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A Simple Beam-switching Printed Array Antenna Composed of Strips and Slots

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1. Introduction

A Printed antenna generating a circularly polarized conical pattern can be effectively employed as a land-mobile antenna for satellite communications. Because of the conical pattern and fairly wide beamwidth in a vertical plane, there is almost no need for tracking the satellite. The authors have presented the design of a printed antenna composed of strips and slots generating circularly polarized conical patterns [1]. However, the original design is not suitable for the application of the higher gain. In order to get the higher gain, various types of antennas with an electronically auto-tracking mechanism have been studied recently [2]-[4]. Such antennas require phase shifters or switches to form a desired beam. In this paper, we propose a beam-switching printed array antenna composed of strips and slots.

2. Antenna configuration

Figure 1 shows two types of Circularly Polarized Printed Antenna Composed of Strips and Slots (CP-PASS). CP-PASS is a kind of circularly polarized printed antenna [5]. A pair of strip dipole and slot radiates circular polarization. On the conical-beam CP-PASS as shown in Figure 1(a), each pair is arranged radially and fed in phase through a four-port power divider. On the other hand, a beam-switching CP-PASS, we present in this paper, is shown in Figure 1(b). This antenna uses four 1-bit (180 degrees) phase shifters or switching elements. When four 1-bit phase shifters are used, one pair of strip and slot is fed 180° out of phase, and the others are fed in phase in order to form a directive pattern in the azimuthal direction. This antenna covers whole azimuthal direction by selecting the element fed 180° out of phase. When four switching elements are used, only three elements are fed in order to form a directive pattern.

In this paper, we investigated two arrangements of the elements. One is a radial arrangement as shown in Figure 2(a) and the other is a parallel arrangement as shown in Figure 2(b).

3. Calculation model

To predict radiation performances of this beam-switching array antenna, equations for the radiation patterns will be derived as follows.

In the case of radial arrangement, assuming that the effect of the mutual coupling can be neglected, the nth strip dipole of which center is located at $(r,\phi,z)=(r_{st0},\phi_{stn},h)$ and the nth slot of which center is located at $(r,\phi,z)=(r_{sl0},\phi_{sln},0)$ produce the electric far fields as follows

$$E_\theta^{stn}(\theta,\phi)=-2jE_0 I_{n0} A_{stn}(\theta,\phi) C_{stn}(\theta,\phi)\cos\theta\cos(\phi-\phi_{stn})\sin(k_0\sqrt{\varepsilon_r}h\cos\theta)$$
$$E_\phi^{stn}(\theta,\phi)=2jE_0 I_{n0} A_{stn}(\theta,\phi) C_{stn}(\theta,\phi)\sin(\phi-\phi_{stn})\sin(k_0\sqrt{\varepsilon_r}h\cos\theta)$$

$$E_\theta^{sln}(\theta,\phi)= E_0\frac{K_{n0}}{\zeta_0}A_{sln}(\theta,\phi)C_{sln}(\theta,\phi)\sin(\phi-\phi_{sln})$$
$$E_\phi^{sln}(\theta,\phi)= E_0\frac{K_{n0}}{\zeta_0}A_{sln}(\theta,\phi)C_{sln}(\theta,\phi)\cos\theta\cos(\phi-\phi_{sln})$$

$$A_{stn,sln}(\theta,\phi) = \exp\{jk_0 r_{st0,sl0} \sin\theta \cos(\phi - \phi_{stn,sln})\}$$

$$C_{stn,sln}(\theta,\phi) = \frac{2\pi a_{st,sl} \cos\{k_0 a_{st,sl} \sin\theta \cos(\phi - \phi_{stn,sln})/2\}}{\pi^2 - \{k_0 a_{st,sl} \sin\theta \cos(\phi - \phi_{stn,sln})\}^2}$$

where I_{n0} and K_{n0} are complex amplitudes of electric current and magnetic current, respectively. E_0 is a constant, ζ_0 is the free space wave impedance, k_0 is the wave number and h is the substrate thickness. Therefore, the total far field from the overall antenna is expressed by

$$\vec{E}^{\,total}(\theta,\phi) = \vec{\theta} \sum_{n=1}^{4} \left(E_\theta^{stn}(\theta,\phi) + E_\theta^{sln}(\theta,\phi)\right) + \vec{\phi} \sum_{n=1}^{4} \left(E_\phi^{stn}(\theta,\phi) + E_\phi^{sln}(\theta,\phi)\right)$$

4. Numerical results

At first, we calculated the radiation pattern of conical-beam CP-PASS. Figure 3(a) shows the contour of directive gain in the case of radial arrangement and Figure 3(b) shows that in the case of parallel arrangement. The former result was almost uniform in the azimuthal direction, but the latter showed considerable deviation in the azimuthal direction. The maximum gain of the former was 6.6dBi at an elevation angle 55° and that of the latter was 6.7dBi at an elevation angle 56° .

