Dual Beam Antenna for 6-Sector Cellular System

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Abstract- **This paper proposes dual beam antennas for 6-sector cellular systems using multi-element array, suppressing the side lobe level to interfere with adjacent cell area. Dual beam is given by phase controlled feed circuit and parasitic elements.**

I. INTRODUCTION

To increase the channel capacity of current cellular systems, multi-sector antennas are widely introduced. Recent high density base station siting requires 6-sector antenna with the half power beam width less than 60 degree. A narrow beam width is obtained by a wide antenna size, however it is necessary to develop small sized base station antenna due to a lack of place of base station installation.

This paper proposes dual beam antennas for 6-sector base station antenna. The dual beam antenna consists of several antenna elements and a feed circuit to tilt two beams toward ± 30° from the front direction. An array antenna has side lobes and the first side lobe interfere another main beam. A key design issue is to suppress this side lobe level in this dual beam antenna. We examine 2, 3 and 4-elemnt array to obtain dual beam antenna for 6-sector systems.

II. RELATION BETWEEN SIDE LOBE AND ELEMENT NUMBER

First, we show the half power beam width (HPBW) and side lobe level of 2-element array with main beam tilting of ± 30° at 2GHz. This beam tilt is given by exciting antenna elements by 3dB 90° hybrid coupler. As shown in Fig. 1, we set two dipoles with the spacing d=0.5λ placed above a ground plane of 180 × 450mm with the height h=0.25λ. Its radiation pattern is shown in Fig. 2. The pattern has the tilt angle of ± 28°, the HPBW of 54.5° and the first side lobe level of -6.2dB. We should suppress the interference of the adjacent main beam, then we need to suppress the first side lobe level less than -10dB [1]. And, we show the HPBW and the side lobe level of 3-element array with main beam tilting of ± 30°. As shown in Fig. 3, we set three dipoles with the spacing d=0.5λ placed above a ground plane of 180 × 450mm with the height h=0.25λ. This beam tilt is given by exciting antenna elements by the phase difference as in Table 1. Its radiation pattern in Fig. 4 shows that the tilt angle of ± 30°, the HPBW of 42.5° and the first side lobe level of -9.52dB. Both of the HPBW and the side lobe level of 3-element array are suppressed compared with 2-element's ones, however it is difficult to make the feed circuit to provide the excitation phase difference in Table. 1.

TABLE 1
3-ELEMENT ARRAY IN FIG. 3

Tilt angle	Port1	Port2	Port3	Excitation phase difference
+30°	90°	0°	-90°	-90°
-30°	-90°	0°	90°	90°

TABLE 2
4-ELEMENT ARRAY IN FIG. 5

Tilt angle	Port1	Port2	Port3	Port4	Excitation phase difference
+30°	-90°	180°	90°	0°	-90°
-30°	0°	90°	180°	-90°	90°

Next, we show the HPBW and side lobe level of 4-element array with main beam tilting of ± 30°. As shown in Fig. 5, we set four dipoles with the spacing d=0.5λ placed above a ground plane of 280 × 450mm with the height h=0.25λ. This beam tilt is given by exciting antenna elements by the excitation phase difference as in Table 2. Its radiation pattern is shown in Fig. 6. The pattern has the tilt angle of ± 30°, HPBW of 30° and the first side lobe level of -10.4dB.

These results show that the array to obtain dual beam antenna can suppress the side lobe level by increasing exciting element numbers, and it is better to use even element number for the feed circuit.

III. 4-ELEMENT ARRAY

In preceding section, we show 4-element array suppressing the first level side lobe level less than -10dB, however it is difficult to make the feed circuit as shown in Table. 2. In this section, we use a 4-way butler matrix for the feed circuit. A 4-way butler matrix gives the excitation phase differences ± 45° and ± 135°, respectively [2]. When we incline the antenna by +15° as shown in Fig. 7, a tilted beam toward +15° by the phase difference of -45°, and toward -45° by the phase difference of +135° by the 4-way butler matrix in Table 3, then we obtain tilted main beam toward ± 30°. Its radiation pattern is shown in Fig. 8. The patterns by the phase difference of -45° have the tilt angle of +30°, the HPBW of 27° and the first side lobe level of -11.2dB, and by the phase difference of +135° the tilt angle of -30°, the HPBW of -31° and the first side lobe level of -7.88dB. In [1] and [3], the adequate performances of the antenna are the first level side lobe level to less than -10dB and the HPBW of 30° ~ 45° to suppress the interference with adjacent cell area.

