PERFORMANCE OF POWER INVERSION ADAPTIVE ARRAY WITH THE EFFECT OF MUTUAL COUPLING

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Introduction

The power inversion adaptive array [1], PIAA, is a useful antenna system for the cases where information about neither arrival direction nor waveform of the desired signal is known in advance. There have been many papers which have presented the studies of the PIAA. However, the performance of the PIAA has not been investigated fully when the effect of mutual coupling among the array elements is involved.

The effect of mutual coupling on the performance of adaptive array has been studied only for LMS and MSN algorithms by Gupta and Ksienski [2]. Their result, however, may not be exact because the mutual coupling among antenna elements of the open terminals is ignored. In this paper, both the steady state and transient performances of the output SINR (signal-to-interference-plus-noise ratio) of the PIAA are analysed with consideration of the mutual coupling effect by using the method of moments.

Analysis

Consider the PIAA system shown in Figure 1. Vertically directed thin half-wave dipoles are considered here. Each antenna element is considered to have load impedance Z_L at its output terminal. The method of moments is applied to the analysis of the antenna system and the piecewise sinusoidal Galerkin method is used.

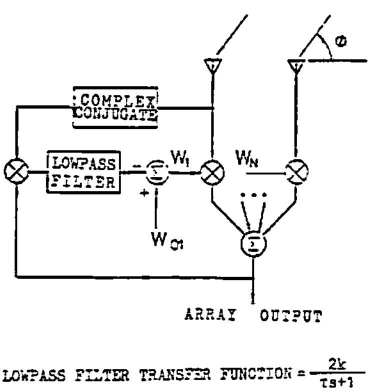


Fig. 1 PIAA system

Assume here that the following conditions hold true:

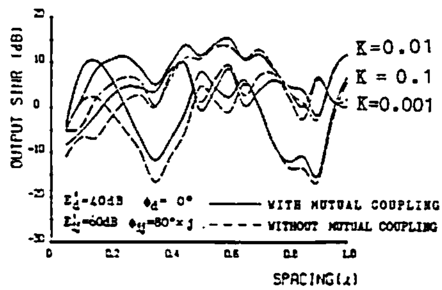
1. The thermal noise voltages of the N elements are statistically independent of each other and each of them is zero mean Gaussian noise with variance σ_n^2.
2. Each of the desired and undesired signals is a narrow-band signal with zero mean, and is statistically independent of the other signals and of the thermal noises.

The steering vector $[1\ 0\ \cdots\ 0]^T$, which is valid when mutual coupling is ignored, does not actually make an omnidirectional quiescent receiving pattern in the horizontal plane, as is desired, due to the mutual coupling effects. To produce such an omnidirectional pattern, the steering vector should be so selected that the total current flowing on each of (N-1) elements becomes zero.

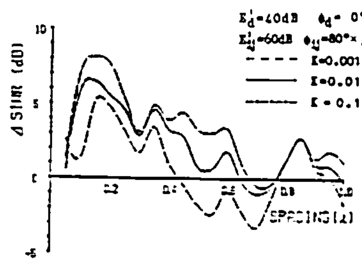
Results and discussion

The equivalent load impedance connected to each element is assumed to be 50 ohms. At first, let us consider the steady state output SINR performance of a five element linear array versus the interelement spacing, as shown in Figure 2(a), where four signals, one desired and three undesired, are assumed to have arrived. The parameters used for the arrival signals are shown in the figure, where $E' = E\cdot\lambda/\sigma_n$. It is seen in the figure that the output SINR changes very much with the loop gain K ($=k\sigma_n^2$). Figure 2(b) shows the differences between the output SINR for cases with and without mutual coupling. It can be concluded that the mutual coupling effect should be taken into account even if the interelement spacing is one wavelength.

The output SINR performance versus loop gain K is shown in Figure 3, and it is seen in curve I that there exists an optimal value in $K=K_{opt}$, which maximizes the output SINR, provided that the desired signal



(a) Output SINR performance



(b) Effect of mutual coupling

Fig. 2 Steady state SINR vs. spacing

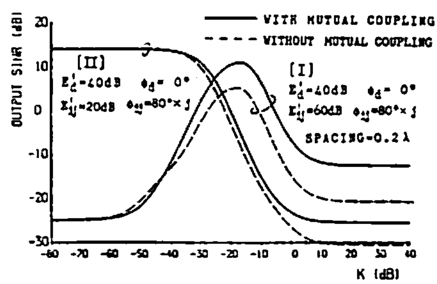


Fig. 3 Steady state SINR vs. K

is weaker than the undesired signals and that the freedom of the pattern of the PIAA (=N-1) is more than the number of incoming undesired signals (m). For a two element array, however, there is no optimal K.

It is clear from Figure 4, which shows a receiving pattern of a two element array spaced 0.1λ, that the null point does not appear just in the direction of the strong incoming signal, if the mutual coupling is taken into account.

