SOFTWARE ANTENNA WITH ALGORITHM DIVERSITY

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ABSTRACT

A software antenna will be a key device realizing flexible and highly reliable wireless communications systems. The software antenna has been proposed to provide an effective means to cope with time-varying severe propagation environment by selecting an optimum algorithm continually. We call the scheme algorithm diversity. The technologies contain i) how to recognize the radio environment, ii) how to determine the optimum adaptive signal processing algorithm, and iii) how to reconfigure the digital beamforming circuit. Based on this concept, two types of antenna configurations, namely a general one and a specific one, are presented.

INTRODUCTION

The software antenna has been proposed to provide an effective means to cope with time-varying severe propagation environment by selecting an optimum algorithm continually. It also enables a finer selection of these algorithms by using "algorithm diversity" [1]-[3]. The technologies contain i) how to recognize the radio environment, ii) how to determine the optimum adaptive signal processing algorithm, and iii) how to reconfigure the digital beamforming circuit.

To implement the algorithm diversity, the antenna system has to be able to dynamically follow changes in the environment by adapting itself in terms of both software (algorithms) and hardware (logic circuits). With a configuration of antenna array, and by performing signal processing which overcomes the limitations of each individual algorithm, it adapts to the existing environment at any time in the manner of a chameleon.

Fig. 1 is a schematic illustration of a software antenna that would be used in a base station for mobile communications. In this paper, two types of antenna configurations, namely a general one and a specific one, will be presented.

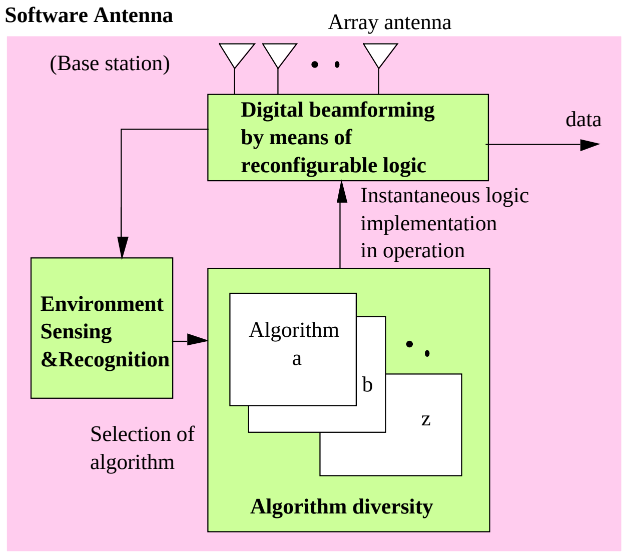


Fig.1 Functional diagram of a software antenna

IDENTIFICATION AND CLASSIFICATION OF RADIO ENVIRONMENTS

The object of the antenna is to receive the wanted signal with the maximum signal-to-noise +interference ratio: SINR against a number of interfering waves (i.e. co-channel interference: CCI and inter-symbol interference: ISI), by utilizing a degree of freedom determined by the number of array elements and the number of taps in the TDL (Tapped Delay Line) under the condition of the least computational load.

Using information both space and time domains, we can classify probable propagation environments into four types [3]. First, through a spatial signal processing based on eigenvalue analysis of the correlation matrix (or covariance matrix) of each antenna output, we can identify the environment by watching the appearance of significant eigenvalues. If the number of the significant eigenvalues is only one, hereafter, we call this case single eigenvalue, the environment can be identified as i) one signal source with single- or multipath without delay spreading, or, ii) one signal source with delay spreading without angular spreading. Time domain (or frequency domain) analysis can identify whether the environment has significant delay spreading or not. As the combination of two-dimensional classification, the following types can be identified.

Type I: The number of noticeable eigenvalues is only one, and delay spreading is negligible,
Type II: Noticeable eigenvalues are more than two, and delay spreading is negligible,
Type III: The number of noticeable eigenvalues is only one, and delay spreading is not negligible,
Type IV: Noticeable eigenvalues are more than two, and delay spreading is not negligible

The classified environments corresponding to each type are shown in Fig. 1.

APPROPRIATE ADAPTIVE SIGNAL PROCESSING SCHEME FOR CLASSIFIED ENVIRONMENT

Let us consider appropriate adaptive algorithms (or circuit configurations) corresponding to each classified type.