TABLE 3
4-WAY BUTLER IN FIG. 7

Tilt angle	Port1	Port2	Port3	Port4	Excitation phase difference
+30°(+15°)	135°	90°	45°	0°	-45°
-30°(-45°)	45°	180°	-45°	90°	135°

A 4-way butler matrix provides tilted beam toward 4 directions, while we need only two directions for the application of base station antenna, and it is not necessary for symmetric antenna structure. To suppress the side lobe level of -30° we adjust the antenna height as shown in Fig. 9, where we set three dipoles with the spacing d=0.5λ placed above a ground plane of 280 × 450mm with the heights from the left are 0.2425λ, 0.2475λ, 0.2525λ, 0.2575λ, respectively. The radiation pattern shown in Fig. 10 by the phase difference of -45° has the tilt angle of +27°, the HPBW of 27° and the first side lobe level of -10.2dB, and by the phase difference of +135° the tilt angle of -33°, the HPBW of -34° and the first side lobe level of -8.58dB. This shows that inclining the antenna by +15° can suppress the first side lobe level at the -30° direction slightly. Then we use parasitic elements of director and reflector to improve radiation pattern as shown in Fig. 11. We set director in the middle of plane with the height of 0.4λ, and reflector by 0.9λ from the right of the middle of plane with the height of 0.4075λ. The radiation pattern shown in Fig. 12 by the phase difference of -45° has the tilt angle of +27°, the HPBW of 29.5° and the first side lobe level of -10.4dB, and by the phase difference of +135° the tilt angle of -33°, the HPBW of -36° and the first side lobe level of -11.1dB. Its can suppress the first side lobe to less than -10dB.

IV. CONCLUSION

In this paper, we revealed the relation between beam tilting and element number to reduce the HPBW and suppress the first side lobe level by increasing the exciting element number. And we proposed 4-element array with parasitic elements fed by the 4-way butler matrix. Its pattern has the first side lobe level of smaller than -10dB and the HPBW of about 30° with main beam tilting of ± 30°.

REFERENCES

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[3] M. Iwamura, et al., "Optimal Beamwidth of Base Station Antennas for W-CDMA," General Conf. of IEICE, B-5-157, May 1999.
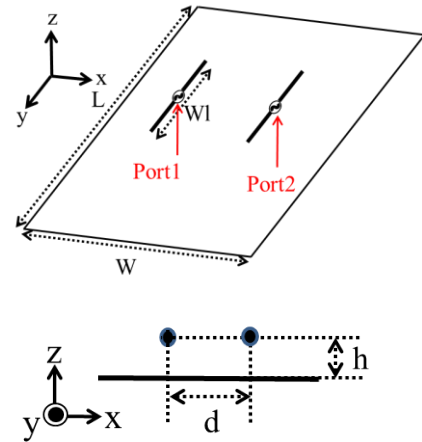
Figure 1. Antenna structure
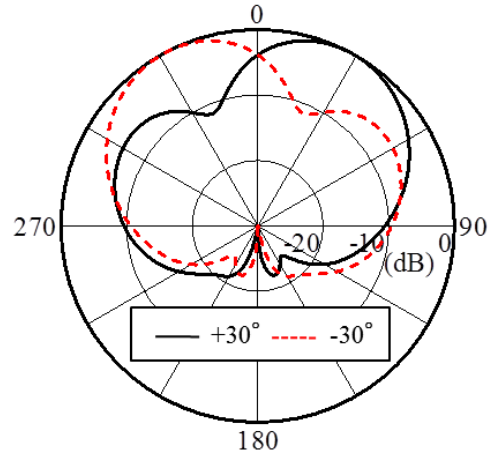2-element
W=180,L=450,Wl=64.5,d=75,h=37.5[mm]
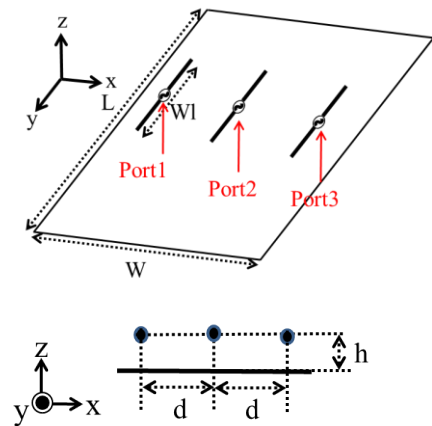

