Extended Butler Matrix Design by Using Phase Reconfigurable CRLH Transmission Line

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***Abstract*—A reconfigurable composite right/left handed transmission line is presented. The designed phase shifter has a good matching and insertion loss for the 9 different bias voltages. For each bias voltage a specific phase response can be achieved. A 70^0 phase differences is achieved by 8 volte bias voltage. The designed phase shifter then added to a conventional butler matrix to increase the number of radiation patterns. The deigned structure can be a good candidate for low cost, low size phased-array antenna.**

I. INTRODUCTION

The demand of beam forming array antenna has been remarkably increased due to the increase of wireless devices and multi-user applications. On the efficient and low cost phased-array antenna is passive beam-forming. Butler-Matrix is one of the widely known beam-forming networks that has been discussed and used in diverse form [1]-[3].

The Butler matrix is one of passive beam-forming network consisting of N input/output port and N input/output antenna elements produced N principal orthogonal beam at different location [4]. However, the restriction of number N will apparently limit the flexibility for many applications that may need the numbers of beams different than 2^n.

There are several projects that tried to change these restrictions either in number of the antenna or beams. An 8×8 butler matrix was proposed in [5] to increase the number of antenna elements. The same idea and miniaturized structure is proposed in [6].

Nevertheless, in all of these published papers they basically increase the number of antenna elements and consequently increasing the number of elements for butler matrix which are 90 degree couplers and hybrids. It means the overall size of the structure is large and again it needs more number of antenna elements.

In this paper we have proposed a new butler matrix by using a CRLH phase shifter that not only keep the size of the structure compact but also has more tenability with the same number of antenna elements.

II. DESIGN OF A CRLH TRANSMISSION LINE

An equivalent circuit model and the ADS schematic view of the proposed CRLH phase shifter is depicted in Fig. 1. It

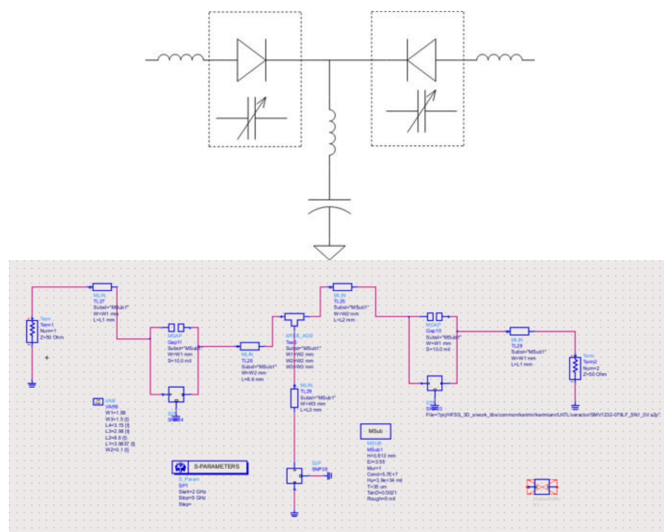
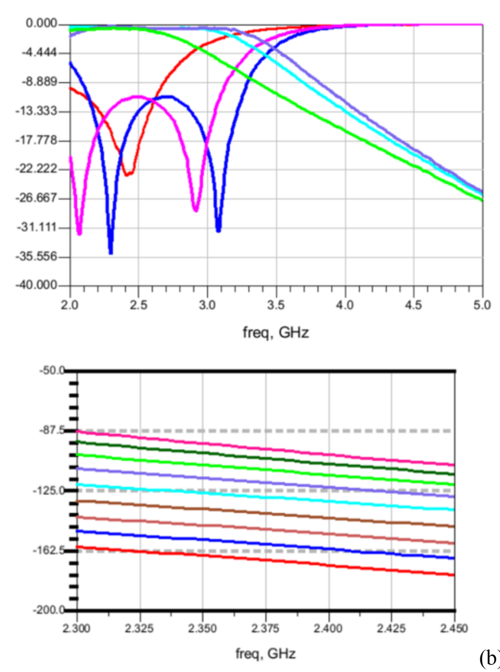


