Effect of Antenna Element Characteristics on SINR

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Abstract There are some problems when adaptive arrays are applied to mobile terminals because they utilize several antenna elements on minute terminals. An analysis and evaluation of the effect of antenna element characteristics on SINR of the adaptive arrays is presented in this paper. It is shown that the influence of elements characteristics on the SINR depend on correlation between arrival waves. And it is also shown that a robust performance can be obtained by the MMSE in mobile environment.

1. Introduction

Spatial control schemes such as adaptive arrays and MIMO systems represent a promising technology that improves the transmission capacity of mobile communications. In these schemes, the directional pattern of the array antennas is adaptively controlled by weighting the coefficients of the received signals [1]. It is assumed in most of the previous studies on these schemes that every antenna element has an omni-directional pattern and that the distances between antenna elements are a half wavelength. However, such assumptions are not plausible when the antenna elements are mounted on mobile terminals [2].

Therefore, the authors evaluated the effect of the antenna element patterns on the antenna pattern control of an array antenna [3]. And it has been clarified that DUR (Desired to Undesired signal power Ratio) can be improved in flat fading environment even if the antenna element pattern is not ideal and the element spacing is insufficient.

In this paper, the performance of adaptive arrays in frequency selective fading environment is evaluated. The numerical results show that the influences of the element characteristics depend on both the control algorithm and correlation between the arrival waves. It is also shown that the MMSE algorithm is suitable for mobile terminals, in which the element characteristics are fluctuate, for obtaining the robust performance.

2. Analytical Expression of SINR

2.1 Analysis Model

We consider an array antenna comprising N antenna elements in an environment where one desired wave and one undesired wave arrive as shown in Fig. 1. A component of the desired signal, $V_D(\theta_D)$, and that of the undesired signal, $V_U(\theta_U)$, included in output signal from the *n*-th element are expressed as follows.

$$V_D(\theta_D) = A_D e^{j\phi_D} \cdot E(n,\theta_D) \tag{1}$$

$$V_U(\theta_U) = A_U e^{j\phi_U} \cdot E(n,\theta_U) \tag{2}$$

Here, $E(n,\theta)$, A, and ϕ are the complex element pattern of the *n*-th element, the amplitude of the arriving waves, and the phase of the arriving waves, respectively. The synthesized directional pattern of the array antenna, $E_0(\theta)$, using optimum coefficients $W_{opt}(n,\theta_d)$ is

$$E_0(\theta)=\sum_{n=1}^{N}E(n,\theta)\cdot W_{opt}(n) \quad (3)$$

Thus, the desired and undesired signal components that are output from the system are as follows.

$$V_{Dout}(\theta_D)=A_D e^{j\phi_D}\cdot E_0(\theta_D) \quad (4)$$

$$V_{Uout}(\theta_U)=A_U e^{j\phi_U}\cdot E_0(\theta_U) \quad (5)$$

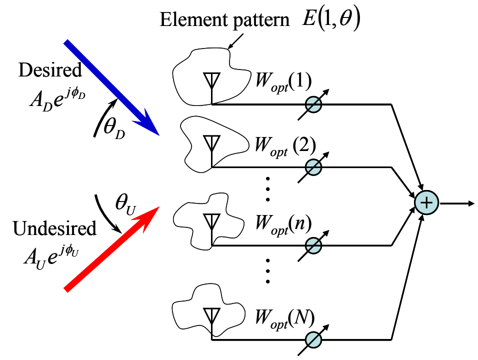


Fig. 1 Analysis model

2.2 Expectation of SINR Value

Here, we suppose the multipath environment and that the undesired wave is delayed wave. Then, the signal component included in the output is expressed as follows.

