Bandwidth Enhancement of Microstrip Line Slot Array Antenna

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Abstract—In this paper, we propose a wideband microstrip line slot array antenna. A microstrip line slot array antenna is constituted by a slot fed in series using the microstrip line. This antenna has features that the feeding loss is small and it is easy to configure the array antenna of the multi-element. However, the bandwidth is narrow compared with a conventional parallel fed array antenna. To overcome this disadvantage, we propose the method of appropriate placement of the slot operating at different frequencies as the method of enhancement bandwidth of slot array antenna.

Keywords—Microstrip line slot array antenna; microstrip structure; bandwidth enhancement; base station

References :

[1] Keizo Cho, et al., "Base Station and Terminal Antenna Technologies Required for Next Generation Moblile Communication Systems," IEICE Trans. Commun., Vol.J91-B, No.3, pp.886-900, 2008

[2] Kaijiro Nakaoka, et al., "Microstrip Line Slot Array Antenna," IEICE Trans. Commun., Vol.J61-B, No.11, pp.943-950, 1978

1. Introduction

➤ Currently, dipole array antennas or patch array antennas fed by parallel feeding circuit are used for the base station antenna[1].

➤ These antennas can be designed radiation elements and feeding circuits separately and have wide band characteristic.

➤ However, the feeding circuit becomes complicated depending on the number of elements of array antenna, so the overall size of the antenna becomes large and the gain of the antenna becomes low by the loss of feeding circuit.

➤ Therefore, it is difficult to apply the parallel feed array antenna to the base station antenna that high gain antenna is needed.

➤ To realize a higher gain antenna, we focus on the microstrip line slot array antenna(MSAA) which is arranged a slot along both edges of the microstrip line.

➤ This antenna is chosen due to the feature that it can be designed using a simple feeding circuit independent on the number of elements due to series feed.

➤ However, the slot array antenna has narrow bandwidth characteristic.

We propose the method of appropriate placement of slots to realize the bandwidth enhancement of MSAA

2. Design method of MSAA [2]

◆ The microstrip line with its width W and its thickness t is located in the bottom of dielectric substrate with its height h and having a relative dielectric constant ε_r.

◆ Slots with its length a and its width b is located on the ground plane.

◆ Each slot is located at a distance l_n and the length L is the distance between N-th slot and open end of microstrip line.

➢ In the design of this antenna, the two important parameters are the resistance value of each slot r_n and an offset position relative to the resistance value d_n.
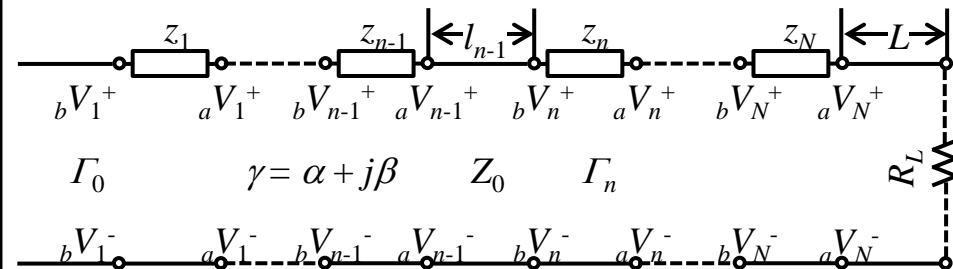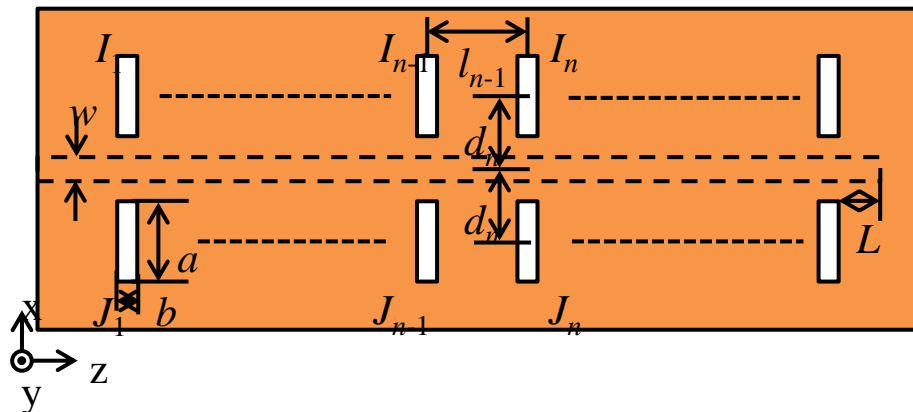
2. Design method of MSAA [2]

