A Novel Adaptive Array for Interference Suppression in ITS Communication

[#]Mitoshi Fujimoto [1] and Toshikazu Hori [1]
[1] Graduate School of Engineering, University of Fukui
3-9-1, Bunkyo, Fukui, 910-8507 Japan, fujimoto@fuis.fuis.fukui-u.ac.jp

1. Introduction

Terrestrial broadcasting will be shifted from analogue broadcasting to digital broadcasting in Japan. After the digitization, a part of frequency spectrum used for analogue broadcasting in present will be utilized for intelligent transportation system (ITS) and mobile communications [1]. Since the radiation power in ITS is considerably small compared with that of broadcasting or mobile communications, it is worried that the ITS may suffer interference from broadcasting system or mobile communication system when the ITS terminal is close to the broadcasting station or handy terminal of mobile communication system.

In this paper, a novel adaptive array is proposed to avoid interferences from such a broadcasting system or mobile communication system. The proposed adaptive array is composed of a power inversion adaptive array (PIAA) [2]-[4] and band pass filters (BPF). In Sec.2, the interference problem for the ITS is explained in detail. The configuration and point of new scheme of proposed system is provided in Sec.3. The effectiveness of the proposed system is evaluated through computer simulations in Sec.4.

2. Spectrum Assignment of UHF in Japan and Its Problem

Figure 1 shows the frequency spectrum assignment of television broadcasting in Japan. In present, whole frequency band from 470 to 770 [MHz] is utilized for television broadcasting. Now, the terrestrial broadcasting is proceeding from analogue broadcasting to digital broadcasting and the procedure will be completed on July 24, 2011. Then the spectrum assignment will be changed.

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 ITS may suffer interference from broadcasting system when the ITS terminal is close to the broadcasting station because the radiation power of the broadcasting is much larger than that of ITS. Moreover, the radio wave from a handy terminal of cellular system in the car might interfere in the ITS because the propagation distance would be very short. Therefore, a countermeasure for these interferences will be required.
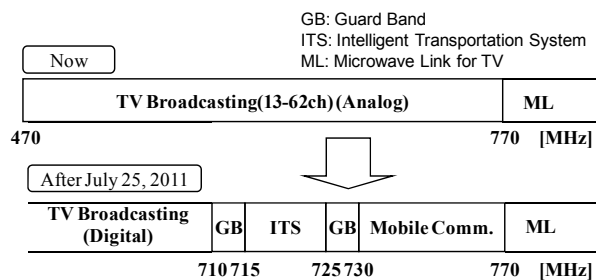

Figure 1: Frequency assignment of terrestrial TV broadcasting in Japan

3. Proposed Adaptive Array

Figure 2 shows the configuration of proposed adaptive array. The system is composed of an array antenna, multipliers, a controller and band pass filters (BPF). If there are no BPF, it is equivalent to a conventional power inversion adaptive array (PIAA). The scheme of the system is described below.

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

(2) At the BPF, only the ITS signals are eliminated and the remaining signals are outputted to the controller. Namely, only the interfering signals without ITS signal are fed into the controller.

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

(4) At the multipliers, the weight coefficients are applied to the signal before filtering. Since the PIAA suppresses the strong signal, the set of weight coefficients forms nulls in the direction of the interfering signals.

The interesting point of proposed scheme is that the weight coefficients are determined using only interfering signals but the coefficients are applied to the signals without filtering [5]. Since the controller is based on PIAA, the information about arrival signals such as directions of arrival, amplitudes and modulation schemes is not required. Therefore, the proposed system is applicable as a countermeasure for interference in ITS communication system.
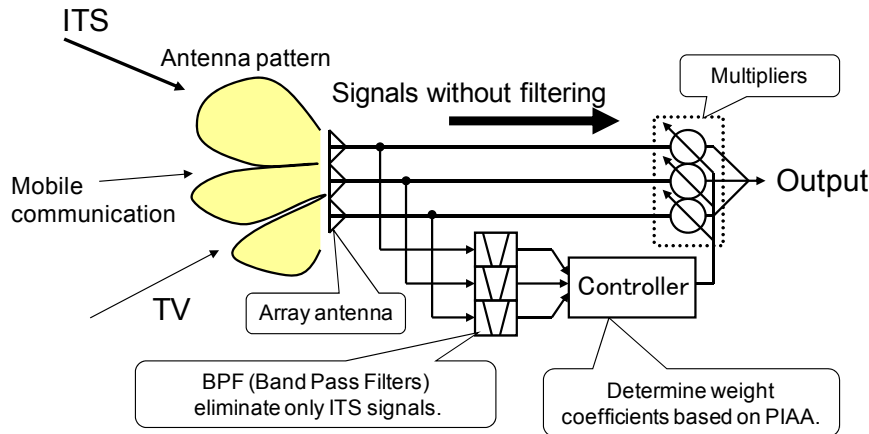
Figure 2: Configuration of proposed system

