Dual PAAs Using the Same Phase Shifters of BFN

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Abstract

PAA (Phased array antenna) has the capability to scan from one beam direction to another beam direction within few microseconds. The BFN (beam forming network) is the part of phased array antenna. The BFN is composed of power dividers and phase shifters. The phase shifters are controlled by BSC (beam steering computer). Usually, one beam pattern is generated by one BFN. Dual identical phased array antennas with symmetry beam patterns is simulated and designed by the same BFN. These two patterns are symmetry in azimuth plane. The performance of new type of phase shifter and its applications will be detailed discussed in this paper.

Keyword: Phased array antenna, phase shifter, BFN

1. Introduction

From one beam direction to another beam direction is steering by antenna positioner for traditionally communication or radar system. Except for the low data rate, the time consuming is also concerned. Most of single beam phased array can solved these problems. BFN is the key of the phased array antenna. Phase shifters play an important rule at BFN. In general, there are ferrite phase shifter and PIN diode phase shifter with digital control phase bits. These types of phase shifters are two ports network. In this paper, phase shifters with three ports network is designed as shown in Fig.1. Port 2 and port 3 are connected to separate antenna element of two PAAs. If the phase shifters are controlled by BSC to θ_0 direction, then two beams at θ_0 and $-\theta_0$ for two symmetry antenna patterns of PAAs will be generated.

2. Operation of Dual Beams Phased Array Antenna

In order to provide the dual PAAs, three ports phase shifter of BFN, as shown in Fig.1, will be discussed. The phase shifter is composed of 1:2 power divider, switches for 0° and 180°, 6 bits step attenuators, and 90° hybrid. If the input voltage of phase shifter is 1 volt, then the outputs of ports 2 & 3 are expressed as,

$$
\begin{aligned}
V_2 &= |V_2| \angle V_2 \\
&= \frac{1}{2}\sqrt{(F_i a_i)^2 + (F_q a_q)^2}\, e^{j\left[\tan^{-1}\left(\frac{F_i a_i}{F_q a_q}\right) - \pi\right]}
\end{aligned}
\tag{1}
$$

$$V_3 = |V_3|\angle V_3$$
$$= \frac{1}{2}\sqrt{(F_i a_i)^2 + (F_q a_q)^2}\, e^{j\left[\tan^{-1}\left(\frac{F_q a_q}{F_i a_i}\right) - \pi\right]} \quad (2)$$

The value of F_i, F_q are either -1 or +1 for switching the microstrip line with or without the extra half wavelength. a_i and a_q are the attenuation value of step attenuator. The value of a_i and a_q is smaller than 1 and greater than zero.

The sum of phase V_2 and phase V_3 is simplified as

$$\angle V_2 + \angle V_3 = \tan^{-1}\left(\frac{F_i a_i}{F_q a_q}\right) + \tan^{-1}\left(\frac{F_q a_q}{F_i a_1}\right) - 2\pi \quad (3)$$

Since

$$\tan^{-1}\left(\frac{F_i a_i}{F_q a_q}\right) + \tan^{-1}\left(\frac{F_q a_q}{F_i a_1}\right) = \frac{\pi}{2} \quad (4)$$

Then Eq.3 is simplified to $-\frac{3\pi}{2}$ radians. If the unit is expressed in degrees, then

$$\angle V_2 + \angle V_3 = -270^\circ \quad (5)$$

The properties of phase shifters as shown in Fq.5 can be used for two identical PAAs. The beam maximum directions for these two PAAs are symmetry in opposite directions.

3. Simulation Results of Dual PAAs

In order to verify the properties of phase shifter can be used for two PAAs, simulation results will be expressed.

Two identical PAAs are in parallel with antenna element spacing is $\lambda/2$. Each PAA is composed of 8 antenna elements and beam scan of PAA 1 is at -20°. Ports 2 & 3 of N phase shifters at BFN are shared by dual identical PAAs as shown in Fig.2. The calculated phase outputs of 8 phase shifters are shown in table 1. Two symmetry beam directions with main beams at -20°, 20° are generated as shown in Fig.3.

4. Conclusions and Future Works

New type of phase shifter for BFN of identical PAAs is simulated and developed. The relationship of two phase outputs of phase shifter has been discussed. By using this property, BFN with this type of phase shifters can be shared by two identical PAAs. Two symmetry opposite beam patterns can be generated by these two PAAs.

Hardware implementation of phase shifter is designed as shown in Fig.4. The computer modeling of BFN is shown in Fig.5. The hardware of BFN is shown in Fig.6. The computer model of antenna element and prototype is shown in Fig.7. Test results will be detail discussed during the presentation.

Acknowledgment

This work was supported by the National Science Council, Taiwan, R.O.C., under contract NSC 96-2221-E-161-001.

