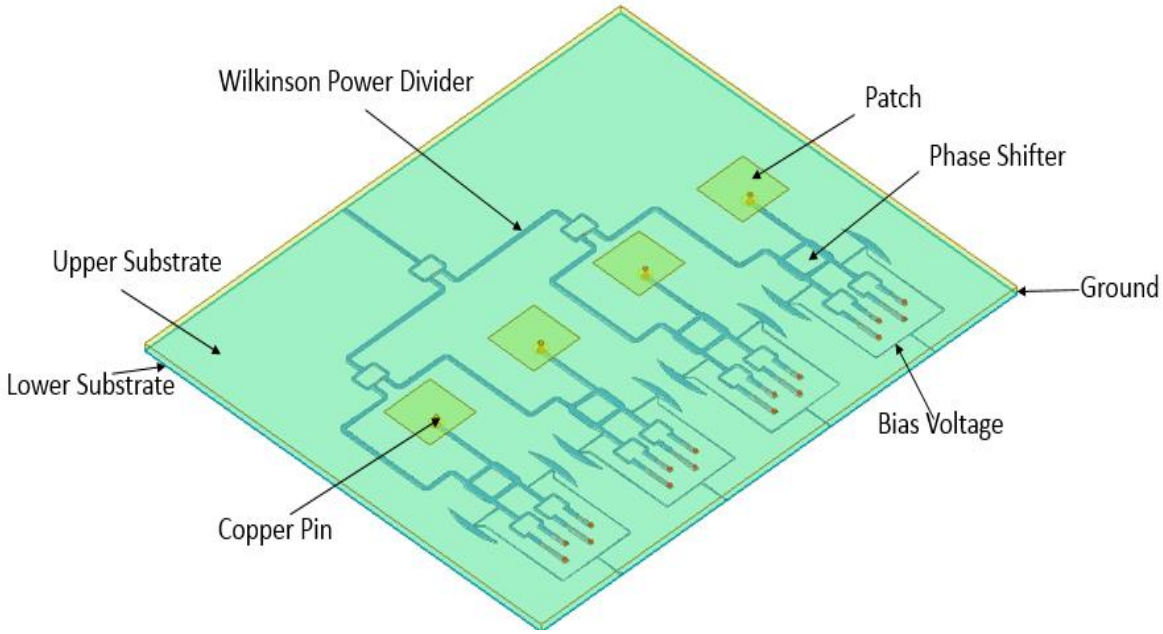

Figure 9: Four Element Linear Probe Fed Microstrip Array Antenna Integrated with Reflection Type Phase Shifter

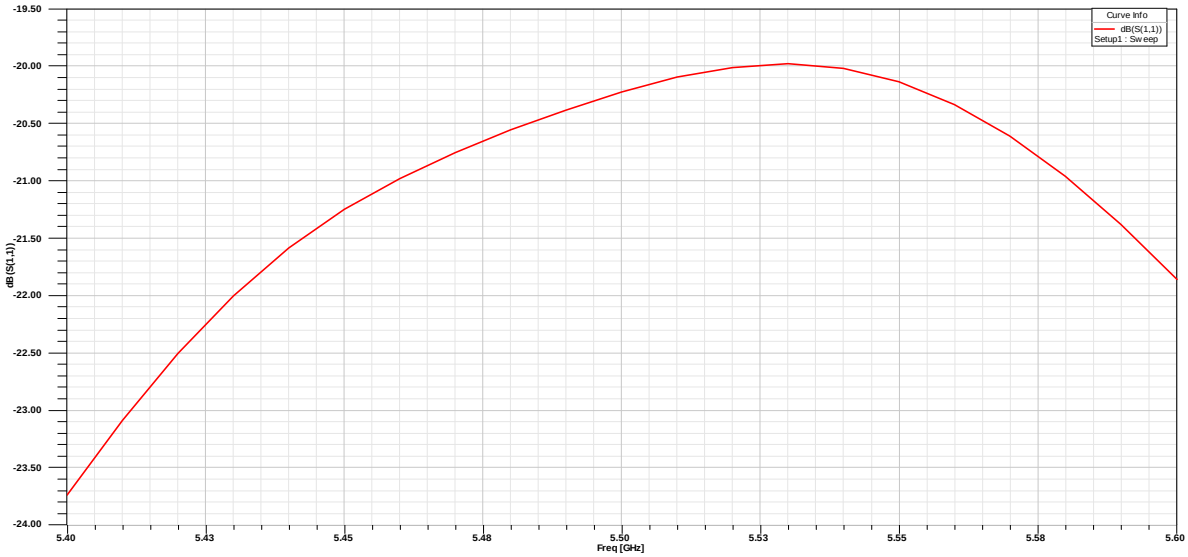

Figure 10: Return loss of Four Element Linear Probe Fed Microstrip Array Antenna Integrated with Reflection Type Phase Shifter