➢ For the equivalent circuit of this antenna, the resistance value of each slot r_n is obtained by following equations,

$$r_n = A_n r_N \frac{|1 - \Gamma_N|^2}{|1 - \Gamma_n|^2} \frac{1}{K}$$

$$\Gamma_{n-1} = \frac{\frac{r_n}{2} + \left(1 - \frac{r_n}{2}\right)\Gamma_n}{1 + \frac{r_n}{2} - \left(\frac{r_n}{2}\right)\Gamma_n} e^{-2\gamma l_{n-1}}$$

$$\Gamma_N = e^{-2\gamma L}$$

$$K = \prod_{i=n+1}^{N} \left|\left\{1 + (1 - \Gamma_i)\frac{r_i}{2}\right\} e^{\gamma l_{i-1}}\right|^2 \quad (n = 1, 2, \cdots, N - 1)$$

$\gamma = \alpha + j\beta \qquad l_n = \lambda_g, L = \lambda_g / 4$

λ_g is equivalent wavelength A_n is amplitude distribution

1. Substitute the initial value r_N in the above equation
2. Calculate the resistance value of each slot r_n and reflection coefficient Γ_0
3. Change the value of r_N until Γ_0 is under a certain value and obtain r_n

2. Design method of MSAA [2]

➤ The offset position relative to the resistance value d_n is obtained by following equations,

$$R_d = 4 \frac{\left(\int_{-\frac{a}{2}-d}^{\frac{a}{2}-d} \left\{ \frac{1}{2\pi} \int_{-\infty}^{\infty} g(\zeta) \frac{e^{-j\zeta x}}{e^{|\zeta h|}} d\zeta \right\} \cos \frac{\pi}{a}(x+d)dx \right)^2}{\frac{32}{3\pi} \sqrt{\frac{\varepsilon_0}{\mu_0}} \frac{a^2}{\lambda_0{}^2} \left\{ 1 - 0.374 \left(\frac{a}{\lambda_0}\right)^2 + 0.13 \left(\frac{a}{\lambda_0}\right)^4 \right\}} \qquad g(\zeta) = \frac{\sin\left(\frac{\zeta w}{2}\right)}{\frac{\zeta w}{2}} - \frac{1}{2} \frac{\sin^2\left(\frac{\zeta w}{4}\right)}{\frac{\zeta w}{4}}$$

Obtain the offset position that satisfies the resistance values obtained from the above calculation from the following graph
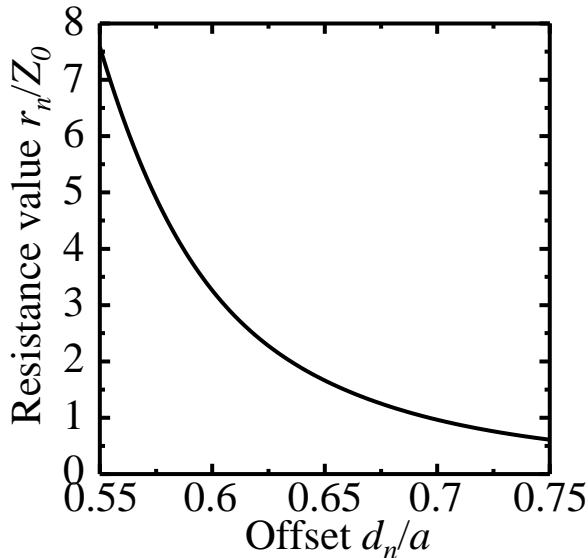

Offset d_n/a

|	Resistance value of each slot r_n Offset position relative to the resistance value d_n							
/Z_0	r_1	r_2	r_3	r_4	r_5	r_6	r_7	r_8
Uniform	1.82	2.01	2.19	2.37	2.52	2.65	2.73	2.78
Taylor	0.99	1.64	2.77	3.68	3.84	3.14	2.03	1.47
/a	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8
Uniform	0.6425	0.6343	0.6278	0.622	0.6174	0.6139	0.612	0.6108
Taylor	0.6977	0.6579	0.6147	0.5942	0.5903	0.6019	0.6320	0.6591

2. Design method of MSAA [2]

➢ Design 2×8 elements MSAA

   ✓ The −10 dB bandwidth of these antenna are 4.56 ~ 4.72 GHz

   ✓ The gain of these antenna are 17.2 dBi at 4.65 GHz.

