An Adaptive Array Using Pseudo-noise for Interference Suppression in ITS Communications

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1. Introduction

Terrestrial broadcasting will be shifted from analogue broadcasting to digital broadcasting in Japan. After the digitization, a frequency band from 715 to 725 [MHz] will be utilized for ITS (Intelligent Transportation System), and this “ITS band” will be assigned between the bands of television broadcasting and mobile communications [1]. It is worried that the ITS may suffer interference from broadcast system or mobile communication system. To suppress the interference, the authors have proposed a power inversion adaptive array [2]-[4] with band-pass filters. However, the system tends to suppress the desired signal when the arrival interference is very weak.

In this paper, a novel technique using pseudo-noise is proposed to avoid the problem. Numerical results show that excellent SINR values can be obtained by the proposed technique even if the arrival interference is very weak. Moreover, optimum pseudo-noise level is discussed.

2. Power Inversion Adaptive Array with Band-pass Filters and Its Problem

To suppress the interference in the ITS, the authors have proposed a power inversion (PI) adaptive array with band-pass filters [5]. Figure 1 shows the configuration.

The system is composed of an array antenna, multipliers, a controller and band pass filters (BPF). Frequency characteristics of the BPF are drawn in Fig. 2. The interesting point of this system is that the weight coefficients are determined using only interfering signals but the coefficients are applied to the signals without filtering.

It is necessary to remove the signals completely except for the guard band (GB) by BPF to achieve a high interference suppression effect. However, the signals except for GB cannot be removed completely by BPF, because the ITS band is close to television broadcasting band and mobile communications band.

When the interference is very weak, the desired signal becomes the dominant component because the desired signal component cannot be removed completely by the BPF. In this case, the weight coefficients are decided so that a null point is formed toward the direction of desired signal.

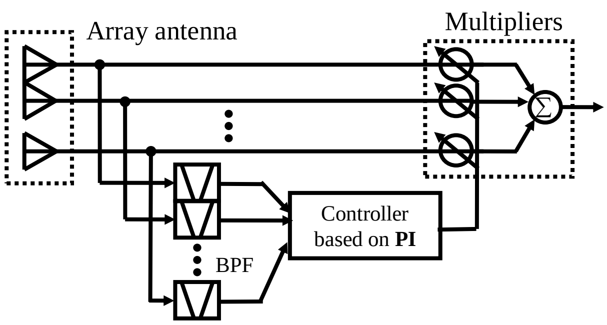

Figure 1: Power inversion adaptive array with band-pass filters

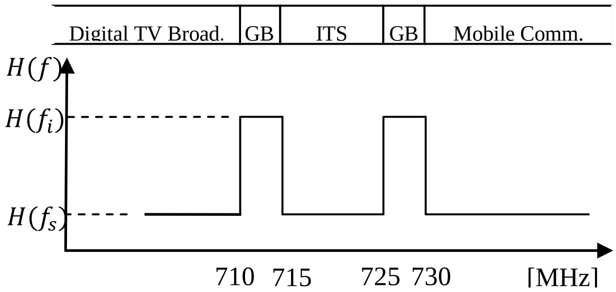

Figure 2: Frequency characteristics of BPF

For example, Fig. 3 shows the optimized directional patterns of the array antenna when desired signal cannot be removed completely. The filter gain in ITS band, $H(f_s)$, is -20dB and desired signal power, P_s, is 0dB. It is found in Fig. 3 that a deep null is formed when the interference is strong (P_i=0dB). However, the null toward the interference disappear and another null is formed toward the desired signal as interference power, P_i, becomes small. From the results, a PI adaptive array with BPF cannot be expected as a measure for interference when the interference is very week.

