PERFORMANCE OF POWER-INVERSION ADAPTIVE ARRAY WITH RECEIVED SIGNAL LEAKAGE THROUGH WEIGHTING CIRCUITRY

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ABSTRACT The effect of received signal leakage to the output through weighting circuitry is decribed, which often induces the degradation of the desired signal to interference-plus-noise ratio (SINR) in the power-inversion adaptive array (PIAA). It is shown that the output SINR can be restored from such degradation by providing the steering vector with suitable offset, because such above leakage is function of the steering vector. With respect to the leakage effect, the output SINR and the quiescent patterns are also calculated.

1.INTRODUCTION An adaptive array needs weighting circuitries to control the amplitude of received signal for each array element. The device or circurity, which is intended as weight must multiply two signals (received signal and control signal) precisely. In practice, however, the leakage of the input signal to output still remains. Such characteristics are illustrated in Fig.1. This paper deals with such effect on the performance of PIAA [1].

In Section 2, we formulate the problem, derive the control equation and show it has the same effect as the steering vector offset. Section 3 describes calculated results: the quiescent patterns and SINR. Section 4 contains the conclusion.

2.FORMULATION As the simplified model of two-element PIAA with the leakage effect, we considered the block diagram shown in Fig.2. The bypass line of weight, which consists of an attenuator and a phase shifter, is employed to represent the leakage. The gain r_n of the bypass line of each element is given as

$$r_n = r_{In} \cdot \exp(j\phi_{In}) - j\, r_{Qn} \cdot \exp(j\phi_{Qn}) \quad (n = 1,2) \qquad (1)$$

where we assume the amplitude ratio r_{In}, r_{Qn} and phase shift ϕ_{In}, ϕ_{Qn} are real constants. The output signal S of the array is

$$S = X^t (W + R) \qquad (2)$$

where $X = (x_1 , x_2)^t$: input signal vector
$W = (w_1 , w_2)^t$: weight vector
$R = (r_1 , r_2)^t$: leakage vector

and t denotes transpose. Note that the input signal is effectively weighted by W + R, so we define the effective weight vector We as :

$$We = W + R \qquad (3)$$

Then, the control equation for the effective weight vector is given as follows :

$$\tau \, dWe/dt + (I + k \Phi) We = W_o + R \qquad (4)$$

where τ : time constant of low pass filter

k : loop gain

I : identity matrix

$W_o = (w_{10} , w_{20})^t$: steering vector

$\Phi = E[X^* X^t]$: covariance matrix ,

* denotes complex conjugate and E[·] denotes expectation. This equation means that the leakage effect can be considered as steering vector offset or pointing error [2].

Moreover two facts may be found from eq.(4). First, in the case of laekage ratio $R = R_o$, the effect can be cancelled by changing the steering vector from W_o to $W_o - R_o$. Second, convergence time of weight is not affected by the leakage, because expression of the convergence time T of weight contains no components of the steering vector :

$$T = \tau / (1 + k \lambda) \qquad (5)$$

where λ is the eigenvalue of Φ.

3.SIMULATION AND RESULTS Based on the control equation (4), effect of the leakage is examined numerically under the condition as follows. Each element is assumed to be omnidirectional and located half wavelength apart. Gaussian thermal noise with its power σ^2 exists in both elements. The device has the same characteristics in each weighting circuitry. Then, values of attenuation and phase shift of leak signal should be equal r, ϕ respectively :

$$r = r_{In} = r_{Qn} \quad , \quad \phi = \phi_{In} = \phi_{Qn} \qquad (6)$$

And loop gain k is $0.1 / \sigma^2$.

Fig.3 shows the array patterns without signals (quiescent patterns). Fig.4 shows the null depth and direction of quiescent patterns versus r and ϕ. Null depth refers to the ratio of null to mainbeam of the pattern.

In the case of two signals incident (one desired, the other interference), SINR varies with arrival angle θd, θi. Fig.5 shows the SINR for two cases of arrival angle :

(A) $\theta d = -60°$, $\theta i = -10°$: (B) $\theta d = 0°$, $\theta i = 50°$.

Here, the signals are assumed to be narrow band and statistically independent each other, desired signal to noise ratio ξd is 20 dB, interference to noise ratio ξi is 40 dB.