References

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Figures

Phase outputs / Antenna element	Array 1	Array 2
1	0°	-270°
2	-61.6°	-208.4°
3	-123.1°	-146.9°
4	-184.7°	-85.3°
5	-246.3°	-23.7°
6	-307.8°	37.8°
7	-369.4°	99.4°
8	-430.9°	160.9°

Table 1: Phase outputs for at two phased arrays with beam scan at -20° for array 1

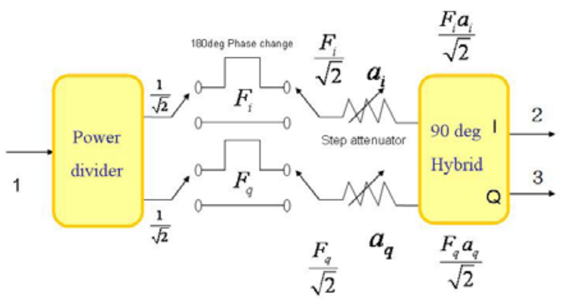


Fig.1: Three ports phase shifter

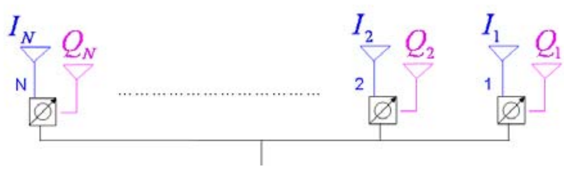


Fig.2: Two phased arrays shared the same phase shifter outputs

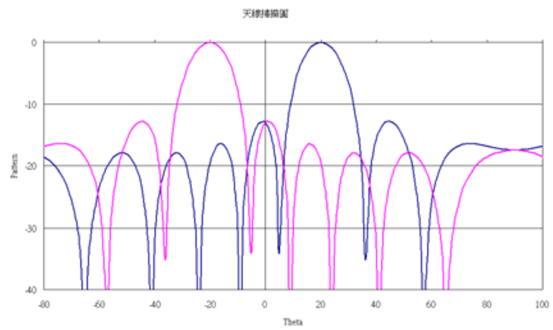


Fig.3: Two beam patterns for the two phased arrays with scan at 20 degrees

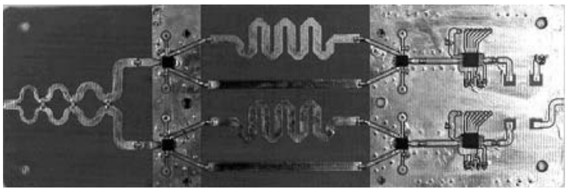


Fig.4 Prototype of phase shifter

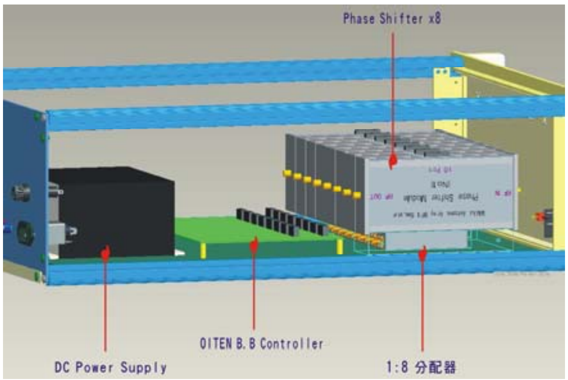
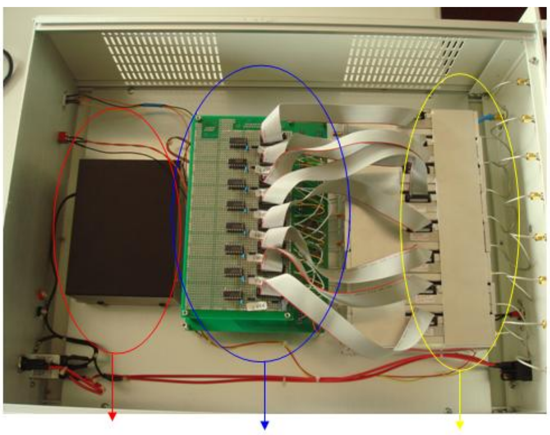
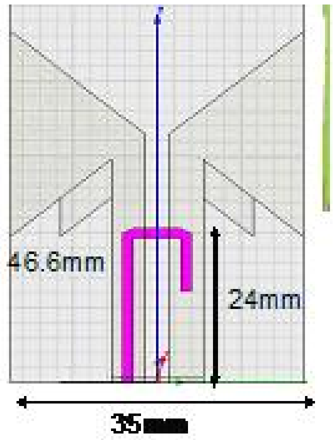


Fig.5: Computer modelling of BFN

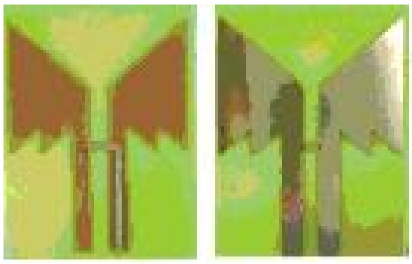


電源供應器　相移器　波束掃描控制器

Fig.6: Mechanical structure of BFN



a. Computer model



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b. Prototype

Fig.7: Antenna elements