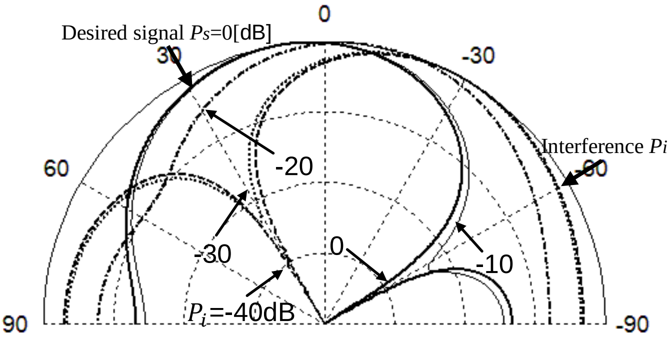

Figure 3: Influence by interference power

3. Improvement of Interference Suppression Performance by Using Pseudo-noise

3.1 Proposal of Using Pseudo-noise

A novel PI adaptive array with BPF using pseudo-noise is proposed to improve the suppression performance when the interference is very week. Figure 4 shows the configuration of proposed adaptive array. The difference between the newly proposed system and conventional one (Fig.1) is only that the pseudo-noises are added after the BPF. A signal flow in newly proposed system is described below.

3.2 Signal Flow in Proposed Scheme

(1) The signals received at the array antenna are fed to the BPF and the multipliers.

(2) At the BPF, only the ITS signals are eliminated and the remaining signals are outputted from the BPF.

(3) The Gaussian pseudo-noise is added after the BPF. Then, the interfering signals and pseudo-noise are fed into the controller.

(4) At the controller, a set of weight coefficients for multipliers is determined based on the power inversion algorithm.

(5) At the multipliers, the weight coefficients are applied to the signal before filtering.

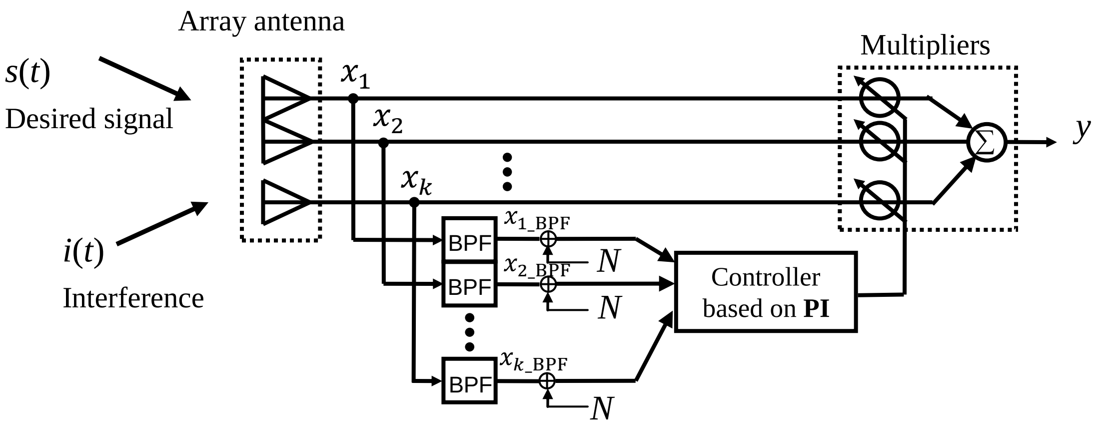

Figure 4: PI adaptive array with BPF by using pseudo-noise

3.2 Role of Pseudo-noise in Proposed Scheme

When the interference is feeble compared with the desired wave or no interference arrives, the signal inputted into BPF can be considered to be only a desired signal. When the BPF is imperfect, a part of desired signal component remains at the output of BPF. Then, the pseudo-noise (white noise) is added after the BPF. By setting the appropriate pseudo-noise level, it is expected that the desired signal components are masked by the pseudo-noise. As a result, weight coefficients in which the null isn't formed in the direction of desired signal are obtained by the PI algorithm.

4. Interference Suppression Performance of Proposed Scheme

4.1 Simulation Condition

Tables 1 and 2 show the simulation conditions of the array and radio environments, respectively. Two-element array with Omni-directional antenna elements is applied. It is supposed in simulation that one desired ITS signal and one interfering signal arrives at the array antenna.

Table 1: Configuration of array

No. of elements	2-elements
Element spacing	0.5 wavelength
Element pattern	Omni-directional
Algorithm	Power inversion

Table 2: Radio environments

	Desired signal	Interference
Frequency	720[MHz]	712.5[MHz]
Direction of arrival	30deg.	-60deg.
Intensity of arrival	0[dB]	-60～+40[dB]

4.2 Effect of Pseudo-noise on SINR

The small value α is added in diagonal element of correlation matrix as pseudo-noise N after the BPF and its influence on the effect of the interference suppression performance is analyzed. The filter gain in ITS band, $H(f_s)$, is -20dB and the value of α is changed. Figure 5 shows the result.

