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Investigation of the characteristics of phase shifter when connecting additional sections

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Abstract

In this paper, the characteristics of the phase shifter are investigated when connecting micropelax segments. To change the phase at the output of devices, it is necessary to connect or disconnect the sections of the microwave line with the help of pin-diodes installed in the structure. Thus it was obtained that the proposed method allows to expand the possibilities of using phase shifters. The electrodynamic analysis of the proposed design was implemented in the NI-AWR program.

1. Introduction

To date, developers around the world are conducting research aimed at improving the theory and technology of phased array antennas (FAS) and expanding the field of their application [1,2]. With the aid of an electrically controlled device, it is possible to control the orientation of the beam of the antenna array in space, for this the phase between the emitters must vary in the process of operation according to a certain law. Controlled devices with lumped elements contain elements with electrically controllable parameters.

The principle of their work is that under the influence of current or voltage, the parameters of the elements that make up such a device change. So it is worth highlighting semiconductor pin-structures, which due to their relative simplicity could find the widest application in the designs of phase shifters (FS). Devices that are able to control the phase of the signal in the microwave path are called phase shifters. Phase shifters can be divided into two main groups: semiconductor and ferrite.

For such devices, the main parameters are: the number of different phase states, the phase shift, its stability, the operating frequency band, etc. Thus, in order to control the excitation phase of the radiators, as a rule, phase shifters of discrete action are used in the array of antenna arrays. The merits of semiconductor phase shifters include small size and weight, high switching speed, simplicity of control devices. In order to realize these advantages in practice, semiconductor phase shifter are manufactured in strip and microstrip design, which makes it possible to use cheap technology for the production of printed circuits.

To date, the following types of phase shifter are widely known: a loaded line, a switched line and based on quadrature couplers [3-12]. However, today well-known phase shifters are not used in their usual design, they are subject to various circuitry solutions that increase their effectiveness. In this paper, we will investigate the possibility of connecting additional microstrip segments using pin-diodes, which will increase the number of possible phase variations at the output of the phase shifter.

2. Design

Initially, standard designs of phase shifters were designed in the AWR program [13]. The material used was a standard FR-4 microwave material, with a dielectric constant $\varepsilon = 4.4$, a dielectric loss tangent $\tan\delta = 0.02$, and a thickness $h = 1$ mm. For greater reliability of the obtained results, the models used real capacitances and pin-diodes.

Initially, a phase shifter based on a quadrature coupler was investigated, with a standard implementation, the phase shifter can provide only one phase change at the output of the device, which limits its use. Therefore, a design solution is used that will eliminate this drawback by connecting an additional loop. This allows you to get three different phase values at the output of the device when switching the state of the p-i-n-diodes. It should be noted that in order to eliminate the influence of the power systems of two separate p-i-n-diodes, a capacitor was added to the segment of the additional pluggable loop, which provides a DC break.

The topology of the three-position phase shifter is shown in Fig. This design allows you to get a phase change of 45, 90 and 180 degrees, respectively. The principle of operation of such a phase shifter remains the same and is based on connecting or disconnecting additional sections of microwave lines that extend the path of the wave along the microstrip line, thus providing the necessary phase shift.

When the p-i-n-diodes are open, the microwave signal travels to the end of the microstrip line from it and passes to the output of the phase shifter, from where the signal is already fed to the input of the radiator. The characteristics of the proposed construction are shown in Fig. 2-3. In the frequency band 1.9-2.1 MHz, the insertion loss level does not exceed 1.5 dB, the level of return loss is not worse than 13 dB. Allows you to obtain a phase change at the output of 45.90 and 180 degrees.