Next, we calculated the radiation pattern of beam-switching CP-PASS. Figure 4(a) shows the directive gain at radial arrangement. The pair #1(st1 and sl1) is fed 180° out of phase, and the others (pairs #2, #3 and #4) are fed in phase. In this case, the maximum gain was 9.2dBi at an azimuthal angle $\phi = 135°$ and an elevation angle 63° . In the case of parallel arrangement, the maximum gain was 10.9dBi at $\phi = 180°$, an elevation angle 63° . It is shown that the maximum gain in the parallel arrangement is higher than that in the radial arrangement.

Figure 5 shows the results when three pairs except pair #1 are fed. The maximum gain in the case of radial arrangement was 9.9dBi (an elevation angle 59°), and in the case of parallel arrangement, it was 10.5dBi (an elevation angle 62°). It is shown that only three-pair elements are able to construct a beam-switching array.

5. Conclusions

We have proposed a simple beam-switching printed array antenna composed of four-pair strips and slots. By using four phase-shifters or switches, this proposed antenna will be able to cover whole azimuthal direction. We have calculated the directive gain, and showed that these would get a higher directive gain compared to the conventional conical-beam CP-PASS. Future work is lowering the elevation angle.

References

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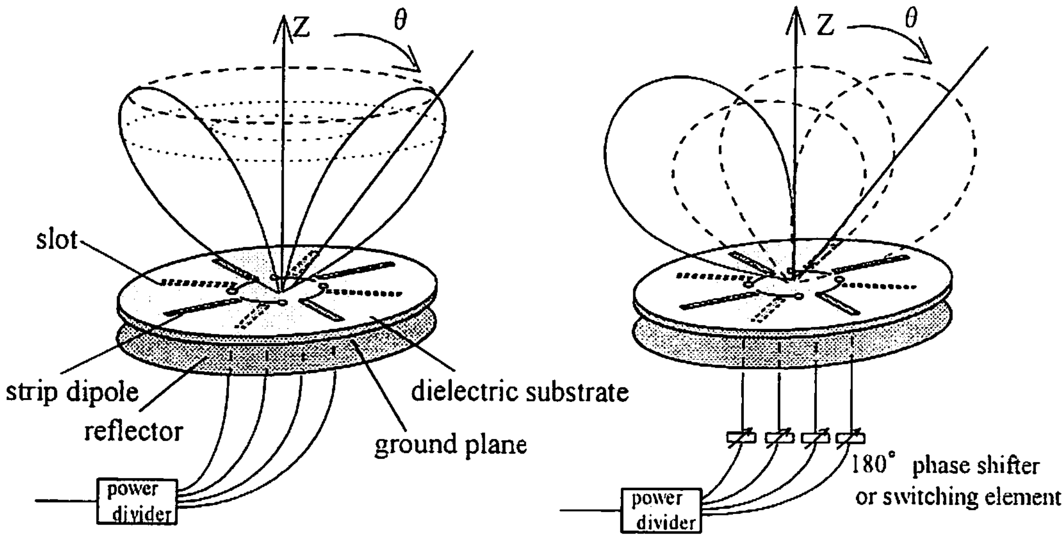
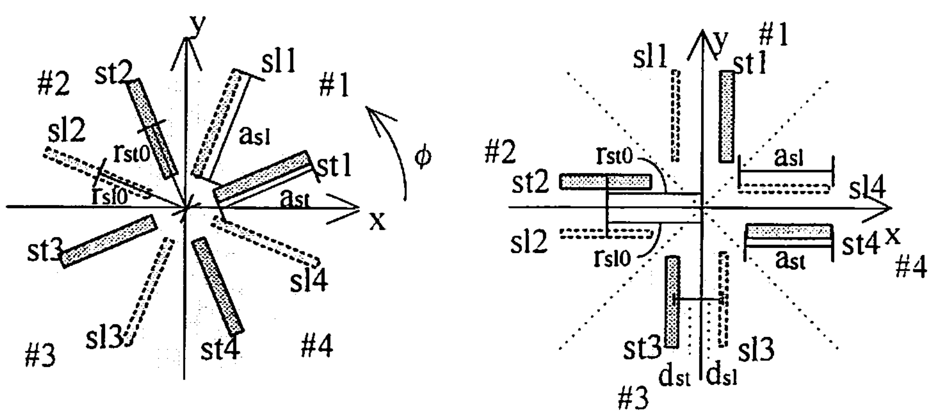