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 (ITS signal)	Interference (Mobile comm.)
Frequency	720[MHz]	727.5[MHz]
Direction of arrival	30 deg.	-60 deg.
Intensity of arrival	0[dB]	-60～+40[dB]

4. Interference Suppression Effect in ITS Communication System

4.1 Simulation Condition

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

Frequency characteristics of the BPF are drawn in Fig. 3. It is important in the proposed system that only the ITS signal should be eliminated while the signal in guard band (GB) is
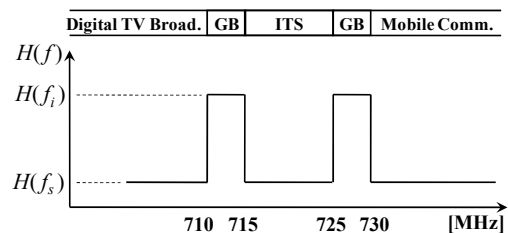
Figure 3: Frequency characteristics of BPF

not attenuated. Since there are two GB besides the ITS band, the filter is a dual band pass filter as shown in Fig.3. In the following sections, the effect of frequency characteristics of the BPF and intensity of arrivals on the performance of the proposed system is evaluated.

4.2 Optimized Directional Pattern

Figure 4 shows the optimized directional patterns of the array antenna when the filter gain in ITS band, $H(f_s)$, is varied. A small value of $H(f_s)$ means that the desired signal is well eliminated at the BPF. The arrows in the figure indicate the directions of arrival. The intensity of the desired signal and the interference is 0dB and -20dB, respectively. This is a usual situation for ITS system.

The thick dashed line ($H(f_s)$=0dB) in the figure correspond to the case of without BPF. It is equivalent to a conventional power inversion adaptive array. A deep null is formed toward the desired signal (ITS signal) because the intensity of the desired signal is much stronger than that of the interference. If the interference is much stronger than the desired signal, it will be easily suppressed by conventional PIAA. In the usual situation for ITS, however, the interference cannot be suppressed as shown by thick dashed line in Fig. 4.

It is found in Fig. 4 that the null toward the desired signal disappear and another null is formed toward the interference as filter gain in ITS band, $H(f_s)$, becomes small. The thick solid line shows the case of, $H(f_s)$ = -40dB. In this case, a deep null is formed toward the interference because the desired signal components are eliminated by the BPF and almost only the interference components are fed to the controller. From the results, we can confirm that the interference is suppressed by the proposed system as expected even if the interference is not so strong.
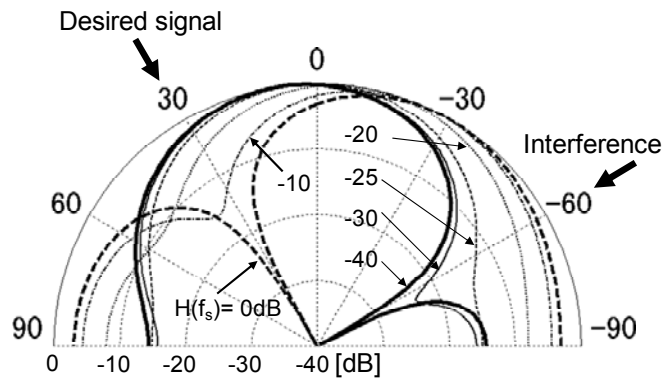

Figure 4: Optimized Directional patterns

4.3 Effect of Frequency Characteristics on SINR

Figure 5 shows the SINR (Signal to Interference plus Noise power Ratio) at the output of the system when the filter gain, $H(f_s)$, in ITS band is varied. The parameter in the figure is filter gain in the GB, $H(f_i)$. When a single antenna with Omni-directional pattern is used, the SINR value becomes 0dB as pointed in the figure.

