HIGH PERFORMANCE ADAPTIVE ANTENNA ARRAY FOR WCDMA COMMUNICATION SYSTEM

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ABSTRACT
This work presents the uniform linear Array model of a simple adaptive antenna array based on signal to interference plus noise ratio (SINR) maximization. A simple adaptive antenna array which can form part of a WCDMA base station structure was developed. Interference and noise reduction capabilities of an adaptive antenna array were investigated, comprehensive analysis of omnidirectional antenna and adaptive antenna array was done based on SINR maximization. The SINR was investigated for a conventional narrow band beam former by varying the number of the antenna array elements and the number of interfering signals or users. The principle of adaptive antenna array and mathematical model was deployed. Adaptive antenna as observed from the analysis indicated great improvement in the SINR over omni-directional antenna. It was discovered as well that there is significant improvement in SINR as the number of antenna elements increases in the presence of large interferences for odd number array, precisely when odd numbered elements were used with inter-element spacing of $d = 0.5\lambda$. Improving the interference suppression and noise reduction capabilities of any system in the presence of large interferers hence increases the capacity of that system. Thus, comparing SINR for $d= 0.5\lambda$ and $d= 0.75\lambda$, the result obtained showed that SINR for $d= 0.5\lambda$ is always less than that for $d= 0.75\lambda$, therefore the odd numbered array 9 and 11 gives significant improvement in SINR when compared to even numbered array with value remaining the same in the presence of six or more interferences. When the reversed, the desired improvement for high performance antenna system was not achievable.

Keywords: SINR, Antenna Array, Radio Frequency, Capacity.

1.0 INTRODUCTION

In telecommunication system, an antenna is the port through which radio frequency (RF) energy is coupled from the transmitter into space and from space to the receiver, antennas have been the most neglected of all components in communications systems. The manner in which RF energy is distributed into and collected from space has a great influence on the efficient use of spectrum, the cost of establishing new communications networks and quality of service provided by those networks.

Smart antennas are antenna arrays with smart signal processing algorithms used to identify spatial signal signature such as the direction of arrival (DOA) of the signal, and use it to calculate beam-forming vectors, track and locate the antenna beam on the mobile. Smart antenna have emerged as one of the leading innovations for achieving highly efficient networks that maximize capacity and improve quality and coverage, Smart antennas provide greater capacity and performance benefits than conventional antennas because they can be used to customize and fine-tune antenna coverage pattern to the changing traffic or radio frequency (RF) conditions in a wireless communication system such as the WCDMA network (Hafeth, 2005). It is techniques are used notably in acoustic signal processing, track and scan radar, radio astronomy and radio telescopes, and mostly in cellular systems like W-CDMA, UMTS and LTE. Beam forming (BF) which is a key technology in smart antenna systems is a process in which each user's signal is multiplied by complex weighted vectors that adjust the magnitude and phase of the signal from each antenna element. Beam forming appropriately combines the signals received by different elements of an antenna array to form a single output. Many adaptive algorithms have been developed to determine the optimal weight vectors of array antenna elements dynamically based on different performance criteria (Chris et al., 2003). The weight vectors produce the desired radiation pattern that can be changed dynamically by considering the position of users and interferers to optimize the signal-to-interference and noise ratio (SINR) (Kim and Cho,1998).

This work models a mobile base station with signal-to- interference and noise ratio (SINR) management to improve link capacity of a WCDMA base station structure by combining the effect of multipath propagation/constructively exploiting the difference in the data streams from the different antennas. To investigate the interference and noise reduction capabilities of an adaptive antenna array, comparative analysis of Omni-directional antenna and adaptive antenna array based on SINR maximization was also presented.

2.0 METHODOLOGY

ULA is composed of M elements and the received one desired narrow band signal $S_0[k]$ arriving at angle θ_a and N- narrow band.

Signals $S_i[k]$ from undesired (or interference) users arriving at directions $\theta_1, \theta_2, \ldots\theta_N$. The direction of arrivals (DOA) is known as priori using any of the DOA estimation techniques such as MUSIC and ESPIRIT. The input signal at each antenna element is the convolution between the transmitted signal and the channel impulse response. Each received signal at element m also includes additive Gaussian noise. Time variation of the arriving signal is represented by the Kth time sample. The overall received signal vector X[k] is given by the superposition of desired signal vector $X_0[k]$, interfering signal vector $X_1[k]$ and an MXI vector n[k] which represents zero mean Gaussian noise for each channel (Godra, 1997). Hence, x[k] can be written as:

$$X[k] = X_0\,[k] + X_i\,[k] + n\,[k] \qquad (2.1)$$

where

$$X_o\,[k] = a_0\,(\theta_0)\,S_0\,[k] \qquad (2.2)$$

$$X_i\,[k] = [a_1\,(\theta_i)a_2\,(\theta_2)]a_N(\theta_N)]\,.\begin{bmatrix} S_{i1} & [K] \\ S_{i2} & [K] \\ S_{iN} & [K] \end{bmatrix} \qquad (2.3)$$

