POS1-10

Characteristics of Equal Ratio Space Array Antenna with Offset Feed for Same Pattern Between Rx and Tx

Ryo YAMAGUCHI, Jiang HUILING, and Keizo CHO
Research Laboratories, NTT DoCoMo, Inc.
3-5 Hikari-no-oka, Yokosuka, Kanagawa, 239-8536 Japan
E-mail：yama_ry@m.ieice.org

1. Introduction

In mobile communication base station antennas that employ the FDD (Time Division Duplex) system, a difference in the radiation patterns must essentially occur because the reception and transmission frequencies are different. There are only a few reported RF techniques [1] that address this problem and among those some use base band signal processing such as digital beamforming [2-3]. One proposal that does not use signal processing employs a reception and transmission beam agreement method [4] that focuses on the element spacing and feeding system for application to the adaptive array antenna. The validity of this RF method was investigated using horizontal array antennas comprising a small number of elements. Since this method does not fundamentally use signal processing techniques, it is thought that it can be easily applied even in a fixed beam case such as a vertical array antenna for mobile communication base stations.

On the other hand, the mobile communication base station antenna in many cases is arranged in a multi-element vertical array configuration. The side-lobes within the service area do not correspond although the direction of the main lobe roughly correspond even in the FDD mobile communication base station where the reception and transmission frequencies are different. This tendency becomes remarkable as the frequency ratio increases. Therefore, deterioration in communication services may result due to a disproportion in the electric field strength between reception and transmission. The agreement in the vertical beam pattern is thought to become especially important because services in line-of-sight (LOS) environments are expected to increase in the next generation mobile communication systems using the microwave band. However, application of the antenna pattern agreement method on the side-lobe characteristics within the service area has not been thoroughly studied. This paper describes a new equal ratio spacing application for the offset feeding method in [4] to a fixed beam vertical array antenna of a base station, and clarifies various characteristics of this method and the beam agreement.

2. Principle of Proposed Method

Figure 1 shows the beam patterns of a conventional equal spaced array antenna. The patterns in this cases for R = 1.1 and 1.3 are indicated as relative directivity when the aperture length, element spacing, and number of elements are 16λ, 0.5λ, and 33, respectively. The solid line indicates the reception pattern and the dashed line indicates the transmission pattern. Here, each element is excited in the same phase and the same amplitude to direct the pattern broadside. The patterns of R = 1.1 and 1.3 can be plotted such that one is on the left and one is on the right because each pattern is symmetrical. From this figure, we find that the deviation in the pattern increases when the beam direction or frequency ratio increases. The proposed array and feeding configuration are introduced in order to address these problems. As an example, an eight-element array with six-feeder elements is used as shown in Figure 2. When the element spacing between Elements # 1 and # 2 is d, and the spacing ratio is σ (>1), the next element spacing (#2-#3) becomes σd. Similarly, each element is arranged with equal ratio spacing from d to σ^6d. Here, the relationship between frequency ratio R and spacing ratio σ becomes $\sigma^2=R$. The reception array group feeds the RF power to the six elements from #3 to #8. On the other hand, the transmission group feeds to the six elements from #1 to #6. It is very important that the normalized size of the sub-array antenna for

ISBN: 978-4-88552-223-9 C3055©IEICE

each frequency of the reception group and the transmission group becomes equal. In other words, two array antennas have similar configurations although some elements are mutually shared. When the desired weights (*w*3-8) are used for the eight elements (#3-8) of the reception array, the same weights (*w*3-8) are used for the eight partially overlapped elements (#1-6) of the transmission array (This means a two-element offset). Thus, even if arbitrary reception weights (w3-8) are used for the transmission array (#1-6), the reception and transmission array patterns correspond exactly in principle. This is a simple example of an antenna with a two-element offset, an eight-element array, and six-feed elements. Generalized parameters are shown in Table 1 for the proposed method for the number of offset elements, N_o.

3. Array Antenna Characteristics

3.1 Evaluation Scheme

The evaluation scheme used in this examination is described in this section. The aperture length is fixed to approximately 16λ as a common condition for the vertical direction. This is because the size of the proposed array antenna changes greatly when changing the other parameters even if the element number is fixed. Since characteristics related to only the vertical directivity are evaluated in this paper, the number of horizontal elements is set to one. The directivity pattern to consider mutual coupling using the moment method is calculated. A two-element Yagi-Uda antenna that consists of a half wavelength dipole and a reflector is used as an element antenna for the simplification of the calculation. Here, two horizontal polarized elements of the Yagi-Uda antenna are horizontally arranged, and each element is divided into seven segments.