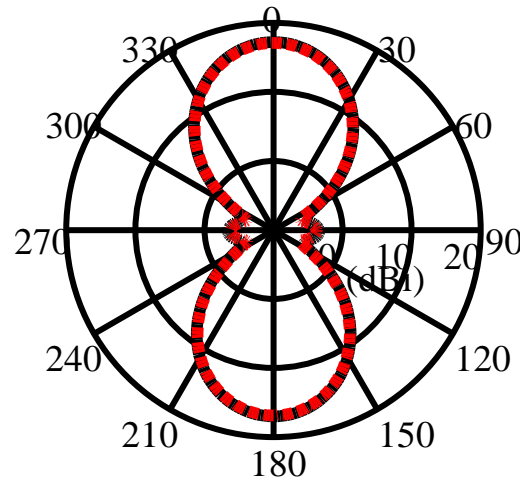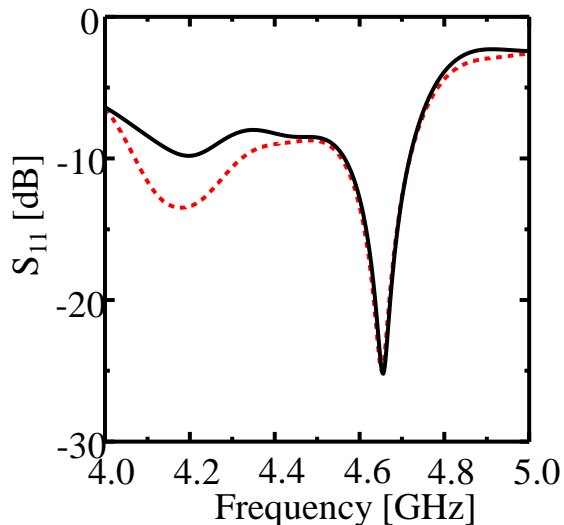   ✓ 1st sidelobe level using Taylor distribution is lower than one using uniform one
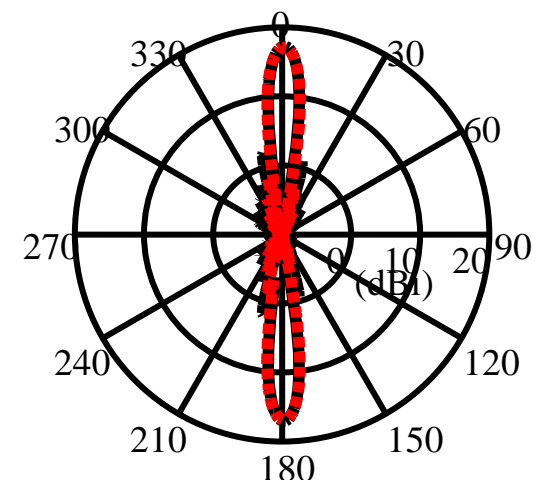
➢ Uniform distribution
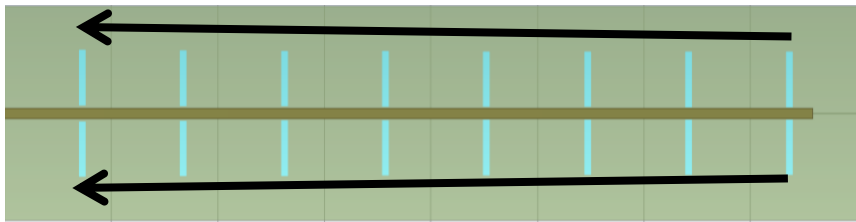
➢ Taylor distribution
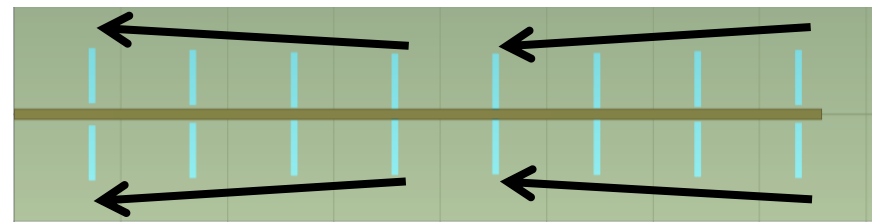
(a=27.0, b=3.2, l_n=48.0 L=10.9, ground: 408×100 [mm])

yz plane

xy plane

3. Bandwidth Enhancement of MSAA

Investigate the placement of slots to realize the wideband characteristic

➢ Use the slot operating at different frequencies as the method of enhancement bandwidth (Pattern 1).