$a_i\,(\theta_i)$, i = 0, 1,2 …N is M –element array steering vector for the θ_i direction of arrival. It is assumed that the total number of arriving signal N+≤ M. In a more compact form the overall received signal can be written as

$$X[K] = X_o\,[K] + V[K] \qquad (2.4)$$

where

$V[K] = X_i\,[K] + n\,[K]$ is the undesired signal.

The arriving signals is time varying and thus our calculations are based upon K-time snapshots (or samples). The array correlation matrix associated with vector X[K] contains information about how signals from each element are correlated with each other and is given by

$R_{Xx} = E\{X[K]\, X^H [K]\}$ (2.5)

The array correlation matrices for both the desired signal R_o and the undesired signals $R_v = R_i + R_n$ can be approximated by applying temporal averaging over K-sample S:

$R_0 = E\{X_0 [k]\, X_0^H [K]\}$ (2.6)

$R_i = E\{X_i [K] X_i^H [K]\}$ (2.7)

$R_n = E^2 n\, I,$

Where E_n^2 is the noise variance and 1 is an NxN identity matrix.

Matlab/Simulink was deployed.

3.0 RESULT AND ANALYSIS

Maximizing signal-to-interference and noise ratio to investigate the interference suppression and noise reduction capability of an adaptive antenna array, a fixed weight beam former is considered to provide maximum out put SINR in the direction of a desired user. In the simulation, maximum SINR for M-ary by varing M between 1 and 12, with inter-element spacing of d =0.5λ and 0.75λ for the ULA model in chapter three six scenarios were considered with the number of interferers varying between 1 and 12. In each case, the desired user fixed angle of arrival is set at 30^0 and noise variance is taken to be 0.001. both the desired and interfering signal take the form of simple complex- phase modulated signal. Signal amplitude was taken to be 1. Matlab program was used to obtain the data in table 1 when three interferers are arriving at fixed angles of 20^0, 40^o, 60^0.

Table 1: SINR in the Presence of Three Interferers

M	SINR(d=0.5λ)	SINR (d=0.75λ)
1	0.35	0.33
2	0.50	0.16
3	4.30	0.05
4	114.54	24.07
5	165.03	204.11
6	385.72	752.72
7	834.91	1144.30
8	527.92	898.51
9	1708.40	209.65
10	170.49	431.33
11	1368.10	788.53
12	168.64	651.60

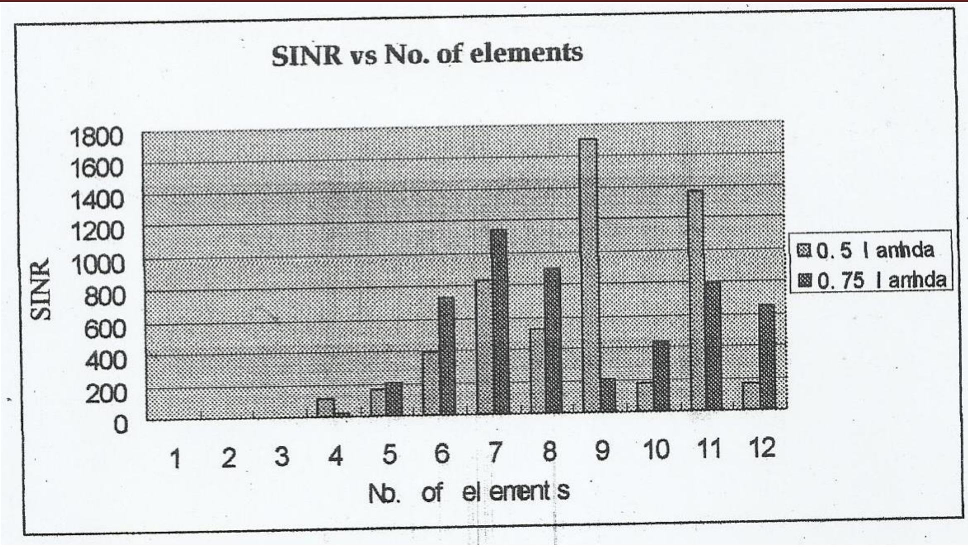

Figure 1: SINR vs No. of Antenna Elements in the presence of Three Interferers (Tanagemann, et al. 2010).

It was observed from figure 1 that SINR is better improved with d=0.5λ and maximum was obtained with 9-ary and 11-ary.

