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Adaptive Beamformer using Nested Arrays and Multirate Techniques

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Abstract

The linear adaptive antenna arrays are examined in this report which are used at the mobile station for a typical Direct Sequence Code Division Multiple Access (DS-CDMA) cellular mobile communications system. The primary objective is to reduce co-channel interference of a wideband CDMA cellular network under a multi-path fading environment. Performance analysis of a randomly positioned mobile terminal with a randomly orientated adaptive antenna array in the forward channel (base-station to mobile) of a multi-cell DS-CDMA system is done and four performance boundaries, viz. BER, PSNR, BEAMWIDTH and SLL are established. A broadband adaptive array beamformer is proposed using harmonic nesting arrays and multirate sampling techniques. An harmonic nesting microphone array is designed to have several uniform linear sub arrays, each covering an octave frequency band. An adaptive beamformer following each subarrays is then implemented using a Generalized Sidelobe Canceler (GSC) structure.

Keywords - *Generalized Sidelobe Canceler, Adaptive Array, Nested Array, Multirate Sampling.*

I. INTRODUCTION

Extensive research on smart antenna cellular applications started in the early 1990s. Interest in this technology has steadily increased since spatial processing is considered as a last frontier in the battle for cellular system capacity with a limited amount of the radio spectrum. Network performance is a complex subject that includes network capacity, call quality, data throughput and other parameters that directly impact the performance seen by the customer. In wireless networks, performance is limited by radio frequency (RF) interference. There is a trade-off between the number of users communicating on the network and the performance that they will experience; having more sub-scribers results in higher RF interference and lower performance quality. As such, reducing network-wide interference has become critical. The smart antenna techniques are one of the few techniques that are currently proposed for new cellular radio network designs. These will be able to improve the systems performance dramatically.

Smart antennas are classified into two main types: Switched Beam and Adaptive Array. A switched-beam antenna system forms multiple fixed beams with heightened sensitivity in particular directions. These antenna systems detect signal strength, choose from one of the several predetermined fixed beams, and then switch from one beam to another as the mobile moves throughout the sector. In addition, the antenna system also measures the RF power or signal strength from a set of pre-defined beams and outputs the RF from the selected beams that afford the best performance to a desired user. Adaptive antenna technology represents the most advanced smart antenna approach to date. Antenna arrays when used in an appropriate configuration, at the base station, in mobile communications significantly improve the systems performance by increasing channel capacity and spectrum efficiency. Arrays can also help to reduce multi-path fading thus increasing coverage.

Adaptive arrays are further classified into two types: dynamic phased arrays and adaptive antenna arrays. Dynamic phased arrays use the direction of arrival (DoA) information from the desired user and steer a beam maximum toward the desired user. This allows continuous tracking of the user, thus improving the capabilities of a switched -beam antenna. In an adaptive antenna array, the weights are adjusted to maximize the signal-to-interference-plus-noise ratio (SINR) and provide the maximum discrimination against interfering signals. In the absence of interferers and with noise as the only undesired signal, adaptive antennas maximize the signal-to-noise ratio (SNR) and thus per-form as a maximum ratio combiner (MRC). By using a variety of signal processing algorithms, the adaptive antenna system can continuously distinguish between the desired signal and the interfering signal and can maximize the intended signal reception.

II. PROPOSED SYSTEM

An adaptive antenna array can be applied to a CDMA mobile communication system to maximize the SINR of the system. The primary aim of the antenna array receiver is to provide acceptable error performance and to maximize the signal-to-interference and noise ratio (SINR) for each user in the system. An antenna array consists of *N* identical antenna receivers, whose operation and one central processor usually controls timing. The geometry of the antenna locations can vary widely, but the most common configurations are to place antennas in a circle (circular array), along a line (linear array) or in plane (planar array). The circular array geometry provides complete coverage from the base station as the beam can be steered through 360^0. As such, the position and spacing between antenna elements are very critical in the design of antenna arrays. The antenna array can take different geometries, and two common antenna arrays are the uniform linear array (ULA) and the uniform circular array (UCA) as shown in figure1.