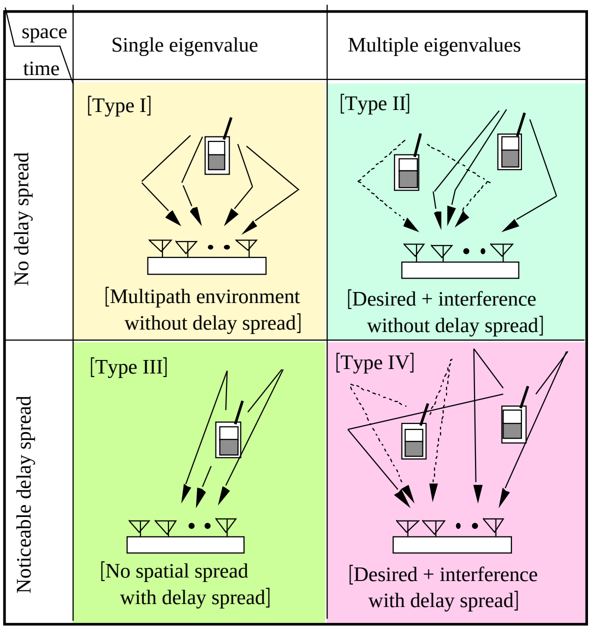
Type I This case corresponds to a multipath environment without delay spread, so an algorithm which receives these waves with maximum S/N is found. This is the maximal ratio combining (MRC). The MRC can be realized using the eigenvector beam (namely, antenna weight vector corresponding to the eigenvector for the maximum eigenvalue).

Type II Spatial signal processing antennas, usually called adaptive antennas, can achieve satisfactory performance. Here, tracking with an optimization algorithm such as LMS, RLS or SMI based on a Minimum Mean Square Error (MMSE) criterion which minimizes the residual error from the reference signal, is appropriate.

Type III In this case, a time-domain signal processor, i.e. an equalizer, is a potential means. To make good use of the gain of the array antenna, it is expedient to use the antenna pattern with the eigenvector corresponding to the maximum eigenvalue. ISI can be eliminated by a time-domain signal processor (i.e., equalizer), while the array antenna plays a role in increasing signal-to-noise ratio of received signal.

Type IV In this case, space/time multi-dimensional signal processing is required. The construction is that of a TDL array or a sub-band signal processing array. The principle of optimization with LMS or RLS under the criterion of MMSE is the same for Type II and Type III. This construction may be viewed as one which aims to minimize distortion and maximize received signal power (= maximize S/N) forming a space/time matched filter for multipath waves dispersed in space and time [4], [5].

Fig. 3 shows a reconfigurable antenna as a general image of the software antenna adapting based on the algorithm diversity.



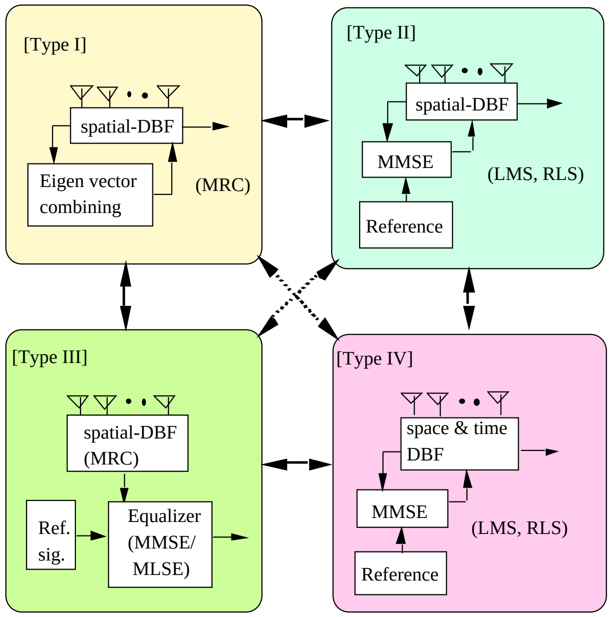


Fig. 2 Classification of radio environments

Fig. 3 A reconfigurable antenna based on algorithm diversity

A SOFTWARE ANTENNA HAVING ROBUSTNESS FOR STRONG INTERFERENCE

A very simple configuration of the software antenna changing between type I and type II operated with blind algorithms is introduced [6]. The configuration is shown in Fig. 4.