Table 2 shows that the single element array is an omni- directional antenna.

Table 2: SINR for Omni - Directional Antenna and 2- Element Array

No. of Interferers	**SINR for Omni-directional**	**SINR for 2-ary**
2	**0.50**	**0.10**
4	**0.25**	**0.60**
6	**0.17**	**0.81**
8	**0.13**	**0.88**
10	**0.10**	**0.92**
12	**0.08**	**0.094**

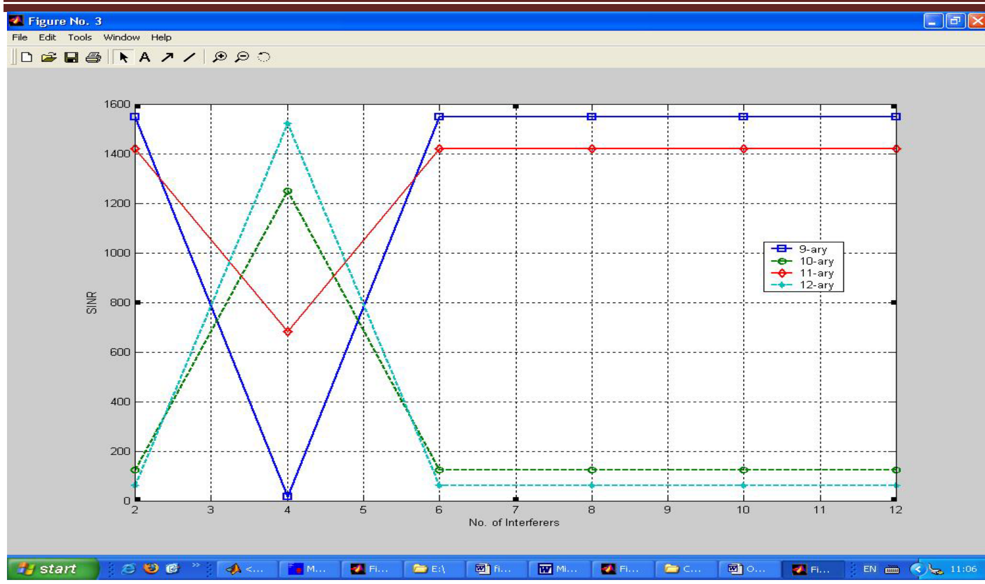

Figure 2: SINR vs. No. of interferes for higher-element array (M=9 to 12) when d= 0.5λ.

Figure 2 shows that odd number and array 9 and 11 give significant improvement in the SINR compared to even numbered array 10 and 12, with the value remaining the same in the presence of six or more interferers.

CONCLUSION

It was observed that the signal – to – interference and noise ratio depends on the number of antenna element the inter–element spacing between the arrays and the number of interferers. There was great improvement in the SINR when odd numbered elements were used with inter – element spacing of d=0.5λ in the presence of large interferers.

Adaptive antenna as observed from our analysis showed great improvement in the SINR over Omni – directional antenna in the presence of large interferers. Finally, improving the interference suppression and noise reduction capabilities of any antenna system in the presence of large interferers, increases the capacity of that system deploying such antennas. Therefore, adaptive antenna proposed here will increase capacity of a WCDMA network.

REFERENCE

Chris, L., Zhizhang, C. and Dylan, J. (2003), *An Overview of Adaptive Antenna Technologies for Wireless Communication*, Communication Networks and Service Research Conference, New Brunswick, Canada, Vol. 162, pp. 1965 -1977.

Godra, L. C, (1997), *Applications of Antenna Arrays to Mobile Communication Part 111: Beam Forming and DOA Considerations*, Proceedings of IEEE on Antenna Syetems, Vol. 85, No. 8, pp. 1195 -1245.

Hafeth, H. (2005), *An Overview of Adaptive Antenna Systems*, Helsinki University of Technology Communication Lab. Project3, pp. 113-124.

Ivan, H. and Faheci, H. A. (2002). *Capacity Analysis based on using Adaptive Antenna Arrays Jointly Optimized for Trucking and Spatial Efficiency*, EURASIP Journal on Applied Signal Processing, Vol. 6, pp. 635- 646.

Kim, C. K. and Cho, Y. S. (1998), *Capacity Improvement of a MCCDMA Cellular System with Antenna Arrays in a Fading Channel,* IEEE Proceedings of 48th Vehicular Tech. Conference, Vol.3, pp. 2032 - 2036.

Tanagemann, M., Hoek, C. and Theinsehmitt, R. I. (2010), *Introducing Adaptive Array Antenna Concepts in Mobile Communication Systems*, Proceedings RACE Mobile Telecommunication Workshop Publication, No. 123, pp. 60.