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Layered Butler Matrix Circuit for Vertical Multi Beam of Cellular Base Station Antenna

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Abstract- **To enhance the channel capacity of cellular systems, we need to reduce the size of coverage area for small cell, provided by sectorization in vertical plane. The multi-sector in vertical plane is given by multi-beam antenna fed by Butler matrix. This paper proposes a layered butler matrix circuit for multi beam antenna feeding system and demonstrates how to use in cellular base station antennas.**

Index Terms **— Butler matrix, Base station.**

I. INTRODUCTION

To increase the channel capacity of current cellular systems, multi-sector antennas are widely introduced. Recent high density base station siting requires various antenna functions in radiation pattern synthesis. For the sectorization in vertical plane, the multi-beam antenna was proposed for the base station antenna [1]. In base station antennas, tilted main beam is widely used to control its coverage area. By introducing a multi beam antenna we can use several beams with different tilt angles to make the vertical sector smaller.

For providing vertical sectorization this paper proposes multi beam antenna for vertical plane using butler matrix circuit. The single layered butler matrix circuit is examined for multi beam antenna [2]. The problem of this butler matrix circuit is its size large to integrate it into conventional base station antenna with column structure. In this paper, we present feed circuit with three-layer structure consisting of micro-strip line on both side of common ground plane coupled by slot to make a directional coupler [3]. By using three-layer geometry we reduce the size of butler matrix circuit. We also examine four-element patch array fed by the proposal butler matrix circuit.

II. BUTLER MATRIX CIRCUIT

First, we present the concept of vertical sectorization. In this paper, we use the butler matrix for the feed circuit of multi beam antenna. By using 4-element butler matrix circuit, a multi beam antenna has the tilt angle of ± 15° and ± 48° like as Fig 1(a), and these beams are completely orthogonal each other. For providing vertical sector, we use only the tilt angle of + 15° and + 48°. In 8-element butler matrix we use the tilt angle of 7°, 22°, 39° and 61° like as Fig 1 (b). The size of butler matrix circuit is too large to integrate it into conventional base station antenna with column structure. Then we propose butler matrix circuit with three-layer structure to reduce the size.

The structure of proposal butler matrix (84×160mm) is shown in Fig. 2. We set feeding circuits on both side of common ground plane coupled by slot to make a directional coupler and the hybrid coupler between these slot couplers. As shown in Fig. 1, we set port 1 and 3 on the upper surface of the substrate, and port 2 and 4 on the bottom surface of the substrate. In the case of using port 1, the output amplitude and phase of the proposal butler matrix circuit is shown in Fig.3 (a). The output amplitude ratios in each output (port 5~8) are -6.3dB, -6.3dB, -6.6dB, -6.2dB, respectively at the target frequency 2 GHz. The output phase characteristic of outputs is shown in Fig. 3 (b). It has the phase difference of -135°, which is good performance for butler matrix circuit. In the case of port 2 feeding, the output amplitude and phase characteristic are shown in Fig. 4. The output amplitude ratios in each output (port 5~8) are -6.5dB, -6.5dB, -6.5dB, -6.2dB, respectively, and it has the phase difference of 45°. The phase characteristic for each input (port 1~4) is shown in Table 1. We confirm the proposal circuit meets the performance of butler matrix circuit. In this paper, we set the input characteristic impedance of 50 Ω, the substrate of FR-4 with the relative permittivity ε_r of 4.3 and thickness of 1.6 mm. These results are simulated by MWstudio, AET Co..

TABLE 1
THE PHASE CHARACTERISTIC OF PROPOSAL BUTLER MATRIX

		Output				Excitation phase
		#5[°]	#6[°]	#7[°]	#8[°]	[°]
Input	#1	153	15	-118	105	-135
	#2	-118	-75	-28	12	45
	#3	12	-28	-75	-118	-45
	#4	105	-119	14	153	135

III. RADIATION PATTERN

In preceding section, we propose the butler matrix circuit with three-layer structure. In this section, we demonstrate the radiation pattern of 4-port multi beam antenna fed by the proposal circuit. In practice the proposal circuit is used for input port 5 and 7 on the upper surface, and port 6 and 8 on the bottom surface for output. We demonstrate the radiation pattern by the simple method in which 4-element patch array is fed by directly by the above 4-port Butler matrix in simulation where the element spacing is 0.4λ like as Fig. 5.

The radiation pattern is shown in Fig.6 have tilt angles of ± 15° and ± 51°. As shown in this result, the proposal butler matrix provides two beams in vertical plane.

IV. CONCLUSION

This paper proposed a layered butler matrix circuit for multi beam antenna for providing vertical sectorization. By using three-layer geometry we reduced the size of butler matrix circuit. Future work is integrating butler matrix circuit into conventional base station antenna.