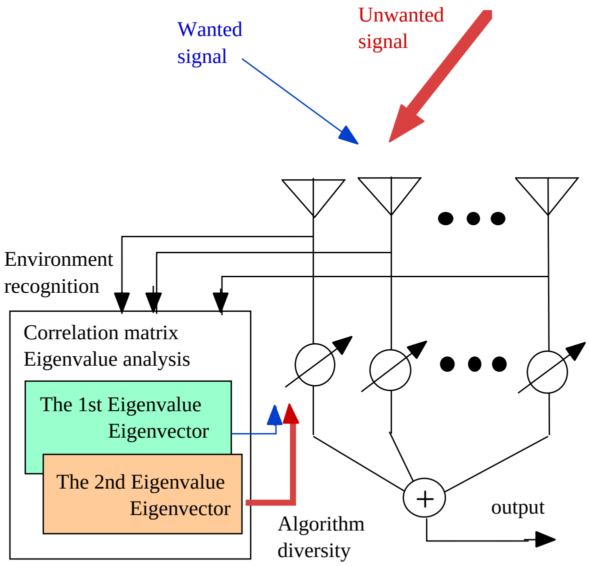


Fig. 4 A software antenna configuration having robustness for strong interference signal coming suddenly

In the case of normal condition where a wanted signal comes to the antenna (Type I), the beamforming can be done by the antenna weight corresponding to the eigenvector producing the largest eigenvalues. The antenna receives the signal with the highest SNR by the maximal ratio combining. When very strong intereference, for example, its power is more than 20dB, enters the antenna suddenly (Type II), the reception system becomes outage condition. However, if we change the operation mode from the largest eigenvalue reception to the second eigenvalue reception, higher CINR can be recovered soon. This mechanism may be similar to the power inversion algorithm. By watching eigenvales in the reception system, we can identify the environment and its change.

We have made a computer simulation assuming i) 4-element linear array with a half wavelength separation, ii) incident angle of 0^{o} and input SNR of 10dB (for each element) for the wanted signal (appearing all time), iii) incident angle of 20^{o} and input SNR of 30dB (for each element) for the unwanted signal (appearing in a limited time period). We made a block by block analysis, and the unwanted signal comes in the period of 3 to 7 blocks. Fig. 5 shows the transition of each eigenvalue. Fig. 6 shows the transition of SINR for the reception with each eigenvector beam.

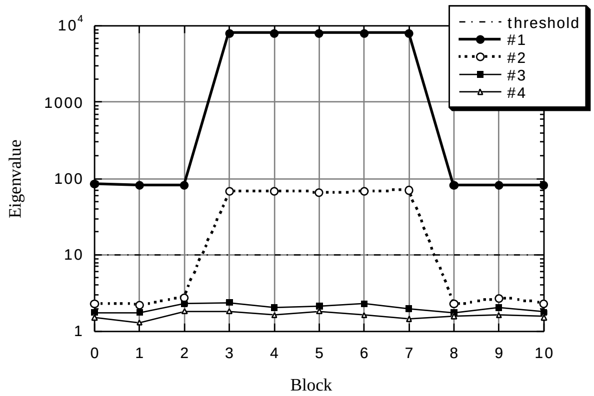


Fig. 5 Transition of each eigenvalue

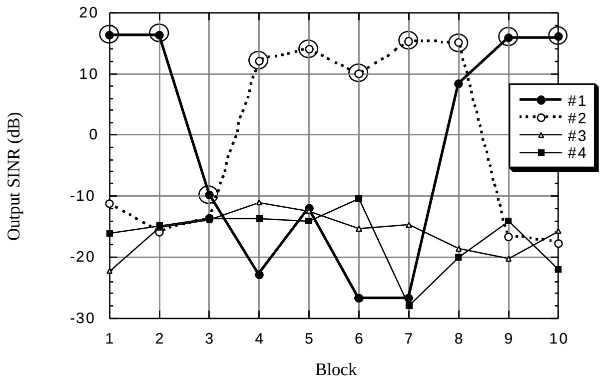


Fig. 6 Transition of each SINR

CONCLUSION

Key technologies on software antennas, namely, (i) radio environment recognition, (ii) the optimum adaptive signal processing algorithm identification (algorithm diversity), and (iii) reconfigurable digital beamforming architecture were summarized, first. Then, an image of a software antenna with reconfigurable eigenvector beamspace configuration covering four different conditions was presented. Finally, as a specific example, a two-state transition antenna having robustness for strong interference coming suddenly was demonstrated.

Reference

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