The Structure and Characteristics of a Revolving Variable Phase Shifter Using Slot Couplings

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1. Introduction

Base station antennas for the mobile communication system appropriately set their service areas by tilting their radiation beams slightly downward. Because of the traffic change or the increasing new base stations, the antenna sometimes must be adjusted their service area by varying the tilt angle. It is more desirable to tilt the radiation beam by electrical manner than mechanical one. Variable phase shifters which can adjust the exciting phase of antenna elements are necessary to electrically change the tilting angle of the antenna. In this paper a variable phases for 2GHz band is described.

This phase shifter is composed of an input-output substrate with input-output ports, and a revolving circular substrate which is located in the center of the input-output substrate. This phase shifter is characterized by the structure that two substrates coupled using slots. By revolving the circular substrate, the output phase is changed according with the movement of the coupling point.

Since this phase shifter is consisted of only two substrates and a supporting structure, it is simple and light in its weight. And since it also has no metallic rubbing parts and no nonlinear elements, noise characteristics and inter modulation characteristics are excellent.

In this paper, the structure of the phase shifter, the mechanism of the slot coupling and electrical characteristics such as VSWR and phase characteristics are described. It's also shown that the phase shifter has sufficient characteristics at 2GHz bands.

2. Structure and principle of the phase shifter

In figure 1 structure of the phase shifter which has one input port and two output ports are shown. It is consisted of an input-output substrate and a revolving substrate. The revolving substrate is overlaid on the input-output one.

The power from the input port passes through the input line and travels to the coupling line via Slot A on the revolving substrate. The high frequency power in the coupling line of the revolving substrate travels via Slot B to the output line of the input-

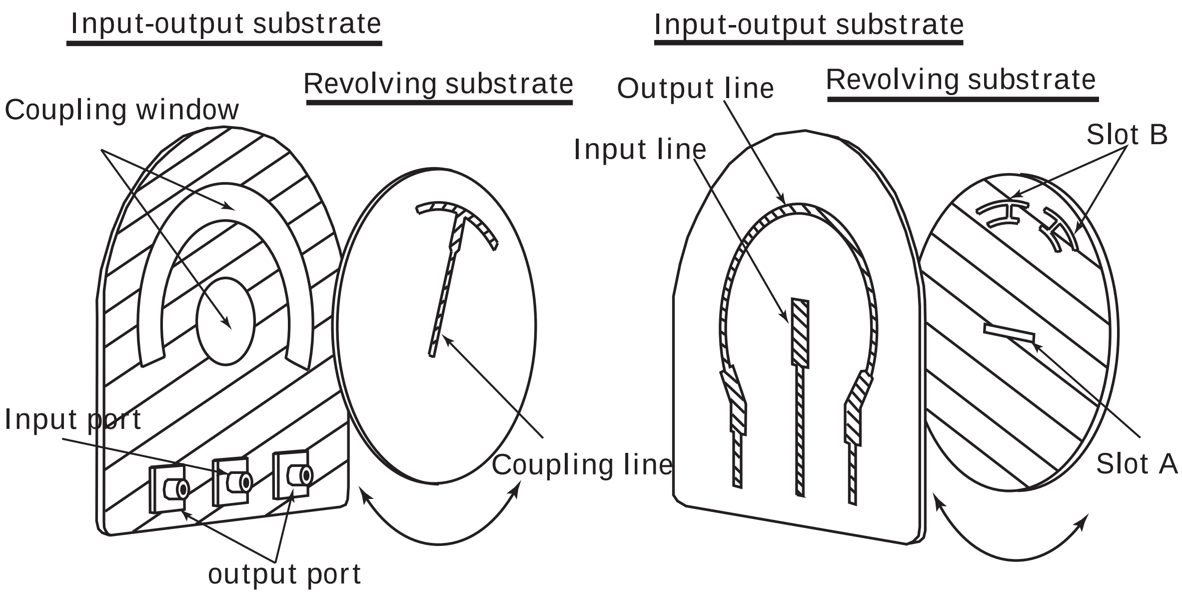

Fig.1 Structure of phase shifter with one input and two output ports
(the front and the back)

output substrate , and arrives at the output port.
Because of this structure, the transfer between substrates performed by slot coupling, and the surface of the substrate is coated, there is no metallic rubbing during revolution.