$$V_S=V_{Dout}(\theta_D)+\sqrt{\rho}\cdot V_{Uout}(\theta_U), \quad (6)$$

where ρ is a correlation coefficient between the desired wave and the undesired wave. Remaining power of the undesired wave correspond to interference component,

$$V_I=\left(\sqrt{1-\rho}\right)\cdot V_{Uout}(\theta_U). \quad (7)$$

Therefore, from (6) and (7), the SINR at the output signal is

$$SINR=\frac{\frac{1}{2}V_S^2}{\frac{1}{2}V_I^2+P_N}=\frac{\frac{1}{2}\left\{V_{Dout}(\theta_D)+\sqrt{\rho}\cdot V_{Uout}(\theta_U)\right\}^2}{\frac{1}{2}\left\{\left(\sqrt{1-\rho}\right)\cdot V_{Uout}(\theta_U)\right\}^2+\sum_{n=1}^{N}\left\{\frac{1}{2}\left|W_{opt}(n)\cdot N_0\right|^2\right\}}, \quad (8)$$

where P_N is power of thermal noise at the output and N_0 is the standard deviation of thermal noise at individual antenna element.

The SINR value is fluctuated due to not only the arrival environment but also the characteristics of the antenna elements. To clarify the influence of the element characteristics, we evaluated the expectation of SINR when the directions of arrivals are distributed from 0 to 2π radians as follows.

$$\overline{SINR}=\iint_{\theta} SINR\, d\theta_U d\theta_D \quad (9)$$

3. Numerical Results

3.1 Model of Antenna Element and Optimum Weight Coefficients

It is assumed in the analysis that the n-th element has directional pattern, $E(n,\theta)$, expressed in (10) and it has a maximum gain in the direction of $\theta_0(n)$ as shown in Fig. 2.

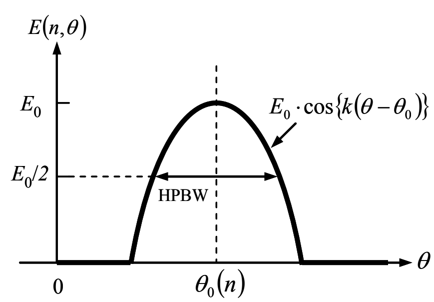


Fig. 2 Analysis model
(Element pattern)

$$E(n,\theta)=\begin{cases} E_0\cdot\cos\{k(\theta-\theta_0)\}, & |k(\theta-\theta_0)|\le\frac{\pi}{2} \\ 0, & |k(\theta-\theta_0)|>\frac{\pi}{2}\end{cases} \tag{10}$$

Here, $\theta_0(n)=2\pi n/N$. We consider that the peak of the directional pattern is normalized by the maximum of itself. Namely, the efficiency of the elements decreases as the HPBW (Half Power Beam Width) becomes narrow.

The optimum weight coefficients, $W_{opt}(n,\theta_d)$, depend on the control algorithm. Four kinds of optimum algorithm are considered in this paper. The optimum weight coefficients for respective algorithm are expressed as follows.

a) Minimum Mean Square Error (MMSE) : $W_{MMSE}(n)=\{V_{Dout}+\sqrt{\rho}\cdot V_{Uout}\}^*$

b) Maximal Ratio Combining (MRC) : $W_{MRC}(n)=\{V_{Dout}+V_{Uout}\}^*$

c) Equal-Gain Combining (EGC) : $W_{EQG}(n)=\dfrac{W_{MRC}(n)}{|W_{MRC}(n)|}$

d) Selection Combining (SC) : $W_{SC}(n)=\begin{cases}1, & for\ \max|W_{MRC}(n)| \\ 0, & else\end{cases}$

Here, the mark,*, means complex conjugate. The expectation of SINR can be obtained by substituting (3),(4),(5),(8) and optimum coefficients into (9). Other conditions are indicated in table 1.

Table 1

Number of element	4
Element space	0.5 wavelength
Intensity of D wave	0dB
Intensity of U wave	-3dB
Noise level	-20dB