3.2 Effects of Frequency Ratio and Offset Number

The effects of the frequency ratio and number of offset feeding elements on various radiation pattern characteristics are evaluated. Typical parameters are given in Table 2. The shortest element spacing of the array antenna is 0.5λt (λt means the wavelength at transmission frequency). Characteristics are estimated at R=1.3 as a typical frequency ratio. The number of offset elements is one and eight. In this case, the total number of array antenna elements changes in proportion to the number of offset elements. It is thought that the influence of the number of offset elements in this evaluation is not significant although there is a difference in the aperture length (16.4λ and 15.5λ). The beam pattern, beam agreement, and side-lobe (within ±60 deg.) characteristics are shown in Figs. 3 and 4, respectively. In the upper half of each figure, the arrangement of the array antenna is indicated. The bottom halves indicate the pattern characteristics. In Case 1, where the number of offset elements is N_o = 1, the element spacing increases greatly with an increase in the number of elements because the relationship becomes σ=R=1.3. The maximum element spacing is 4.1λ. A grating lobe with the same level as the main beam is not generated because it does not have equal spacing. However, some comparatively high level side-lobes are generated except in the ±30 deg. range. Good amplitude agreement is not obtained although the directions of the peak and the zero roughly correspond. Since the frequency ratio is equal to the spacing ratio, the element spacing in the array antenna with a large aperture increases rapidly when the number of offset elements is one.

It is possible to increase the number of offset elements as shown in Case 2, where the number of offset elements is N_o = 8, in order to solve these problems. Because the relationship between frequency ratio R and element spacing σ is expressed as $R=\sigma^{No}$, the element spacing for Case 2 becomes narrower than Case 1 even if the frequency ratios are the same. Therefore, the element spacing changes gradually (see Fig. 4). The maximum element spacing decreases to approximately 0.9λ although the aperture lengths are almost the same compared to Case 1. As a result, the beamwidth of the main lobe increases slightly since the effective aperture of the equal ratio array becomes smaller than that of the equal spaced array. However, we find that grating lobes are rarely manifested although the number of elements increases.

It is well-known that the nulls of side lobe become shallow when the angle spread of arrival increases. Therefore, effects of angle spread on this method are examined as shown in Figure 5. Figure 5 (a) and 5 (b) show the characteristics of power difference between Rx and Tx when angle spreads are 1 and 5 deg., respectively. Horizontal axis indicates the direction of arrival with angle spread. Vertical axis means the difference power between Rx and Tx. From Figure 5 (a), although the power difference of equal spacing is remarkably large, that of this method is small. On the other hand, when the angle spread is large (5 deg.), the difference of two methods becomes smaller. From these figures, it is found that this method can be useful for the environment where the vertical angle spread is small.

4. Conclusion

This paper evaluated a beam-forming method for mobile communication base station array antennas employing the FDD system that uses the same vertical reception and transmission pattern. The offset feeding method employing equal ratio spacing without weight correction signal processing was applied, and the effectiveness was confirmed by numeric simulation. The results show that the described method is useful for not only horizontal small-scale array antennas but also vertical large-scale array antennas. More specifically, the side-lobe characteristics deteriorated (grating lobes were generated) because the element spacing grew too wide when the number of offset elements was small. In order to address these problems, the number of offset elements was increased. Consequently, good agreement is achieved between the reception and transmission beam patterns and low side-lobe levels.

References

[1] D. B. Ward et al., "Design of Frequency-Invariant Broadband Far-Field Sensor Arrays," IEEE AP-S Int'l Sympo., pp.1274-1277, 1994.

[2] I. Chiba, T. Takahashi, and Y. Karasawa, "Transmission null beam forming with beam space adaptive array antennas," Proc. IEEE Veh. Technol. Conf., pp.1498-1502, Stockholm, Sweeden, June 1994.

[3] T. Sekiguchi, and Y. Karasawa, "Frequency-Invariant Adaptive Receiving and Transmitting Null Beamforming," IEICE Trans. B Vol. J83-B, no.1, pp.31-38, Jan. 2000. (in Japanese)

[4] R. Yamaguchi, N. Terada, and T. Nojima, "An Equal Ratio Spacing Array Antenna for FDD Radio Systems," IEICE Society Conf. B-1-107, Sept. 2000. (in Japanese)

Table 1: Generalized Parameter of Proposed Method

Center frequency ratio	$R = f_t / f_r$ (>1)
Element space ratio	σ
Element space #1-#2	d
Total number of elements	N_t
Number of Rx elements	$N_{Rx} = N_t - N_o$
Number of Tx elements	$N_{Tx} = N_t - N_o$
Offset number	N_o
Total array length	$L_{total} = d \sum_{i=1}^{Nt-1} \sigma^{i-1}$
Rx array length	$L_{Rx} = d \sum_{i=No+1}^{Nt-1} \sigma^{i-1}$
Tx array length	$L_{Tx} = d \sum_{i=1}^{Nt-No-1} \sigma^{i-1}$
Relationship R, σ	$R = \sigma^{No}$
Weight (Rx and Tx)	$\{ w_{No+1}, w_{No+2}, \ldots, w_{Nt} \}$

Table 2: Simulation Specifications

	Case 1	Case 2
$R = f_t / f_r$	1.3	1.3
N_o	1	8
N_{total}	11	27
$N_r = N_t$	10	19
L_{total} (λ_R)	16.4	15.5
Maximum spacing (λ_R)	4.1	0.9