As the slot A is located on the center of the substrate, the electrical characteristics vary with the revolving angle. When the slot A and the coupling line are perpendicular to each other (revolving angle is 0 °), the VSWR is less than 1.2 over the band 1.9GHz～2.2GHz and the insertion loss is within 0.1dB.

However, at the revolving angle ±45 ° the worst value of the VSWR becomes 1.4 over the same bandwidth, and the more the revolving angle the worse the VSWR. From the above results, the usable revolving angle range is set between -45 ° and +45 ° , and the characteristics are evaluated within this range.

The slot B is located on the radius R of the revolving subs trate, and is cut so as to perpendicularly intersect with the output line on the same radius R of the input-output substrate. The slot B is composed of two slots. With only one slot, the power propagates both directions of the output line in opposite phase. If the slot is composed of two slots and the distance of the slots is set to a half of the wavelength, the power propagates both directions of the output line in identical phase.

Forming the slots in the manner mentioned above, the input power is divided into the equal power of the same phase, when the revolving substrate is not revolved. When the revolving substrate revolves, the coupling point of the input-output substrate moves according to the revolving angle θ (degree), we will obtain the following expression lead/delay phase ϕ (degree), depending on the transmission line length difference from the coupling point to the output ports

$$\phi = \pm(2\pi \times R \times \theta) / (\lambda \times \text{reduction ratio of the output line})$$

3. Characteristics of a trial phase shifter

Experimental results of a trial phase shifter with one input port and two output ports are shown in figure 1. The substrate used in the phase shifter is 1.6mm in the thickness, the copper foil is 70μm, tanδ is 0.02, and the dielectric constant εr is 10.45.

In figure 2 measured return loss characteristic is shown. It is less than -16dB over the frequency band 1.92GHz～2.17GHz. The relative bandwidth under -13.9dB (VSWR <=1.5) is 22%.

In figure 3 insertion loss characteristic is shown. The loss is -3.8dB at 1.92GHz and -3.9dB at 2.17GHz. As the distribution loss of the phase shifter is -3dB, actual transmission loss is 0.9dB on the average. The frequency characteristics is stable.

In figure 3 the phase characteristic versus the revolving angle is shown. Measured frequency is 1.92GHz. For the revolving range from 45° to -45°, the output phase changes from 160° to -160° and the output phase proportionally changes with the

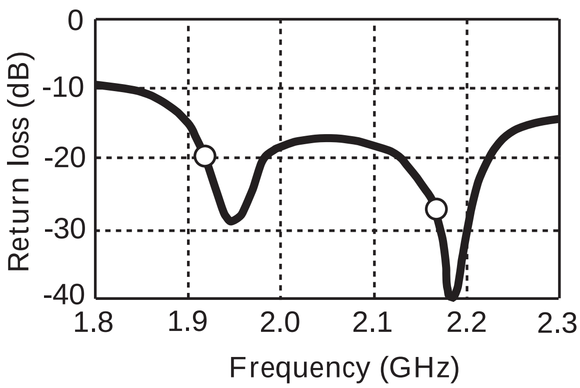

Fig.2 Measured return loss characteristic

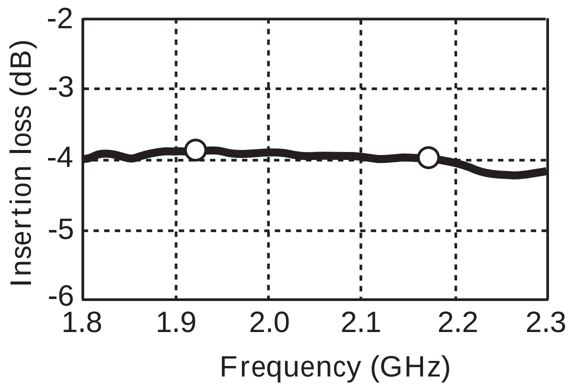

Fig.3 Measured insertion loss characteristic

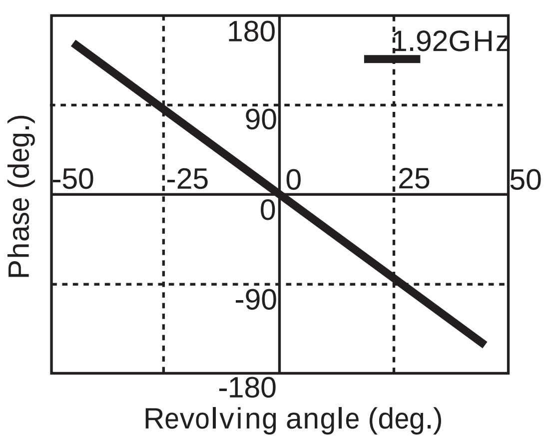

Fig.4 Measured phase characteristic versus the revolving angle

revolving angle.