We can find in the figure that very large SINR can be obtained by the proposed system if the filter gain in ITS band is smaller than -20dB and the gain in GB is 0dB. The frequency characteristics with $H(f_i)$=0dB is an ideal case, and such ideal characteristics cannot be realized. In the real system, the filter gain in GB, $H(f_i)$, tend to be small as the filter gain in ITS band becomes small. However, we can see in the figure that high SINR value can be obtained when the $H(f_s)$ is much smaller than $H(f_i)$ even if the filter gain in GB, $H(f_i)$, is little bit small. For example, more than 30dB of SINR value is obtained when $H(f_s)$ is less than -30dB even if the gain in GB is -10dB. Such the filter characteristics are realizable in real system.
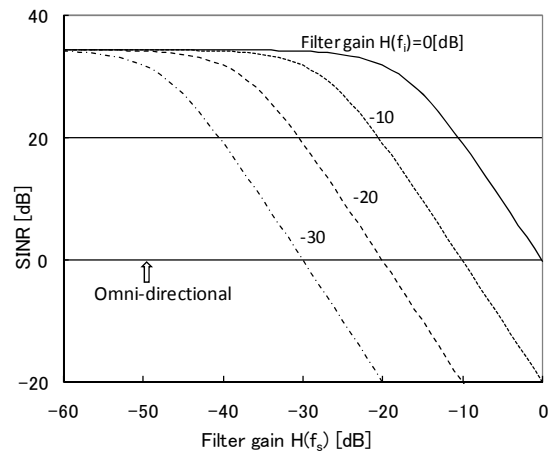

Figure 5: Effect of filter characteristics on interference suppression performance

4.4 Effect of Intensity of Arrivals on SINR

Figure 6 shows the SINR value when SIR (Signal to Interference power Ratio) of arrival signals is varied. The small value of input SIR means that the interference is strong and such situation should be solved. On the other hand, the large value of input SIR means that the interference is weak and it is the usual situation in ITS system. The parameter, $H(f_i)$, is the filter gain in ITS band of the BPF. It is assumed that the interfering signals are not attenuated in the BPF ($H(f_i)$=0dB). The thin solid line shows the case when one element Omni-directional antenna is used.

It is shown in Fig. 6 that the output SINR value in case of $H(f_s)$>-30dB is decreased as the input SIR value becomes large. It is because that the system suppresses the strongest signal. Namely, if the ITS signal is not eliminated enough in the BPF, the system is inapplicable in the usual ITS situation.

On the other hand, the SINR value is kept at high level when the ITS signal is eliminated enough by BPF. Especially, more than 30 dB of SINR can be obtained when the $H(f_s)$=-40dB. Since the elimination of 40dB by digital filters is not so difficult, we can say that the proposed system is applicable for suppression of the interference in ITS communication systems.
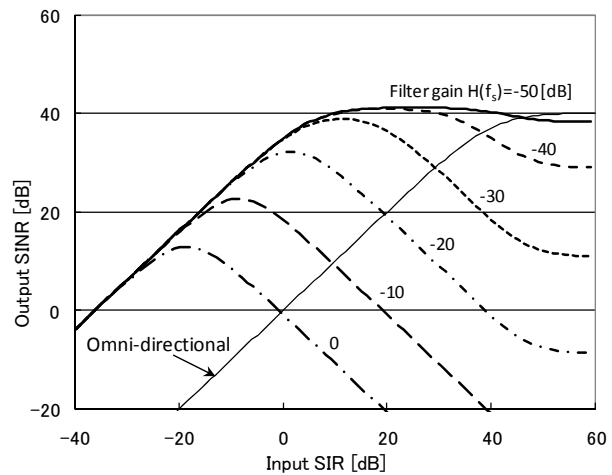

Figure 6: Effect of filter characteristics on interference suppression performance

5. Conclusions

To suppress the interference from neighboring band in ITS system, a power inversion adaptive array with band pass filters was proposed. The feature of proposed scheme is pointed as that the weight coefficients are determined based on the power inversion algorithm using only interfering signals but the coefficients are applied on signals before filtering.

Through the computer simulation, it was confirmed that the interference could be suppressed by forming a deep null toward the interference even in usual ITS situation. Furthermore it was shown that more than 30 dB of output SINR could be obtained by the proposed system when the ITS signal was eliminated more than 40 dB by the band pass filters.

Since the proposed system doesn't require any information such as directions of arrival, the proposed system is expected as an applicable countermeasure for interference in ITS communication system.

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