Design of 180°Six Bit Digital Phase Shifter Using Lumped Network

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Abstract

In scanned antenna array, the antenna beam-steering in the desired direction without physically repositioning the antenna can be made possible by use of phase shifters, which can be implemented in the transmit receive path of the antenna. Phase shifter circuit changes the direction of radiation of the signal passing during it by changing the phase of the signal. The six bit digital phase shifter using lumped components equivalent of transmission line has been designed and implemented. The results of this design are obtained in terms of insertion loss, return loss, and phase errors. And it's simulations in ADS, for all possible combinations of phase shifts at 212MHz frequency.

Keywords: *TR module, Phase shifter, Lumped Networks.*

I. INTRODUCTION

Phase shifters are classified as two port networks. Phase shifter modifies the phase of the input signal and gives the modified output signal. The wideband and ultra wideband 90° phase shifters consisting of coupled-line sections and lumped elements[3]. The design and analysis of this phase shifters are investigated using low-pass, band-pass, and high-pass networks[3,10]. wideband and Ultra wideband transmission can legally operate in the range from 3.1 GHZ to 10.6 GHZ. A 6 bit phase shifter includes 6 digital bits 180°, 90°, 45°, 22.2°, 11.25° and 5.625° degree that they are series [1]. Each phase bit contains a reference circuit and a delay circuit. Phase shifters used for controlling line phase that are in part of receiving and transferring mobile communication systems. There are regulating scan angle in central station, and controlling output signal phase of filter, that provide for processing RF signal, also double control achieved are includes applications of phase shifter. They have important roles in industrial and new communication sciences such as direct receiving in digital satellite system (DSS), cellular telephone, satellite modem, and modems in wireless local area network (WLAN), phase shifters play key and important role[2,4,11]. One of the most important applications of phase shifters is digital phase locked loops (PLL). This operation used for solving phase errors and received signal frequencies. A digital phase shifter have found extensive applications in designing phased array antenna system, frequency up-converters and phase modulators [2]. There are several methods to realize digital phase shifter which include switched-network phase shifter where change in the output phase is obtained by varying switching frequency between two phase shifter networks and it results into a desired differential phase shift. It was found that, transmission phase at the desired operating frequency of 212 MHZ in order to implement these differential phase shifts.

II. PHASE SHIFTER BLOCK DIAGRAM

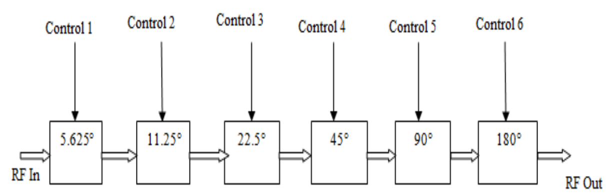

Fig 1: block diagram of six bit digital phase shifter

A digital phase shifter block diagram shown in figure. A 6 bit phase shifters consist of six different blocks and it's includes six digital bits 180°, 90°, 45°, 22.5°, 11.25° and 5.625°. These blocks are arranged in cascade and are controlled by six bit digital control logic. Since the control signal is digital in nature, These digital phase shifter will produce 64 phase shifter of 0 to 360° with 5.625° step. Each basic building block is implemented as a lumped network, output of which provides a required phase change in the input RF signal. This lumped network is equivalent to a piece of transmission line which would have provided the required phase shift.

III. DESIGN OF PHASE SHIFTER

The transmission line has been assumed to be equivalent to a basic Π network, Tee network, L network or any other network. Thus by properly synthesizing the circuit element values, the desired phase shift has been obtained. The derivation for equivalent lumped components considering the modeling of transmission line as a Π.

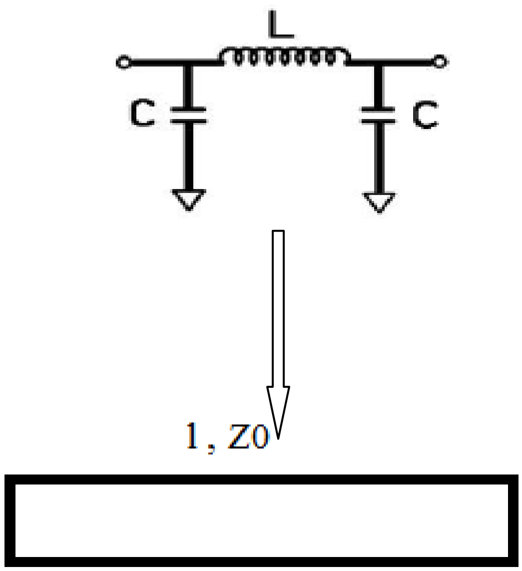

Fig 2: Π network equivalent for a transmission line

Let, βl be the length of transmission line in radians and be its characteristic impedance. Let Y and Z be the admittance and impedance of the equivalent lumped elements, respectively. As per the ABCD parameter which can be simplified as,

$$\begin{bmatrix} 1+YZ & Z \\ Y(2+YZ) & 1+YZ \end{bmatrix} = \begin{bmatrix} \cos\beta l & jz_0 \sin\beta l \\ j\sin\beta l/z_0 & \cos\beta l \end{bmatrix}$$