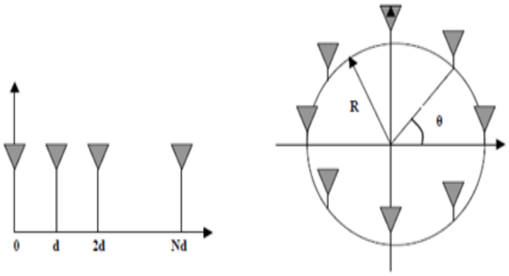

Fig 1: Common Antenna Array Geometries- Uniform Linear Array ULA (left) and Uniform Circular Array UCA (right)

A. Impementation

Figure 2 shows the block diagram of nested array using multirate sampling in which every element is first sampled at F_s, the highest rate required. Then each subarray uses a proper rate of decimation D_i $(i = 1, 2, 3, 4)$ to achieve the desired sampling rate F_i. An analysis filter $H_i(z)$ is placed before each downsampler to avoid aliasing. After down sampling, the four subarrays will have an identical normalized frequency range B_n. Then an identical adaptive beamformer is designed and applied to all the subarrays. The outputs of the adaptive beamformers are up sampled to F_s and then summed. The synthesis filters $G_i(z)$ are needed before the summation to remove the images generated by upsampling. The optional bandpass filter may be also needed to achieve better frequency responses.

Here, F_s is chosen to be *16kHz*, and the sampling frequencies of subarrays are $F_1 = 2kHz$, $F_2 = 4kHz$, $F_3 = 8kHz$ *and* $F_4 = 16kHz$. The downsamplers are $D_1= 8$, $D_2=4$, $D_3 = 2$, and $D_4 = 1$. The analysis filters $H_i(z)$ are designed to have the desired frequency responses for the corresponding subarrays. The identical normalized frequency range for the four subarrays is $B_n = [0.10625,0.2125]$ after the downsamplers. Applying linear and circular antennas to above system, we can get the outputs and four performance boundries are calculated viz. BER, PSNR, BEAMWIDTH and SLL.

III. SYSTEM PERFORMANCE

The performance of the linear system is done for different distances and angles. The four parameters are measured and then they are compared.

Figure 3 have distances as 80, 40, 20, 10cms and angle considered here is 90^0. From array factor polar plot 1 (top left), it can be seen that it has more distorted signal. It is receiving the required signal as well as noisy signal having gain upto 40 dB. The signal is available for all angles with too many interruptions. In array factor plot 2(top right), distance of the array is less, and so signal is received with less number of interruptions. Here, mostly the signals with 50 dB gain are received.

In array factor plot 3(bottom left), the signals with 100 dB gain are received and they are available for all angles except from 140 to 160 degrees. It is receiving the signal with less number of noisy signals. In array factor plot 4(bottom right), the signals with more than 50 dB gain are received and they are available for all angles except from 80 to 160. Here, as the distance of array is less, only required signal we are getting. The four parameters calculated for this are given in table 2.

Figure 4 have distances as 200, 150, 100, 50cms and angle considered here is 180^0. From array factor polar plot 1 (top left), it can be seen that it has more distorted signal. It is receiving the required signal as well as noisy signal having gain closer to 50 dB. The signal is available for all angles with too many interruptions. In array factor plot 2(top right), distance of the array is less, and so signal is received with less number of interruptions. Here, mostly the signals with 50 dB gain are received. In array factor plot 3(bottom left), some of the signals having gain closer to 50 dB are received while others are having gain closer to 100 dB and they are available for all angles except from 140 to 160. It is receiving the signal with less number of noisy signals. In array factor plot 4(bottom right), the signals with more than 50 dB gain are received and they are available for all angles except from 80 to 160. Here, as the distance of array is less, only required signal we are getting. The four parameters calculated for this are given in table 2.

Figure 5 have distances as 10, 20, 30, 40cms and angle considered here is 270^0. From array factor polar plot 1 (top left), it can be seen that it has more distorted signal. It is receiving the required signal as well as noisy signal having gain upto 50 dB. In array factor plot 2(top right), distance of the array is more, and so signal is received with less number of interruptions. Here, mostly the signals with 50 dB to closer 100 dB gain are received. In array factor plot 3(bottom left), the signals with 100 dB gain are received and they are available for all angles except from 140 to 160. Some of them had a gain less than 50 dB. It is receiving the signal with less number of noisy signals. In array factor plot 4(bottom right), the signals with 50 dB gain are received and they are available for all angles except from 80 to 160. The four parameters calculated for this are given in table 2.

Figure 6 have distances as 100, 75, 50, 25cms and angle considered here is 360^0. From array factor polar plot 1 (top left), it can be seen that it has more distorted signal. It is receiving the required signal as well as noisy signal having gain upto 50 dB. The signal is available for all angles with too many interruptions. In array factor plot 2(top right), distance of the array is less, and so signal is received with less number of interruptions. Here, mostly the signals with 50 dB gain are received. In array factor plot 3(bottom left), the signals with 100 dB gain are received and they are available for all angles except from 140 to 160. It is receiving the signal with less number of noisy signals. In array factor plot 4(bottom right), the signals with more than 35 dB gain are received and they are available for all angles except from 80 to 160. Here, as the distance of array is less, only required signal we are getting. The four parameters calculated for this are given in table 2.