✓ Slots operating at one frequency are arranged along one side edges of the line

✓ Slots operating at another one are arranged along the other side edges of the line

✓ The −10 dB bandwidth of this antenna is 4.32 ~ 4.94 GHz

✓ The gain at 4.55, 4.65, and 4.75 GHz are 15.1, 15.5, and 16.0 dBi, respectively

➢ To improve the radiation pattern at yz-plane, we propose another placement of the slots (Pattern 2).

✓ Slots operating at different frequencies are arranged alternately along both edges of the microstrip line.

✓ As compared with Pattern 1, the −10 dB bandwidth of this antenna has same range and the gain is same level.
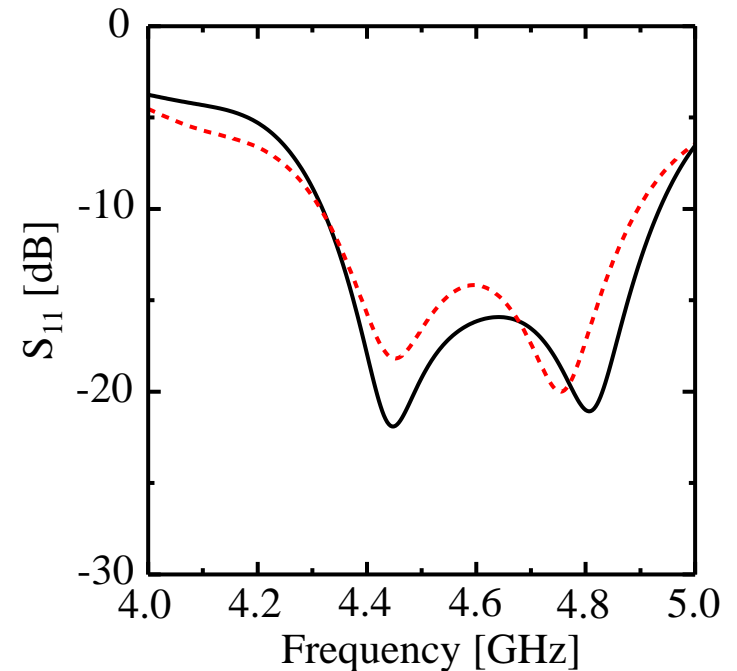
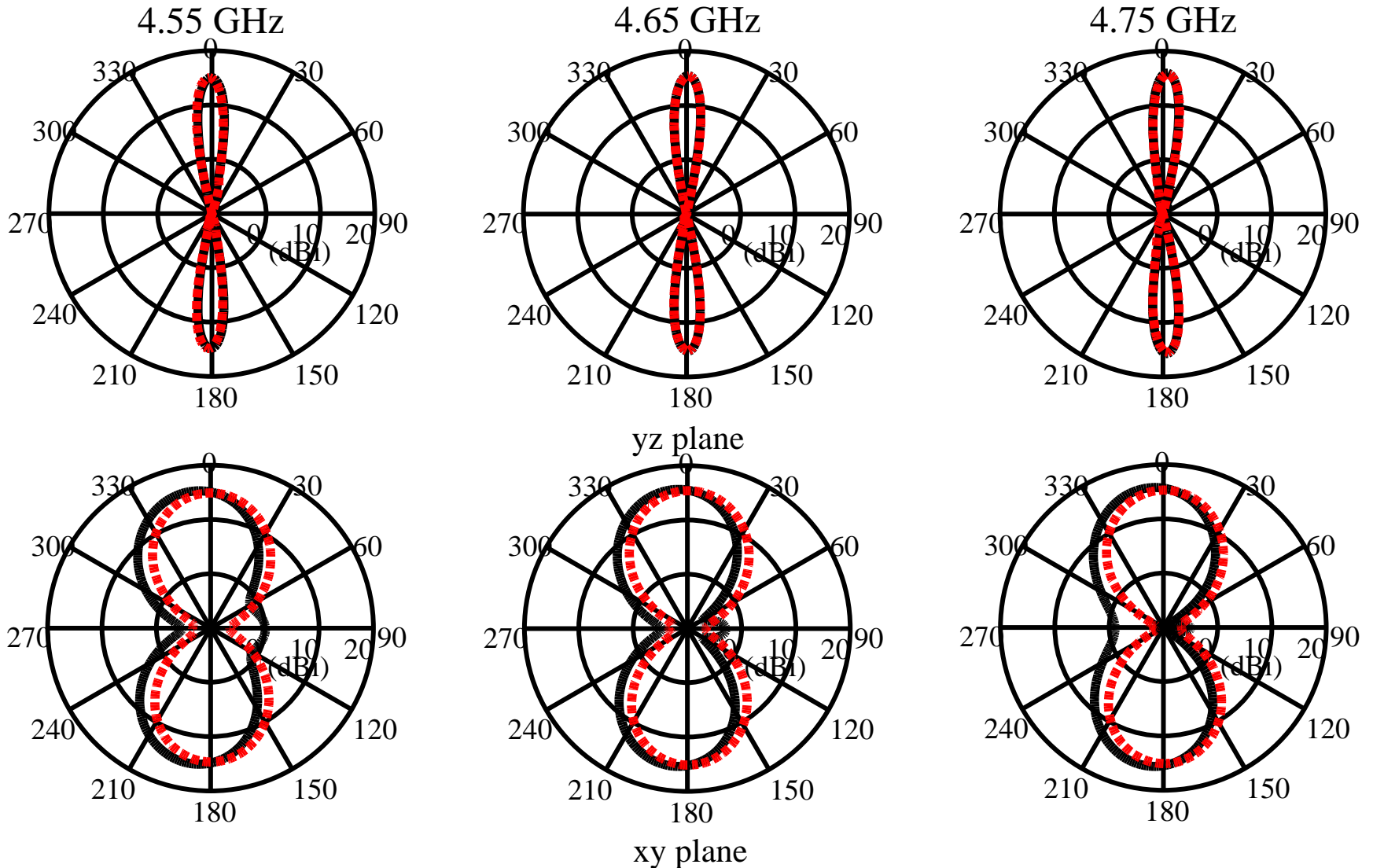# 3. Bandwidth Enhancement of MSAA