Figure 2. Radiation pattern
zx plane, 2-element

Figure 3. Antenna structure
3-element
W=180,L=450,Wl=64.5,d=75,h=37.5[mm]

Figure 4. Radiation pattern
zx plane, 3-element

Figure 5. Antenna structure
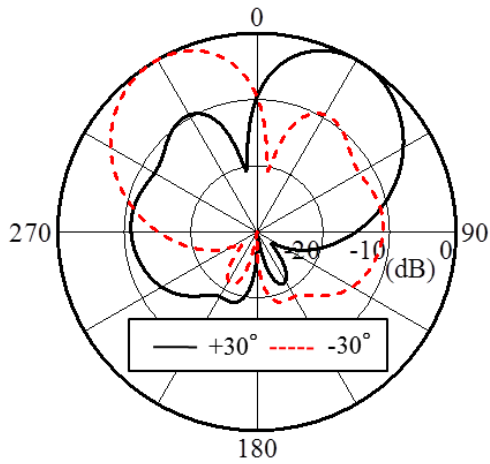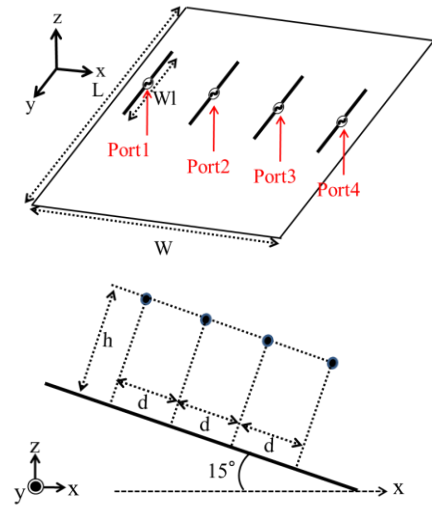4-element
W=280,L=450,Wl=64.5,d=75,h=37.5[mm]

Figure 6. Radiation pattern
zx plane, 4-element

Figure 7. Antenna structure
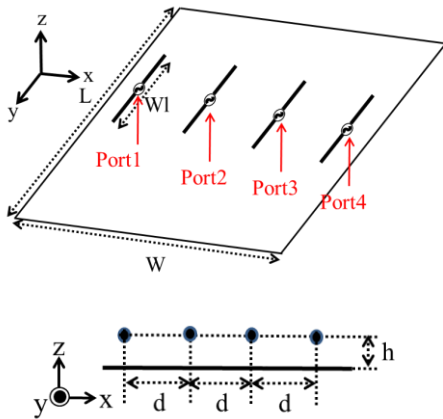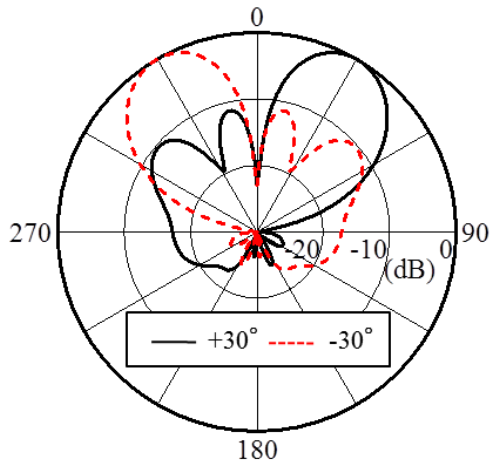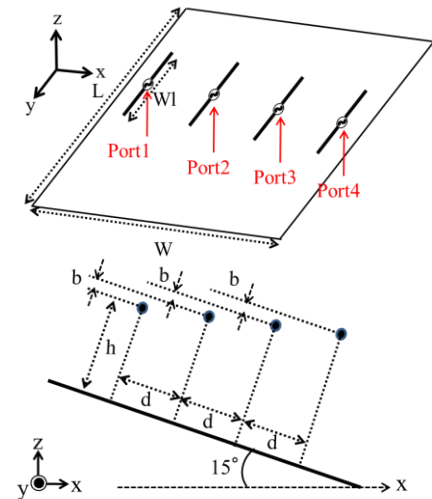4-element inclined plane
W=280,L=450,Wl=64.5,d=75,h=37.5,b=7.5[mm]