Considering the series element to be an inductor and shunt elements to be capacitors, we get

$$\begin{bmatrix} 1+j^2w^2LC & jwL \\ jwC(2+j^2w^2LC) & 1+j^2w^2LC \end{bmatrix}$$

Where,

$$L = \frac{Z_o \sin\beta l}{\omega}$$

$$C = \frac{1-(\cos\beta l)}{\omega L^2}$$

The desired S Parameters are obtained according to the input control signal which in turn verifies the results for the specific values of inductor and capacitors.

The S parameters for each network can also be obtained directly from its Y parameters by,

$$S_{11} = \frac{(Y_o + Y_{11})(Y_o + Y_{22} + Y_{12}Y_{21})}{\Delta Y}$$

$$S_{21} = \frac{-2Y_{21}Y_o}{\Delta Y}$$

After simplifying, we get S_{11} and S_{21} interms of L and C as shown below,

$$S_{11} = \frac{[Y_o + \frac{1-\omega L}{j\omega^2 LC}]^2 + [\frac{1}{\omega L}]^2}{[Y_o + \frac{1-\omega L}{j\omega^2 LC}]^2 - [\frac{1}{\omega L}]^2}$$

$$S_{21} = \frac{2\omega LCY_o}{C(1+\omega^2 L^2 Y_o) + jL(1-\omega)}$$

This Y matrix can be obtained for each lumped network and can be converted into its respective ABCD parameters by using,

A=$\frac{-Y_{22}}{Y_{21}}$, B=$\frac{-1}{Y_{21}}$, C=$\frac{-|Y|}{Y_{21}}$, D=$\frac{-Y_{11}}{Y_{21}}$

Where,

$|Y| = Y_{11} * Y_{22} - Y_{12} * Y_{21}$

By using these expressions of lumped elements we obtain the phase shift and insertion loss in dB.

These mathematical expressions are further verified in ADS and results are shown in below figure.

IV. PHASE SHIFTER WITH FILTER NETWORK

In this three structures of 90° phase shifters are proposed utilizing low-pass, high-pass, band-pass networks in a coupled line section. The phase shifter with filter network circuits are operated in GHZ frequency and the measured insertion loss for all three phase shifters over the operating bandwidth is less than 1dB.