Fig.6 shows the difference of the SINR with steering vector

W_o - R_o from that of W_o. Signal input condition is the same as (A) in Fig.5. Degradation of the SINR is restored at the point of $R = R_o$.

4.CONCLUSION In this paper, the leakage effect in weighting circuitry of PIAA was investigated and some interesting properties became clear as follows :

1. Quiescent pattern is not necessarily omnidirectional.
2. Convergence time of weight is not affected.
3. The performance can be restored by providing the the steering vector with suitable offset.

The simulation in this paper has confirmed the ability to restore the performance of PIAA from degradation which is induced by the leakage, but further studies employing more complex model will be the subject.

5.REFERENCES [1] R.T.Compton,Jr.:'The power-inversion adaptive array : concept and performance',IEEE Trans.Aerosp. Electron.Syst.,Vol.AES-15,No.6,pp.803-814 (Nov.1979)

[2] R.T.Compton,Jr.:'Pointing accuracy and dynamic range in a steered beam adaptive array',IEEE Trans.Aerosp. Electron.Syst.,Vol.AES-16, No.3,pp.280-287 (May 1980)

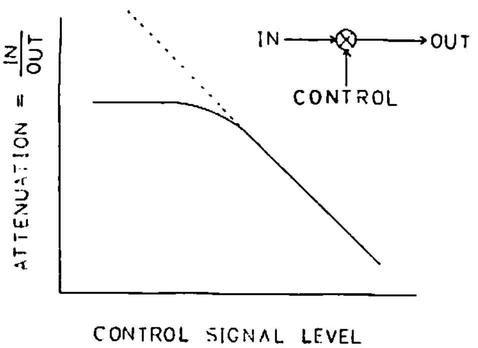


Fig.1 Typical characteristics of practical multiplier.

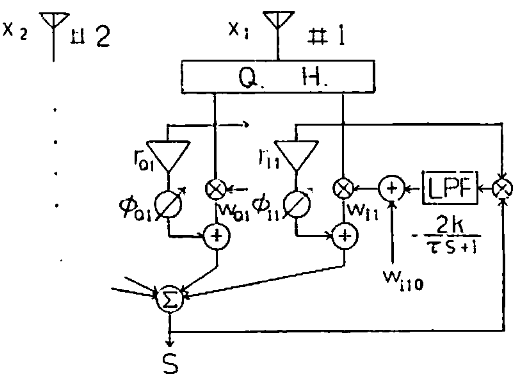


Fig.2 Model of PIAA with leakage effect.

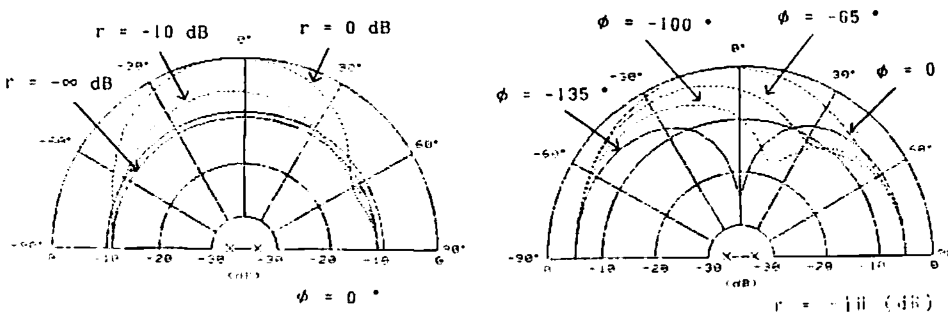


Fig.3 Quiescent patterns.