As mentioned above, we obtained preferable results both in the return loss characteristic and the insertion loss for the phase shifter having one input port and two output ports. We could also confirm that the output phase proportionally changes with the revolving angle.

4. Multi output ports phase shifter

Using the same principle using slot coupling, we can construct a multi output ports phase shifter by locating plural coupling lines on the same substrate. The structure of a phase shifter having one input port and seven output ports is shown in figure 5. As the fourth port of the seven output ports phase shifter is the center port, it is not necessary to vary its output phase. So, its power is divided on the input-output substrate. The rest of the input power is transferred to the revolving substrate and is divided into three parts. They are guided to the output lines of different radius.

As the phasing amount is proportional to the radius of the output line, we can realize a phase shifter having many output ports by adjusting the radius properly.

5. Conclusion

In this paper we described the structure and characteristics of a variable phase shifter using a slot coupling for the 2GHz bands. Because this phase shifter has a simple structure, it is simple and light in its weight. It also has preferable noise characteristics and inter modulation characteristics. Insertion loss characteristic will be improved by using materials with low tan δ, such as alumina substrate.

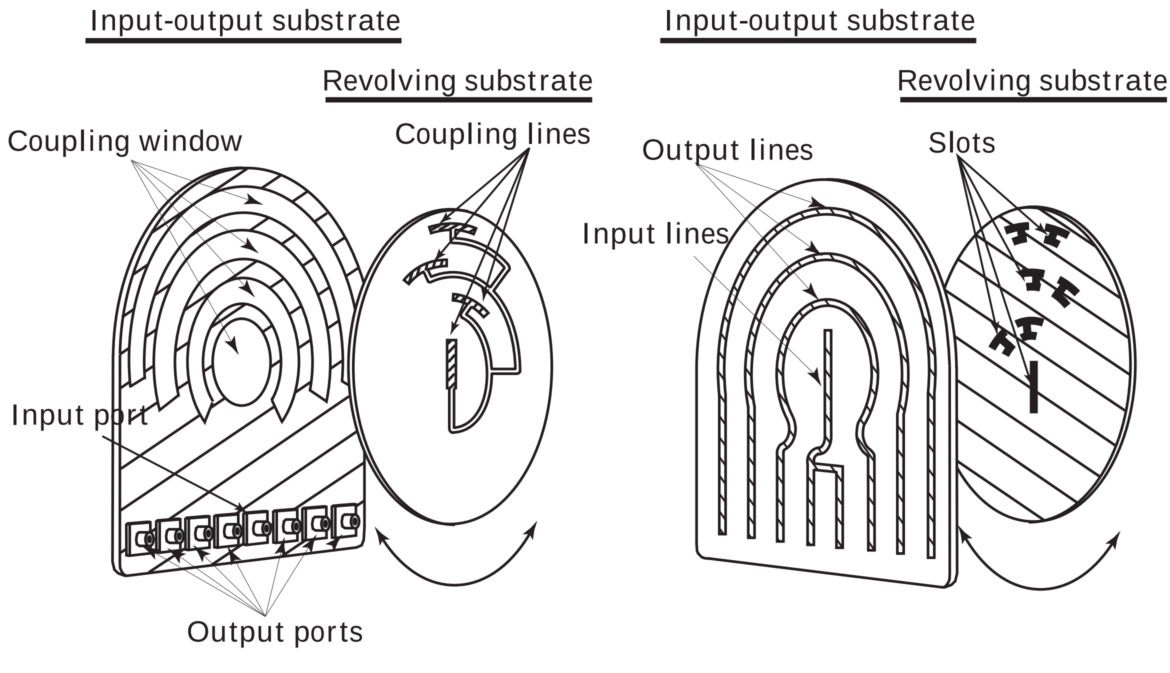

Fig.5 Structure of phase shifter with one input and seven output ports (the front and the back)