V. SIMULATION RESULTS

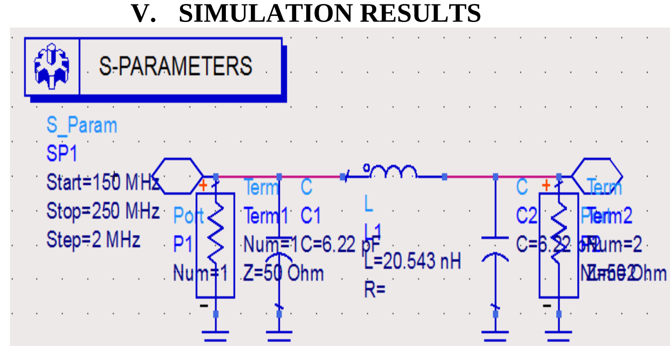

Fig 3: design of 45° phase shifter

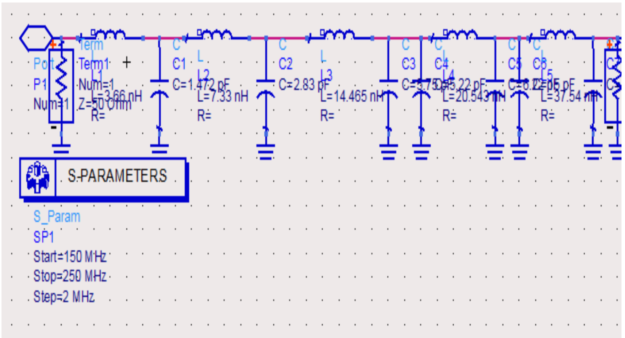

Fig 4: design of 180° phase shifter

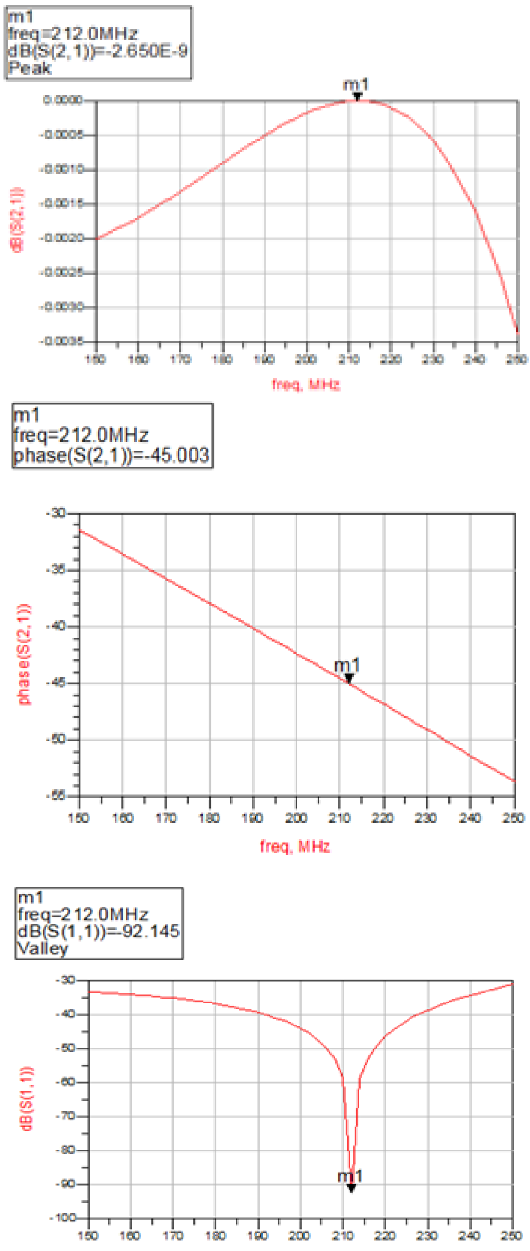

Fig 5: simulation results for 45° phase shifter

It is seen that the phase shift (phase of S21) achieved is -45.003 degree with the insertion loss (magnitude of S21) and return loss (magnitude of S11) respectively. Fig.4 shows the design implementation for 4 cascaded lumped network blocks to result in phase shift of 180 degree.

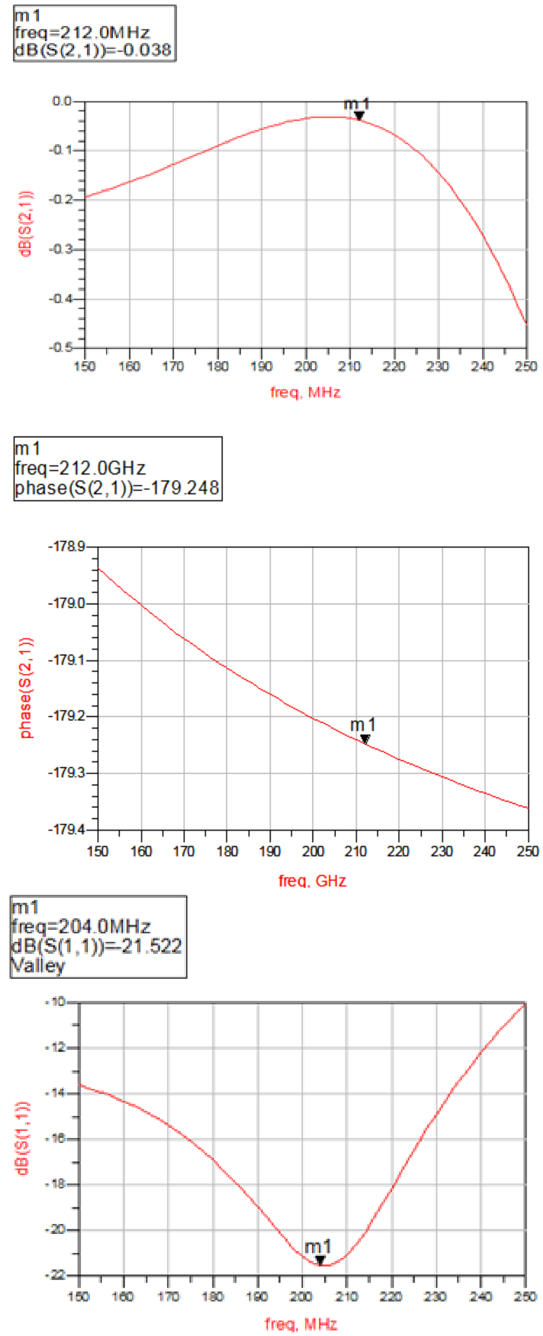

Fig 6: simulation results for 180° phase shifter

VI. CONCLUSION

A complete bit section of 180° phase shifter has been designed and simulated in Advanced Design System software at 212 MHZ. This design has been proposed for the Transmit Receive Module for radar applications. In logical design result into the desired output signal depending on the input control bits, which was further supported with mathematical modeling. This design consists of 6 classifications. We can consider 64 modes totally, having phases 180°, 90°, 45°, 22.5°, 11.25°, 5.625° and having steps 5.625°. This phase shifter has been tested for all the 64 combinations of phase states and its resulted in the insertion loss of 5.8±0.4 dB and return loss of less than -13dB. The maximum phase error of ±1.72° is achieved.

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