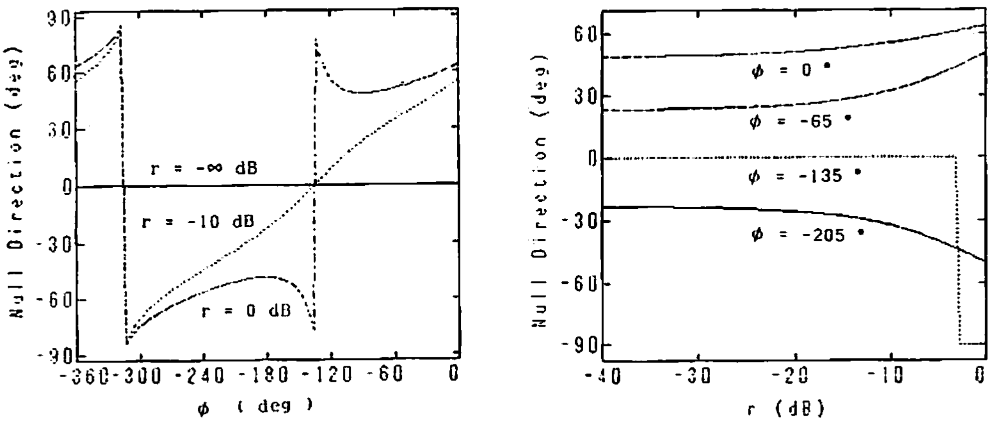


Fig.4(a) Null direction of quiescent patterns.

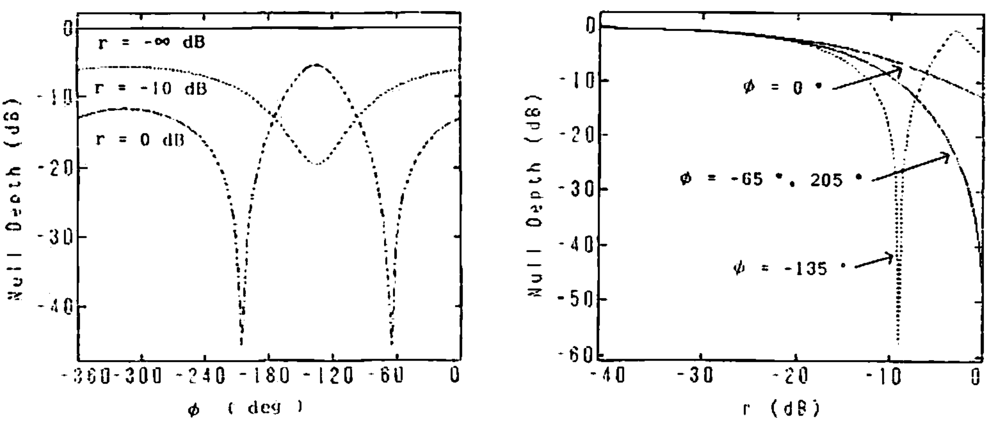
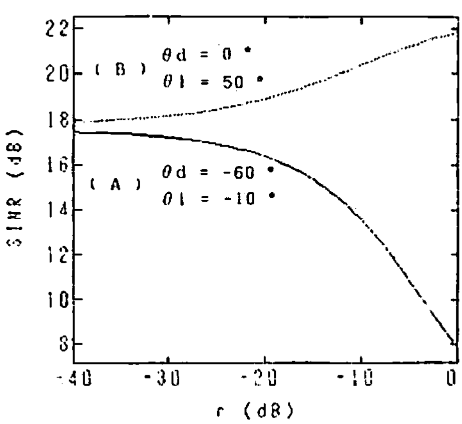
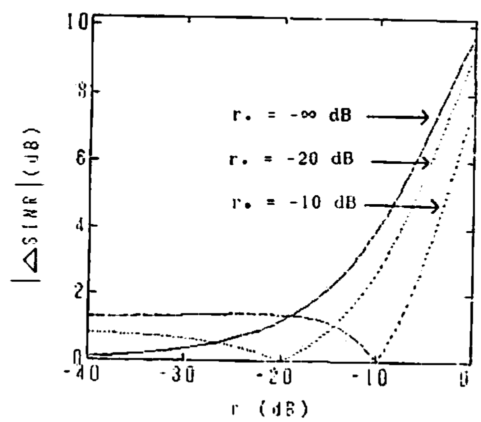


Fig.4(b) Null depth of quiescent patterns.



ξd = 20 dB, ξi = 40 dB , φ = 0 °

Fig.5 SINR versus r.



θd = -60 °, θi = -10 ° , φ = 0 °
ξd = 20 dB, ξi = 40 dB

Fig.6 Difference of SINR for offsetted steering vector.