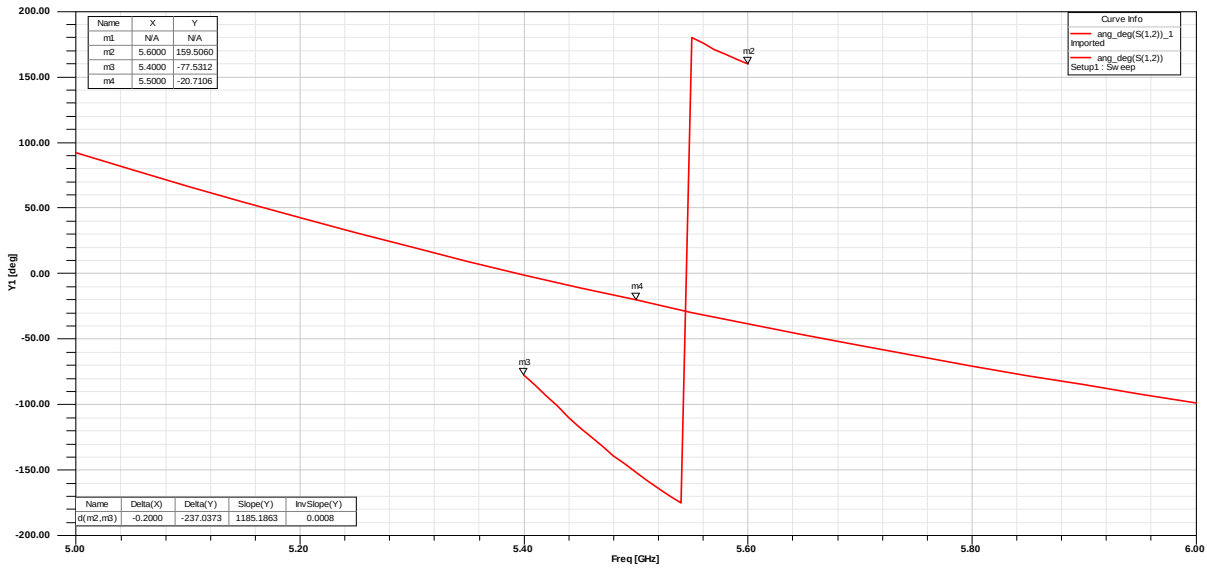

Figure 11: Phase Shift of Four Element Linear Probe Fed Microstrip Array Antenna Integrated with Reflection Type Phase Shifter

The lower substrate is Roger RO (3003 having the relative permittivity of 3 and relative permeability 1 with the loss tangent of 0.0013 and the upper substrate is Roger RT/duroid 5880 (tm) having the relative permittivity of 2.2 and relative permeability 1 with the loss tangent of 0.0009.

1:4 wilkinson power divider is used to feed the array. A resistor is used in the Wilkinson power divider for achieving the higher isolation between the ports. Return loss (S_{11}) of the wilkinson power divider is -24.09 dB is being achieved. The feeding structure feeds the four varactor loaded reflection type quadrature hybrid phase shifter by which a phase shift is generated by varying the capacitance value of the varactor diode through DC bias line in the phase shifter.

The reflection type phase shifter is integrated with the probe fed microstrip patch antenna and for feeding the array 1:4 wilkinson power divider is used. The return loss (S_{11}) of four element phased array integrated with the reflection type phase shifter and wilkinson power divider is -20.30 dB and phase shift of the array is -237^0.