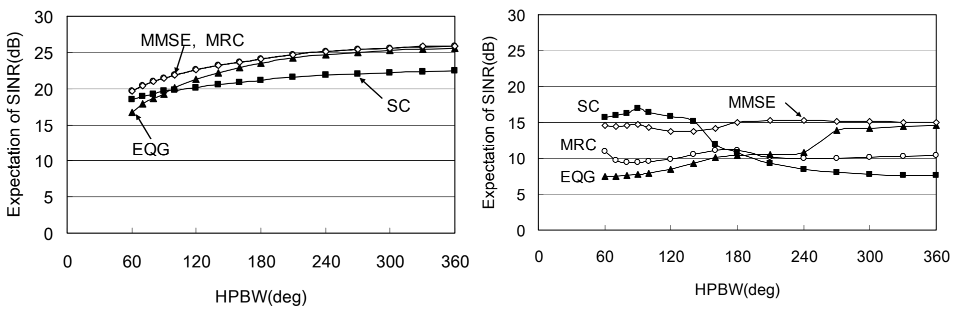
3.2 Effect of Antenna Element Pattern

We evaluated the effect of the antenna element pattern on the expectation of SINR by changing factor *k* in (10). The relationship between the Half Power Beam Width (HPBW) and the expected SINR is shown in Fig. 3. Figures 3(a) and 3(b) show the cases for correlation ρ =0.9 and ρ =0.1, respectively.

Figure 3 shows that a high SINR value is obtained when ρ =0.9, however, the value is decreased when ρ is small. And it is also found that the SINR is varied with HPBW of antenna elements and optimization algorithm. Especially, EQG has almost the same performance with MMSE when HPBW is wide; however, the SINR of EGC decreases as HPBW becomes narrow. Furthermore, SC provide good SINR when HPBW narrower than 120 degrees.

3.3 Effect of Correlation Between Arrival Waves

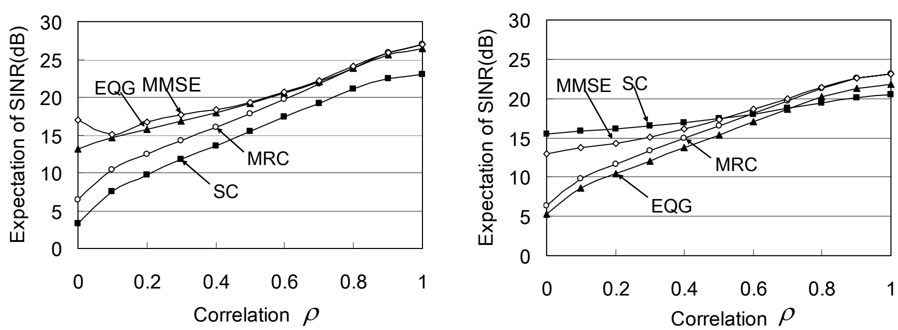
The variation of the expected SINR versus the correlation coefficients between arrival waves is shown in Fig. 4. The correlation is determined by the ratio of delay time of delayed wave to symbol rate of transmitted signal. The large value of correlation corresponds to flat fading environment and the small value corresponds to frequency selective fading environment.



(a) Correlation $\rho = 0.9$ (b) Correlation $\rho = 0.1$

Fig. 3 Effect of distortion of element pattern

It found from the Fig.4 that the expected SINR decreases as the ρ becomes small. Thus, we can't expect the high value of SINR in frequency selective fading environment. MMSE and MRC has almost the same performance when correlation ρ is large (in flat fading), however, MRC deteriorate when ρ is small (in selective fading). It can be said that MMSE has a robust performance in unstable environment such as mobile terminal.



(a) HPBW=360deg (a) HPBW=120deg

Fig. 4 Effect of Correlation between arrival waves

4. Conclusion

The effect of the antenna element pattern and the correlation between arrivals on the performance of array antenna was valuated in this paper. The results showed that the elements characteristics greatly influence on the SINR when correlation of arrivals was small. And it was also shown that a robust performance could be obtained by the MMSE in mobile applications.

References

[1] "Special Issue on Adaptive Array Antenna Techniques for Advanced Wireless Communications Signal Processing Technology in Antennas," IEICE Trans. Commun., vol. E84, no. 7, pp. 1703-1875, July 2001.

[2] M.Fujimoto, et.al, "Experimental Study of Adaptive Array Antenna System for Land Mobile Communications",ISAP96, 3, pp.769-772, Sep., 1996.

[2] Mitoshi Fujimoto, Toshikazu Hori : Effect of Antenna Element Pattern on Antenna Pattern Control of Array Antenna, 2005 IEEE AP-S, vol.4B, pp.39-42, Washinton, DC, USA, July, 2005.