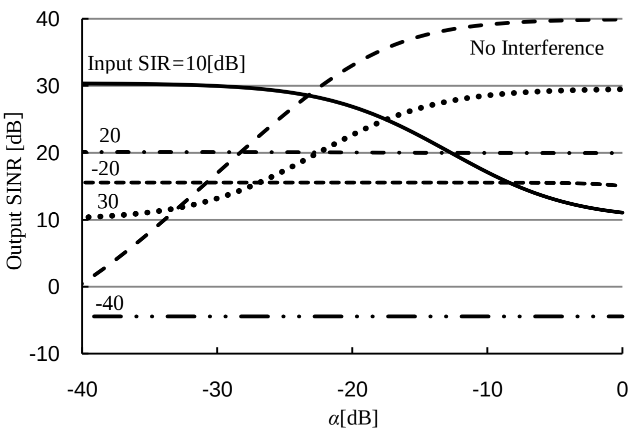

Figure 5: Effect of Pseudo-noise on SINR

The following features are confirmed from the figure.

A) High output SINR is obtained as the pseudo-noise level increase when there is no interference.
B) When input SIR is small (when input SIR=-20, -40 dB in the figure), in other words, the interference wave is strong, there is no influence by the pseudo-noise. This is because interference is stronger than the added pseudo-noise level.
C) Output SINR is improved when the added pseudo-noise level is enlarged when input SIR=30dB. On the other hand, Output SINR is decreased as the added pseudo-noise level is enlarged when input SIR=10dB.

The similar characteristics are confirmed for other $H(f_s)$. Therefore, it is necessary to decide the value of α in consideration of the input SIR to obtain high output SINR.

4.3 Effect of Intensity of Arrivals on SINR

The effect of intensity of arrivals on SINR is analyzed. Here, two types of assumption to decide the pseudo-noise level is considered.

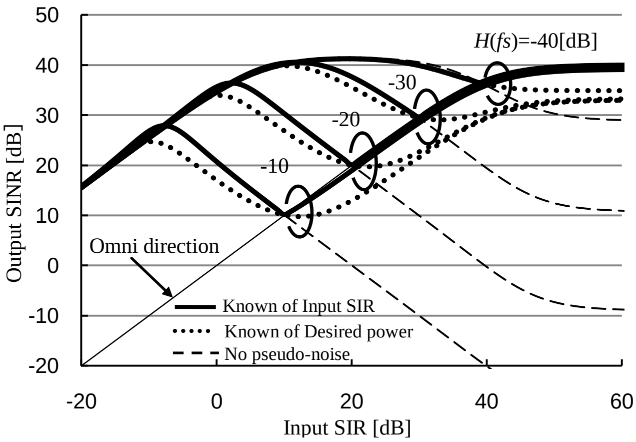

Figure 6: Effect of Intensity of Arrivals on SINR

(a) **Desired signal power is known**: The level of the pseudo-noise is set as the same level of desired signal. The result is shown by the dotted line in Fig. 6. It can be confirmed from the figure that the output SINR has improved greatly when the interference is slight.

(b) **Input SIR is known**: When the input SIR is small, the level of the pseudo-noise is reduced and when input SIR is large, the level is enlarged. The result is shown by the solid line in Fig. 6. Output SINR is the same as that of no pseudo-noise (conventional system) when input SIR is small. On the other hand, output SINR is the same as that of Omni-direction pattern when input SIR is large. Output SINR is improved greatly when the interference is very week. Especially, when the filter gain in ITS band, $H(f_S)$, is -20dB and input SIR is 40dB, Output SINR is improved by about 30dB.

5. Conclusions

A novel technique using pseudo-noise was proposed to avoid the problem.

It was shown that the appropriate pseudo-noise level was the same as desired signal level when desired signal power was known. Output SINR was improved greatly when the interference was very week. Especially, when the filter gain in ITS band, $H(f_S)$, was -20dB and input SIR was 40dB, Output SINR was improved by about 30dB. Inaddition, when input SIR was known, high output SINR was always obtained by setting the pseudo-noise at appropriate level.

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