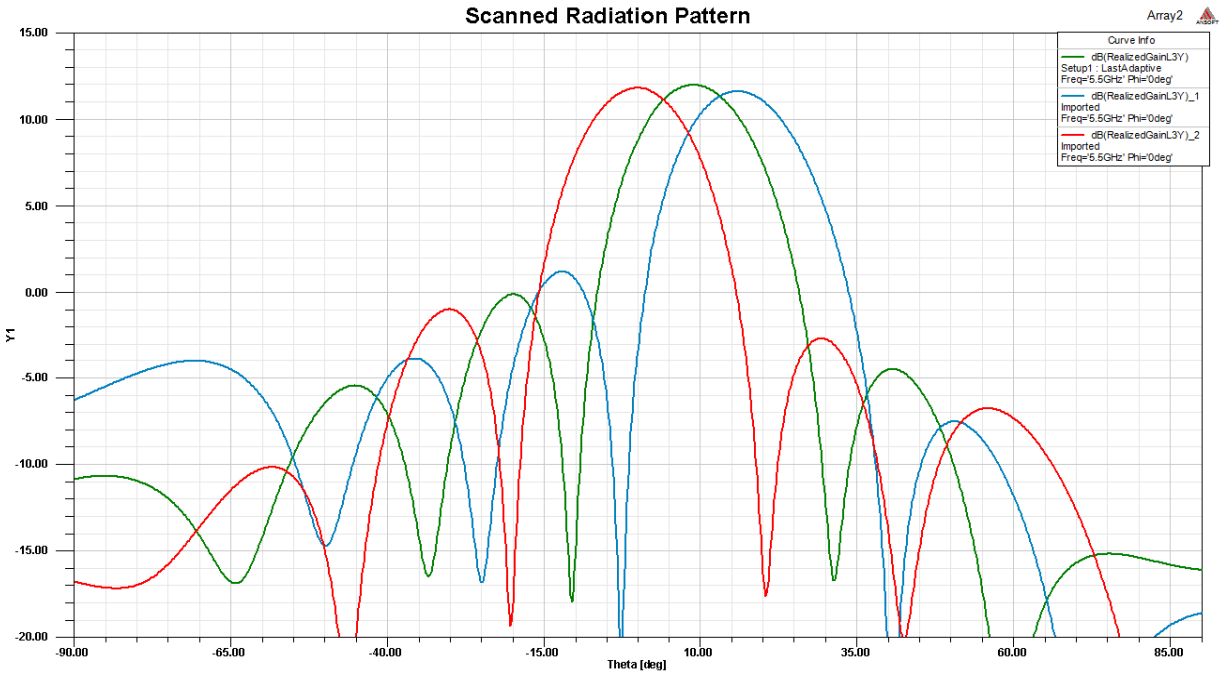

Figure 12: Scanned Radiation Pattern for Four Element Linear Probe Feed Microstrip Array Antenna Integrated with Reflection Type Phase Shifter

These phase shifted signal moves to the probe fed microstrip patch antenna by which it is being excited. Desired scanning of the radiation beam is done by changing the progressive phase between the four array elements.

V. CONCLUSION

The paper shows the how the varactor diode can be used for the reflection type phase shifter for achieving the desired phase shifter by varying the capacitance of the varactor diode connected at the terminal of the phase shifter. The phase shift generated is -215^0. By varying the length and the increasing the varactor diode, phase shift generated is -259.66^0. Return loss (S_{11}) of the wilkinson power divider is -24.09 dB is being achieved. Return loss (S_{11}) of four element phased array is -20.30 dB and phase shift of -237^0.

REFERENCES

1. Fenn, A. J., *Adaptive Antennas and Phased Arrays for Radar and Communications*, Artech House, Boston, 2007.
2. Ohmori, S., Y. Yamao, and N. Nakajima, \The future generations of mobile communications based on broad-band access technologies," *IEEE Commun. Mag.*, Vol. 38, 134{142, 2000.
3. Ehmouda, J., Z. Briqech, and A. Amer, \Steered microstrip phased array antennas," *World Academy of Science, Engineering and Technology*, Vol. 49, 319{323, 2009.
4. Godara, L. C., \Applications of antenna arrays to mobile communications. Part I: Performance improvement, feasibility, and system consideration," *Proc. IEEE*, Vol. 85, No. 7, 1031{1060, 1997.
5. Mailloux, R. J., *Phased Array Antenna Handbook*, 2nd edition, Artech House, Boston, 2005.
6. Hansen, R. C., *Phased Array Antennas*, John Wiley & Sons, Inc., New York, 2009.
7. Skolnik, M. I., *Radar Handbook*, 3rd edition, McGraw Hill, New York, 2008.
8. M. X. Xiao, S. W. Cheung and T. I. Yuk, "A wideband 360^0 analoge phase shifters design", 978-1-4244-3508-1/09 IEEE 2009
9. M. X. Xiao, S. W. Cheung, and T. I. Yuk, "Design of Linear Voltage Controlled 360^0–Analogue Phase Shifter", MICROWAVE AND OPTICAL TECHNOLOGY LETTERS / Vol. 52, No. 8, August 2010
10. Chien-San Lin, Sheng-Fuh Chang, Chia-Chan Chang, Yi-Hao Shu,"Design of a Reflection – Type Phase Shifter with Wide Relative Phase Shift and Constant Insertion Loss", IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, VOL. 55, NO. 9, SEPTEMBER 2007
11. Mohammed A. El-Tanani, Gabriel M. Rebeiz,"", Proceedings of the 4th European Radar Conference, October 2007, Munich Germany

12. Khaled Khoder, Marc Le Roy, André Pérennec,"", Proceedings of the 44th European Microwave Conference, 6-9 Oct 2014, Rome, Italy
13. E. C. Nlehenke, V.V. DMarco, and A. Friedberg,"Linear Analoge Hyperabrupt Varactor Diode Phase Shifter", 1985 IEEE MTT-S Digest.
14. Antenna theory: analysis and design / Constantine A. Balanis, third edition, Hoboken, NJ: Wiley, 2005, ISBN 047166782X (hbk).
15. The Microwave encyclopedia online, http://www.microwaves101.com/encyclopedia/couplers.cfm
16. Watson, T., "Affordable phase shifters for electronically scanned phased array antennas", article RFDesign Magazine, Oct. 1, 2003. (http://rfdesign.com/mag/radio_affordable_phase_shifters/index.html).