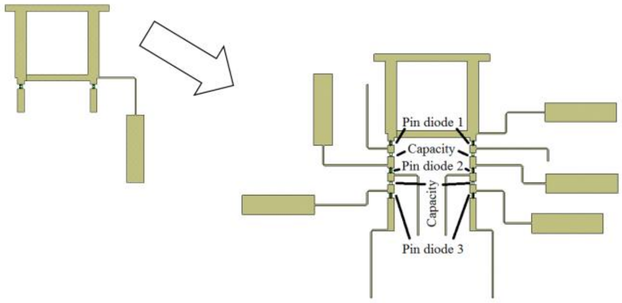

Figure 1. The topology of the phase shifter

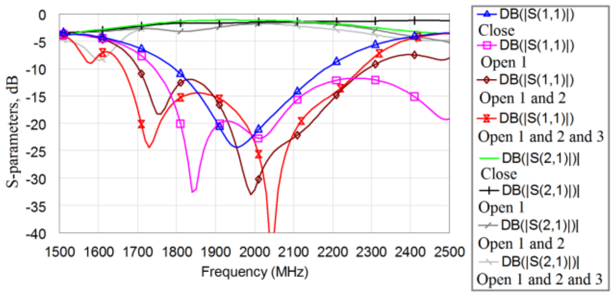

Figure 2. Graph of the dependence of the S-parameters on the frequency

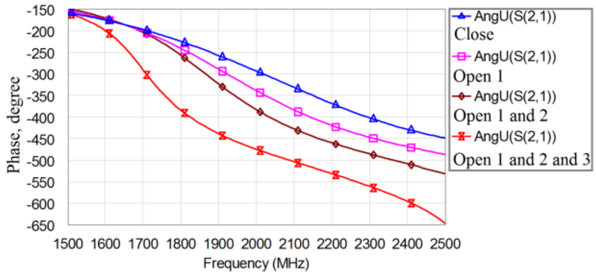

Figure 3. Phase value depending on the applied voltage

The next design for the study is a phase switch of the "switched line" type. The topology of the three-position phase shifter is shown in Fig. The principle of operation of such a phase shifter is based on switching between microwave lines of different length, thus providing the necessary phase shift. Depending on the length of the selected segment, the phase entering the output of the phase shifter will change.

It is worth noting that to implement additional phase shifts on the phased rotator of the "switched line" type, it is necessary to have the overall microstrip capacitances in the diode supply system to replace the capacitors with the chip, this will allow increasing the number of possible phase variations at the output of the phase shifter. The characteristics of the proposed construction are shown in Fig. 5-6. In the frequency band 1.9-2.1 MHz, the level of insertion loss does not exceed 1.2 dB, the level of return loss is not worse than 15 dB. Allows you to obtain a phase change at the output of 0, 47 and 240 degrees.