Figure 8. Radiation pattern
zx plane, 4-element inclined plane

Figure 9. Antenna structure
4-element inclined plane and elements
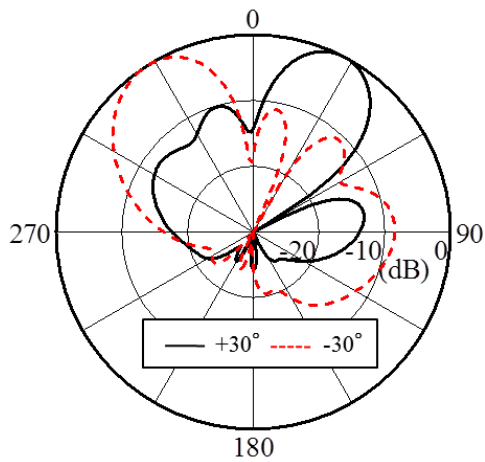W=280,L=450,Wl=64.5,d=75,h=26.25,b=7.5[mm]

Figure 10. Radiation pattern
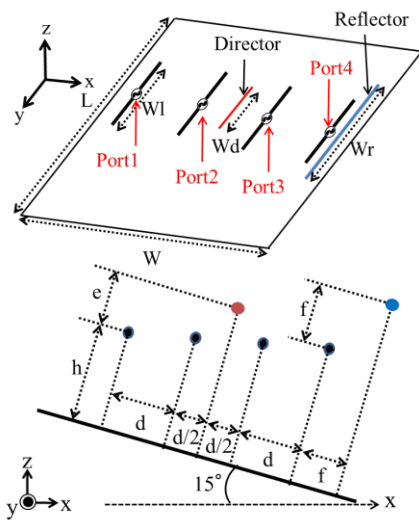zx plane, 4-element inclined plane and elements

Figure 11. Antenna structure
4-element inclined plane and elements, w/ director and reflector
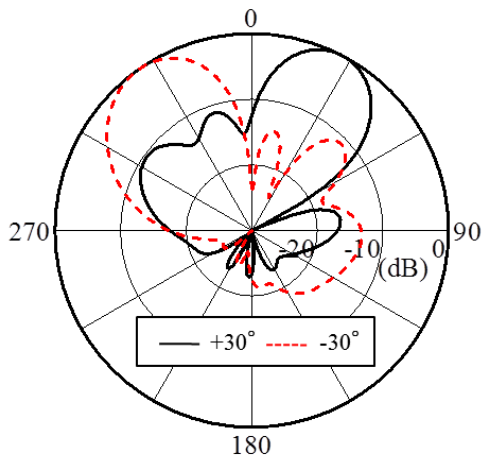W=280,L=450,Wl=64.5,Wd=54,Wr=90,d=75,h=26.25,e=33.75,f=22.5[mm]

Figure 12. Radiation pattern
zx plane, 4-element inclined plane and elements, w/ director and reflector