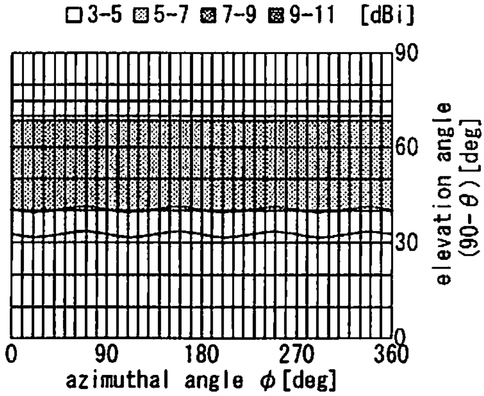
(a) conical-beam antenna (b) beam-switching antenna

Figure 1 Applications of CP-PASS for land-mobile antenna

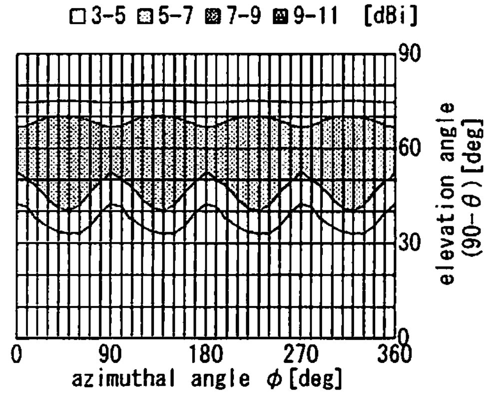


(a) radial arrangement (b) parallel arrangement

Figure 2 Arrangements of four pairs of strip and slot

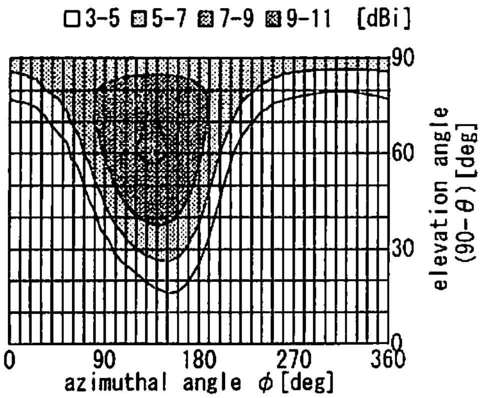


(a) radial arrangement

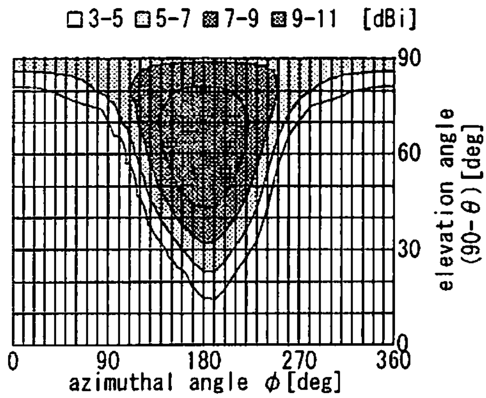


(b) parallel arrangement

Figure 3 Directive gain of conical-beam CP-PASS (#1-#4 are fed in phase)

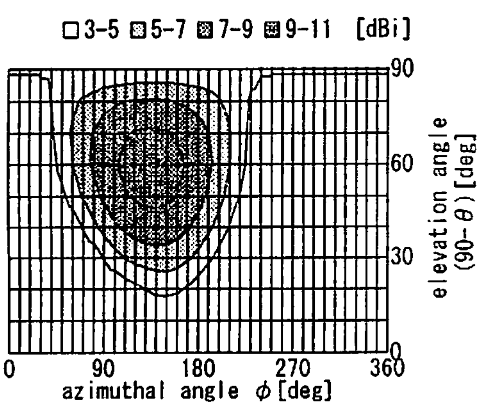


(a) radial arrangement

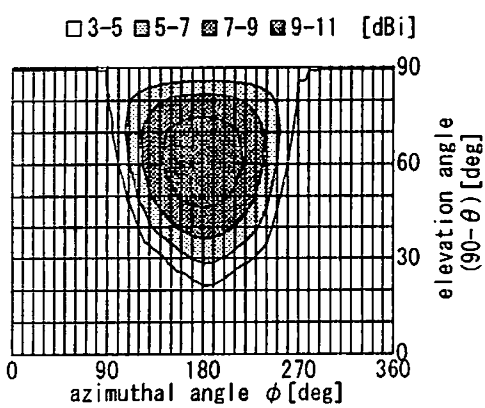


(b) parallel arrangement

Figure 4 Directive gain of beam-switching CP-PASS (#1 is fed 180° out of phase)



(a) radial arrangement



(b) parallel arrangement

Figure 5 Directive gain of beam-switching CP-PASS (#2, #3 and #4 are fed)