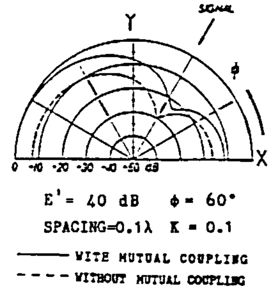


Fig. 4 Example of array pattern

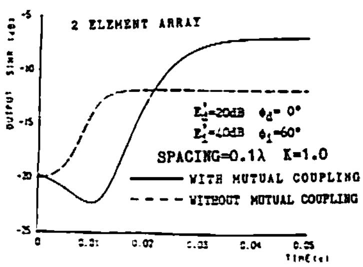
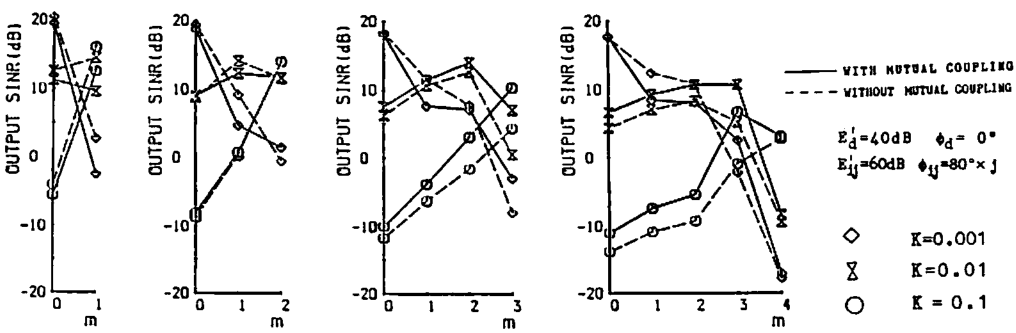


Fig. 5 Transient SINR performance

The transient performance of the PIAA is very important if the array is used in such cases as mobile communications, where sharp fading occurs. It is seen in Figure 5 that the convergence time greatly increases if mutual coupling is taken into account.

Figure 6 shows the steady state performance of the output SINR versus the number of elements and the undesired signals. It is seen that the performance does not deteriorate so long as, when K is chosen properly, N≧m+1 holds true if the number of undesired signals does not change, or N≧m+2 holds true if it does change. Figure 7 shows the optimal K corresponding to the cases given in Table I. The value of the optimal K becomes smaller if more elements are used, or if fewer undesired signals arrive. It is also seen that the value of the optimal K is not only changed approximately inversely by the arrival signal levels, but it is also changed by either



(a) two- (b) three- (c) four- (d) five-element array

Fig. 6 Steady state SINR vs. N and m

interelement spacing or signal arrival directions.

The comparison of the output SINR obtained by using the method of moments and Gupta and Ksienski's method is presented in Figure 8 for a five element array. It indicates that the difference between these two results is about 2-4dB, which is appreciable when considering the amount of the effect produced by the mutual coupling. The difference is caused by Gupta and Ksienski's having ignored in their treatment of mutual coupling the effect of mutual coupling upon the open terminal voltages at each array element.

Tab. I Arrival signals used in Figure 7

	E_d'	ϕ_d	E_{ij}'	ϕ_{ij}	d
case 1	40 dB	0°	60 dB	80°×j	0.2 λ
case 2	20 dB	0°	40 dB	80°×j	0.2 λ
case 3	40 dB	0°	60 dB	80°×j	0.5 λ
case 4	40 dB	0°	60 dB	30°×j	0.2 λ

ϕ : Angle from the axis of array

$j = 1, 2, \cdots, m$

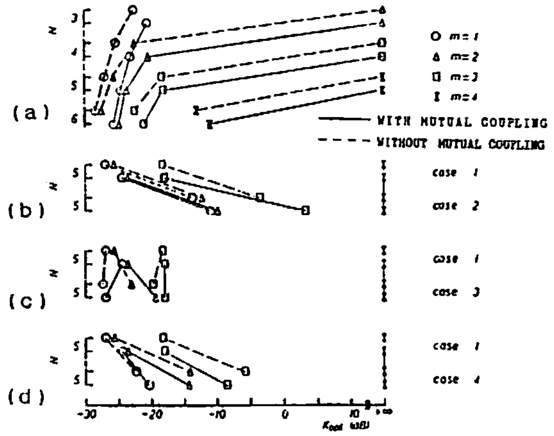


Fig. 7 Optimal K value

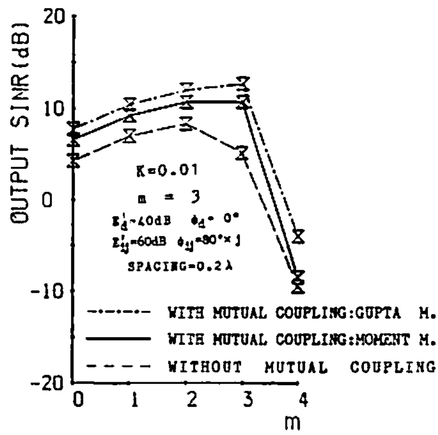


Fig. 8 Comparison of methods

Conclusion

The effect of mutual coupling on the performance of the PIAA has been discussed with the conclusion that the output SINR performance is greatly affected by mutual coupling when interelement spacing is narrowed. Moreover, a way to determine the selection of optimal parameters of the PIAA has been found.

References

[1] R. T. Compton, Jr., "The power inversion adaptive array: Concept and performance", IEEE Trans. Aerospace Electron. Syst., Vol. AES-15, No. 6, Nov. 1979

[2] I. J. Gupta and A. A. Ksienski, "Effect of mutual coupling on the performance of adaptive arrays", IEEE Trans. Antenna Propagat., Vol. AP-31, No. 5, Sept. 1983