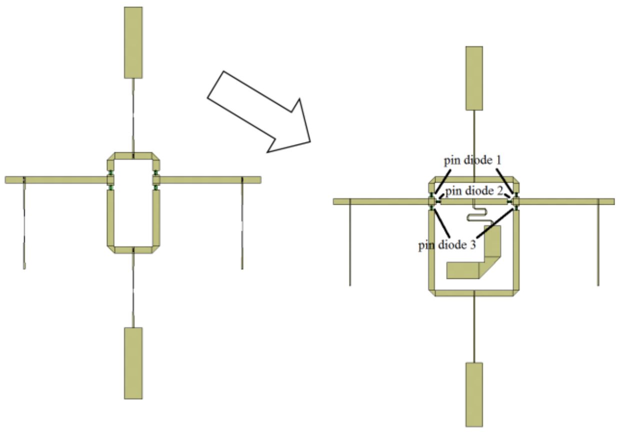

Figure 4. The topology of the phase shifter

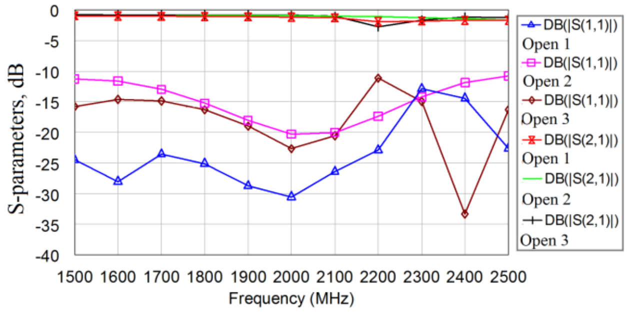

Figure 5. Graph of the dependence of the S-parameters on the frequency

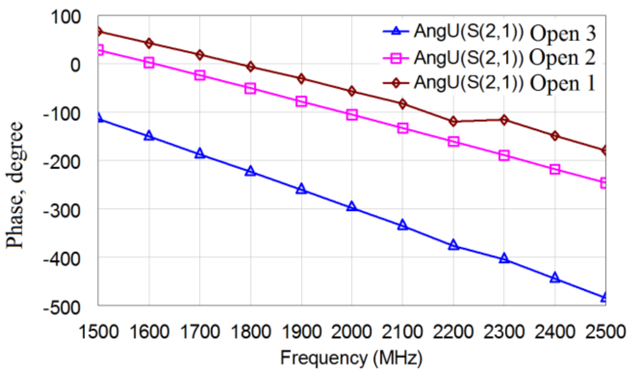

Figure 6. Phase value depending on the applied voltage

The last design for the study is a phase-shifter of the "loaded line" type. The topology of the three-position phase shifter is shown in Fig. The characteristics of the proposed construction are shown in Fig. 8-9. In the frequency band 1.9-2.1 MHz, the insertion loss level does not exceed 1.5 dB, the level of return loss is not worse than 13 dB. Allows you to get the phase change at the output at 0, 15 and 26 degrees.

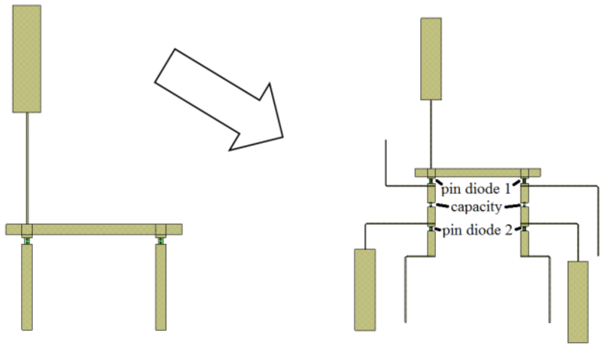

Figure 4. The topology of the phase shifter

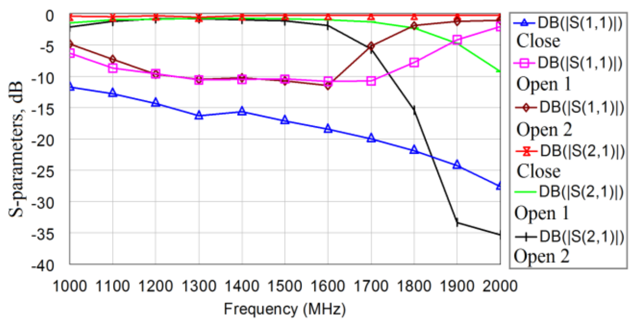

Figure 5. Graph of the dependence of the S-parameters on the frequency

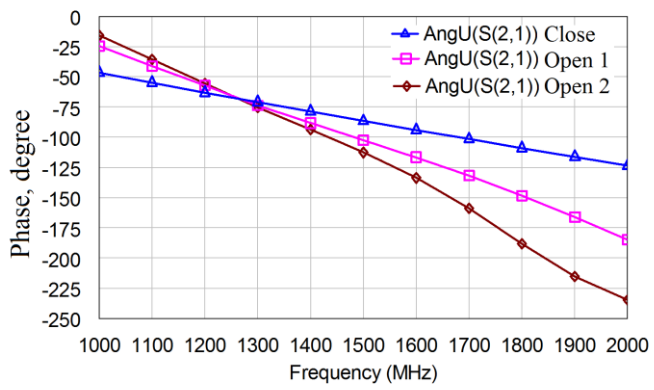

Figure 6. Phase value depending on the applied voltage

3. Conclusion

In this paper, three designs of widely known phase shifter were designed - this is based on quadrature bridges, a loaded line, a switched line. By connecting additional loops, we received an additional phase change at the output of the phase shifter. The magnitude of the controlled phase shift is controlled by the state of the pin-diodes, which allow you to disconnect or connect additional sections. As a result of the simulation, good values of PFC and SWR were obtained. The proposed method for implementing phase shifts can be used in the array of antenna arrays. They can also be manufactured using standard methods of manufacturing printed circuit boards.

6. Acknowledgements

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