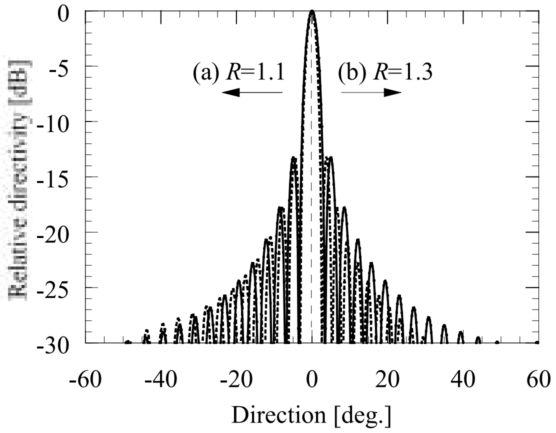


Figure 1: Characteristics of Conventional Array Antenna

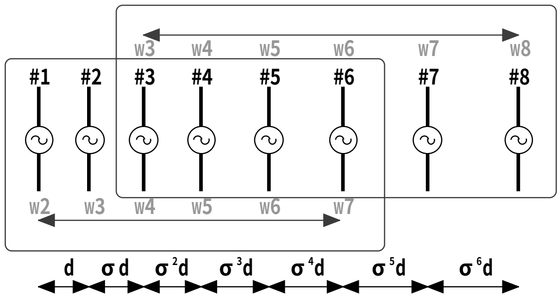


Figure 2: Principle of Proposed Array Antenna

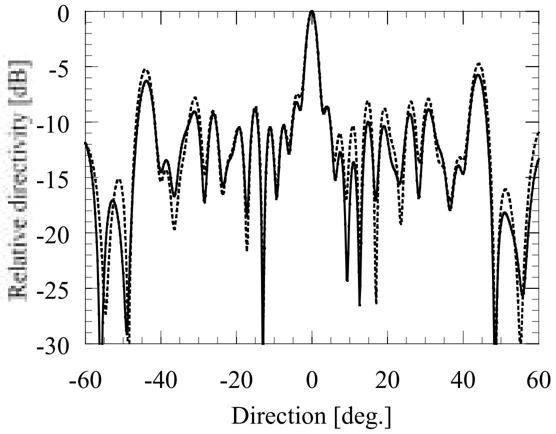


Figure3: Beam Pattern (R=1.3, N_0=1)

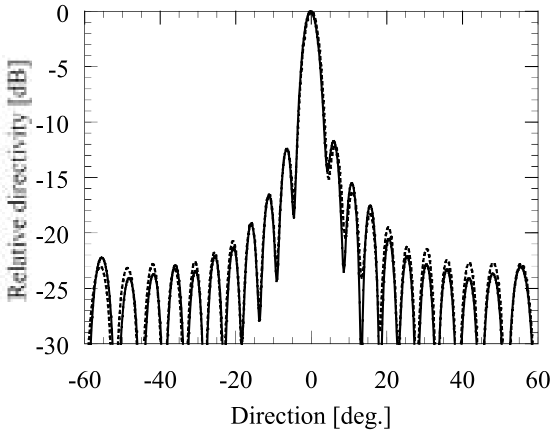
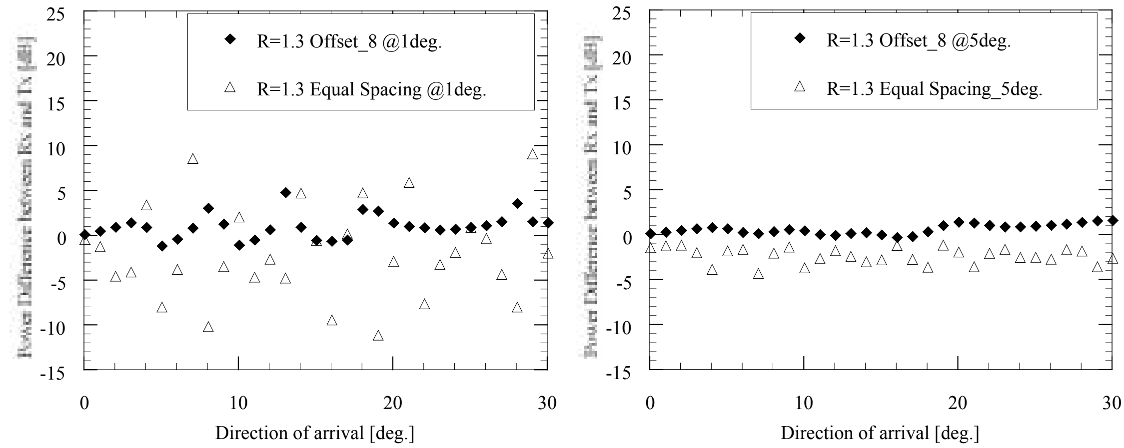


Figure 4: Beam Pattern (R=1.3, N_0=8)



(a) angle spread = 1 deg. (b) angle spread = 5 deg.

Figure 5: Power Difference between Rx and Tx