Smart Antenna System for Wideband CDMA Signals

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Abstract - Smart antennas have been successfully implemented in CDMA cellular communication systems in order to increase the system capacity and improve its performance. However, it has been shown in [1] that the use of wideband CDMA signals results in a significant deterioration of the narrowband system performance. The use of adaptive array to reject wideband interferences and track wideband signals have been proven to be more efficient if frequency compensation is used [2]. This paper presents an extension of the interpolated constant modulus algorithm (ICMA) introduced in [2] to wideband CDMA signals (WCDMA). Simulation results show that the ICMA yields significantly better performance as compared to the conventional narrow-band adaptive algorithm.

I. INTRODUCTION

Smart antenna systems have recently played a central role in removing narrowband multiple-access interference (MAI) in CDMA cellular systems [3]. However, due to the actual need for increasing channel capacity, the required bandwidth is becoming wider and can bring significant deteriorations of the narrowband adaptive systems. These performance degradations are mainly caused by the fact that the inter-element phase shift becomes a function of the frequency while the adaptation weights are kept independent of frequency.

Consider a two-element array, with adjacent elements spaced at λ0/2, where λ0 is the wavelength at the mid-range frequency, f0, of the incident signals. The phase shift is given by the following equation

\[ \phi = \frac{\pi f}{f_0} \sin \theta \]  

where \( f \) and \( \theta \) are the instantaneous frequency and the arrival angle of the incident signals (signal or interference), respectively.

The contribution of a single interference, \( s_i(t) \), at the output of the two-element array is

\[ y_i(t) = \begin{bmatrix} 1 & w_{agg} \end{bmatrix} \begin{bmatrix} s_i(t) \\ -j\pi f_i \sin \theta \end{bmatrix} = s_i(t) + w_{agg} \times s_i(t) e^{j\pi f_i \sin \theta} \]  

(3)
In the narrowband case, the weight, \( w_{\text{opt}} \), is adjusted to null the interfering signal at its center frequency of \( f_0 \), therefore

\[
\text{w}_{\text{opt}} = -e^{j\pi f_0 t_0}
\]  

(3)

If the carrier frequency of the received signal changes from \( f \) to \( f + \Delta f \), then the phase shift changes by

\[
\Delta \phi = \frac{\Delta f}{f_0} \sin \theta
\]  

(4)

and the adaptive system attempts to readjust the optimal weights with respect to the new null depth value. That is,

\[
\text{w}_{\text{opt}'} = -e^{j\pi f_0 t_0} e^{j\frac{\Delta f}{f_0} \sin \theta} = \text{w}_{\text{opt}} \times \Delta w, \quad \text{where} \quad \Delta w = e^{j\frac{\Delta f}{f_0} \sin \theta}
\]  

(5)

At a high data rate, the null depth varies rapidly with frequency over the signal bandwidth and the narrowband adaptive system is therefore not able to follow the frequency variation of the incident signals.

To handle the wideband signal or to cancel the wideband interference perfectly, the adaptation should take into account the frequency dependance of inter-element phase shift. The processing behind each element must be able to provide a weight that varies with frequency.

To compensate the effect of the inter-element phase variations, a new approach called the interpolated constant modulus algorithm (ICMA) was first introduced for wide FM signals [2]. This paper presents an extension of the ICMA to WCDMA signals. The system is based on an interpolation technique [4] used in conjunction with the constant modulus algorithm (CMA) [5].

II. THE ICMA IN A DS-CDMA SYSTEM

A practical layout for implementation of the ICMA in a DS-CDMA system using four antenna elements is depicted in Fig. 2. The user data are spread by a PN sequence code and transmitted on the carrier using BPSK modulation. Each user in the CDMA system is assigned a unique pseudorandom code sequence.
The received signal will consist of the sum of five different transmitted signals (one desired user and 4 undesired users). The signals (desired and undesired) are received by the array, downconverted to a suitable intermediate frequency, amplified and decomposed into non-overlapping narrowband components using analog bandpass filters. The decomposed signals are then passed into an interpolation block to provide the transformed signals to be weighted by the narrowband CMA (NBCMA). The interpolation technique used here to generate the interpolated array output is the one explored in [4].

III. PERFORMANCE OF THE ICMA IN PRESENCE OF WCDMA SIGNALS

A wideband DS-CDMA signal is transmitted and the interference is a combination of wideband CDMA signals from four other users. The signal and the interference are assumed to be spread over the same bandwidth and their direction of arrival (DOA) are respectively fixed at 0° and 30° degrees. A carrier frequency of 2 GHz, a bit rate of 2Mbps, and bandwidths of 8, 16 and 32 MHz have been considered.
Fig. 3 shows array patterns of the narrowband CMA and the wideband ICMA arrays in presence of wideband CDMA signals. From Fig. 3 a), it is noted that the ability of the CMA array to reject interference degrades as the bandwidth of the incident signals increases. The interference null depth is reduced from -40 dB to -17 dB in the case of a BW=16 MHz and to -17 dB in the case of a BW=32 MHz.

Using the ICMA in the case of a bandwidth of 32 MHz, Fig. 3 b) shows that the interference level power has been increased to -18 dB.

According to these numerical results, it can be concluded that a smart antenna system designed for narrowband communications is therefore seen to be seriously affected by the presence of wideband CDMA signals. The use of the ICMA algorithm shows a significant improvement over the system without compensation.

IV. CONCLUSION

An extension of the ICMA beamforming algorithm to wideband CDMA signals has been presented. It is shown that for uniform linear ICMA array, it is possible to reject wideband CDMA signals and achieve considerably superior performance as compared to the narrowband CMA.

V. REFERENCES