➢ Pattern 1
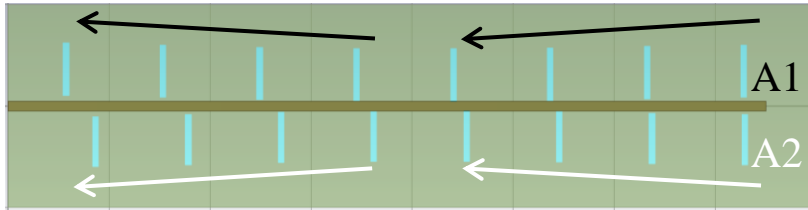
➢ Pattern 2
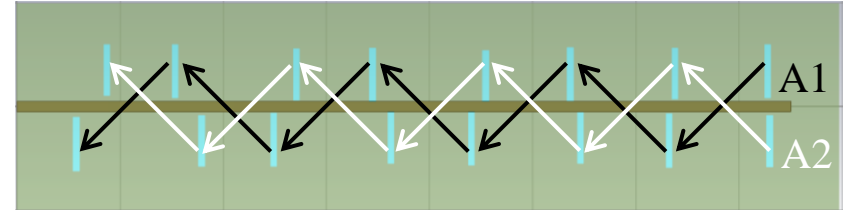
(A1: a=26.2, b=3.2, l_n=47.9 L=11.1 [mm]), (A2: a=25.0, b=3.2, l_n=45.9 L=10.6 [mm])

Resistance value of each slot r_n Offset position relative to the resistance value d_n								
$/Z_0$	r_1	r_2	r_3	r_4	r_5	r_6	r_7	r_8
A1	0.99	1.52	2.62	3.56	3.79	3.16	2.07	1.50
A2	1.01	1.55	2.66	3.60	3.82	3.18	2.08	1.51
$/a$	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8
A1	0.695	0.656	0.613	0.593	0.589	0.6	0.63	0.656
A2	0.705	0.664	0.62	0.6	0.596	0.608	0.639	0.667

3. Bandwidth Enhancement of MSAA

Realize bandwidth enhancement of MSAA using the slot operating at different frequencies that are arranged alternately along both edges of the microstrip line

4. Conclusion

- ☐ This paper proposed the method of bandwidth enhancement of MSAA.
- ☐ The proposed method is that slots operating at different frequencies are arranged alternately along both edges of the microstrip line.
- ☐ The antenna designed using proposed method has wideband characteristic and good radiation pattern.

yz plane

xy plane