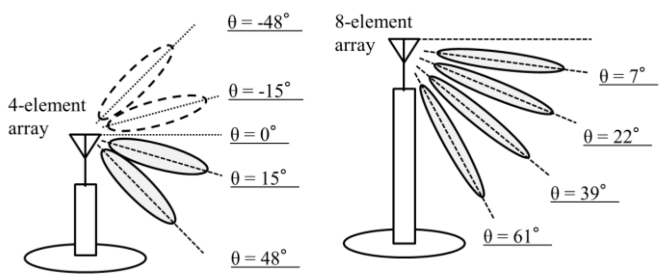
REFERENCES

[1] H. Arai, "A remark of base station antenna systems for future mobile communication," *Technical report of IEICE*, AP2014-6, Apr. 2014. (in Japanese)

[2] N. Nakajima and T. Hori, "900MHz-band Multibeam antenna using butler matrix," *Technical report of IEICE*, AP84-50, Aug. 1984. (in Japanese)

[3] T. Tanaka, et al., "Slot-Coupled Directional Couplers on a Both-Sided Substrate MIC and Their Applications," *IEICE Trans. C-electronics*, p570-577, Apr. 1988. (in Japanese)

[4] H. Ito, et al., "A consideration on Multi Beam Planar Antenna," *Technical report of IEICE*, AP2002-106, Oct. 2002. (in Japanese)



(a) 4-element butler matrix (b) 8-element butler matrix

Figure 1. Antenna pattern in vertical pattern

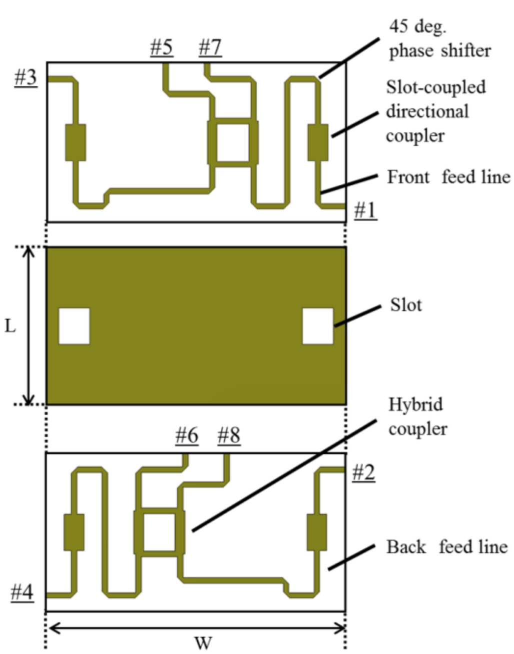
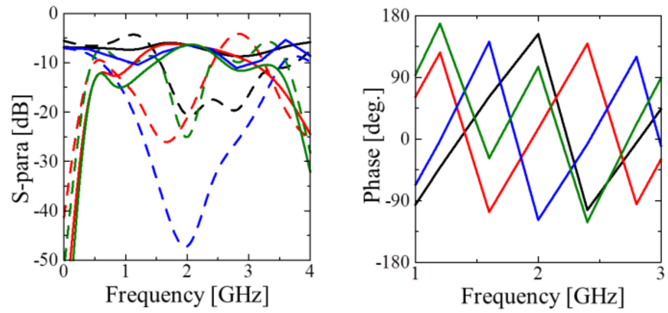


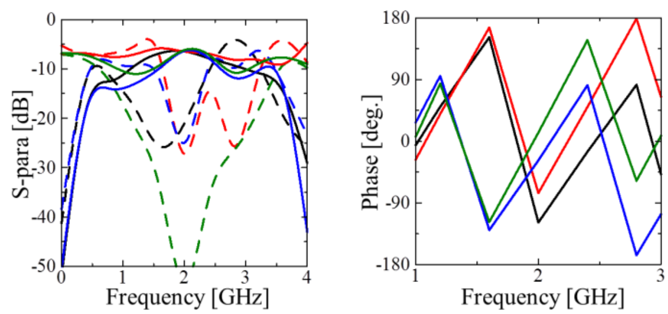
Figure 2. Butler matrix structure
L = 84, W=160 [mm]



(a) Amplitude (b) Phase

Figure 3. Output characteristics fed by port 1

S51 S61 S71 S81 S11 S21 S31 S41



(b) Amplitude (b) Phase

Figure 4. Output characteristics fed by port 2

S52 S62 S72 S82 S12 S22 S32 S42

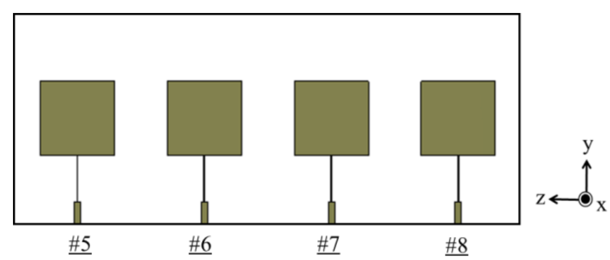


Figure 5. Antenna structure

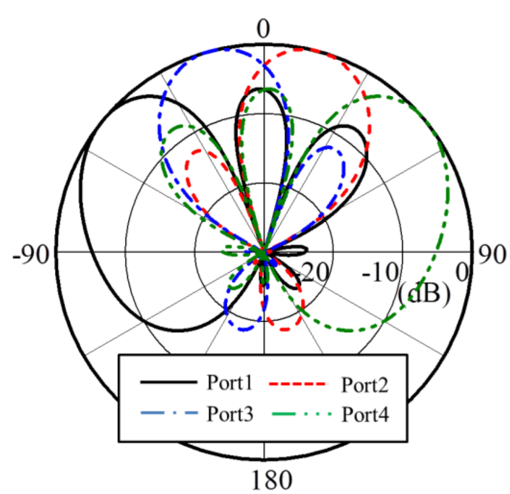


Figure 6. Radiation pattern in zx plane (θ[°])