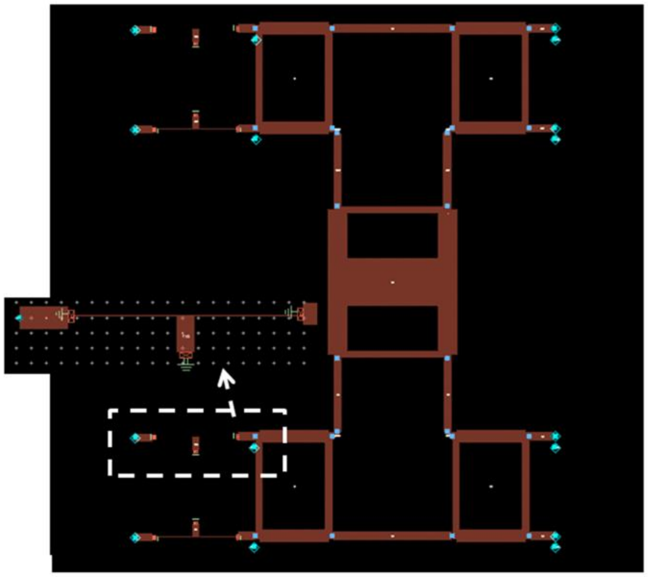
Fig. 1. The circuit model and the schematic view of the proposed CRLH transmission line by using two varactor diodes and a fixed capacitor.



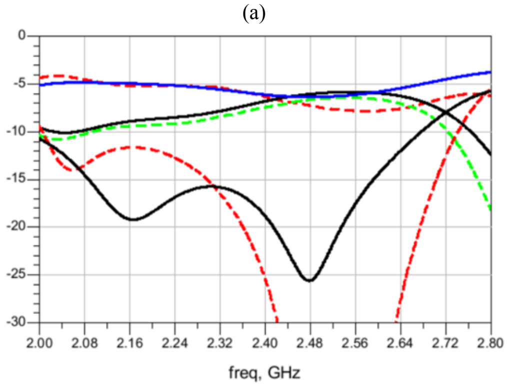
(a)

(b)

Fig. 2. Scattering parameters and the phase response of the proposed phase shifter



(a)



(b)

Fig. 3. (a) Layout view of the proposed extended butler matrix (b) Scattering parameters comparison between conventional and the proposed extended butler matrix

consists of two varactor diode of the Skyworks Solution, a fixed capacitor and transmission lines which acts as an inductor. The varactor diode has a variable capacitor based on a bias voltage. In this project a bias volt up to 8 volt is used. It is worth mentioning that based on the application the bias voltage can be higher or lower than what is used here. Figure 2 shows the scattering parameters and the phase response of the proposed phase shifter. For the simplicity the return loss and insertion loss is shown for three sample voltages; ie, 0, 4, and 8. As it is cleared from the figure 2(a) the return loss satisfied the requirements for our desired 2.4 GHz frequency. The insertion loss for the desired frequency is less than 0.6 dB for all bias voltages. Figure 2 (b) represents the phase response for 9 different bias voltages from zero to 8 volts. 70 degree phase difference is observed for our bias voltages. It should be noted that the scattering parameters of Skyworks Solution is used for the simulation. As a result the variation between each bias voltage is limited by the data. However, a more fine voltage variation and consequently finer phase variation can be achieved by tuning other voltages. The width and length of all transmission line are optimized for all bias voltages to have the best scattering parameters response.

III. Extended Bulter Matrix

The designed phase shifter from the previous section has been used to modify a conventional butler matrix. Figure 3 (a) depicts the layout schematic of the proposed butler matrix. As it is cleared form the figure, four phase shifter is added at the output ports of the butler matrix. The designed extended butler matrix now can be used for a high resolution beam steering antenna. The conventional butler matrix has four main beams with 45, 135, 270, and 315 phase difference. As a result it will be limited to four patterns. By using the proposed phase shifter one can extend the beam steering resolution. The four main beams will be the fundamental beams and by changing the phase of the phase shifter at the end of the butler matrix the number of radiation patterns can be increased. Potentially 4N different radiation patterns can be achieved by the proposed butler matrix. N is the number of bias voltage. Figure 3 (b) shows the comparison between a conventional butler matrix and the proposed butler matrix. The solid curves represent the conventional butler matrix and the dashed-curve shows the proposed butler matrix. As it is cleared form the figure, for both structures the reflection coefficient satisfies the requirements and even a better response has been achieved with the proposed structure. The insertion loss of the proposed butler matrix as it can be seen from the figure has a little more loss compare to the conventional one.

IV. Conclusion

A novel butler matrix by adding a phase shifter at the end of the conventional butler matrix were designed and discussed in this paper. The simulation results show a good response by the ability of increasing the number of radiation patterns direction.

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