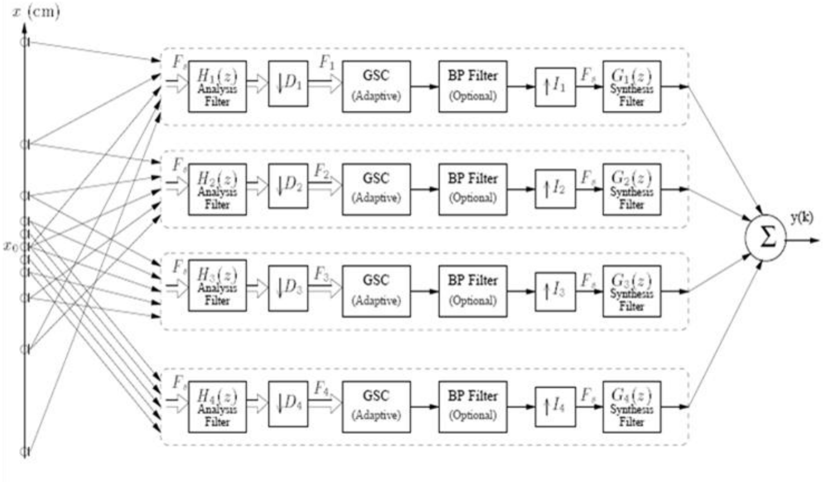

Fig 2: Nested Array using Multirate Sampling

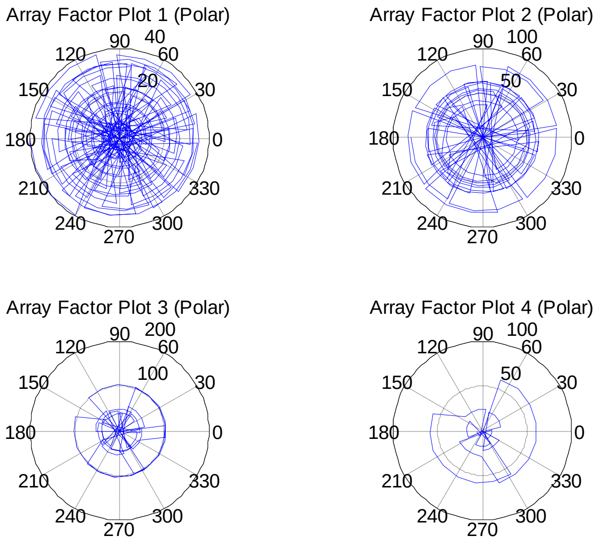

Figure 3: Linear array antenna output with distances 80, 40, 20, 10cms and angle 90^0

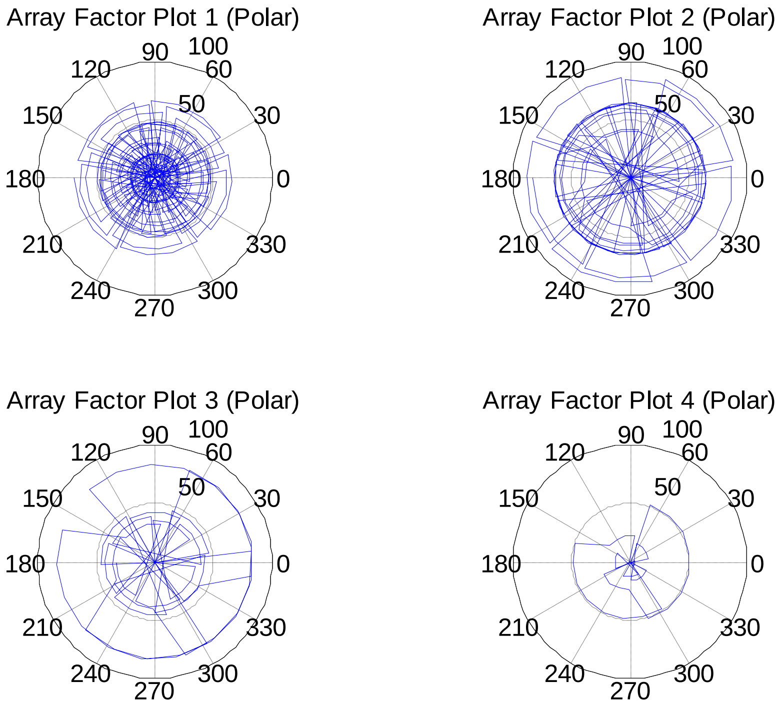

Fig 4: Linear array antenna output with distances 200, 150, 100, 50cms and angle 180^0

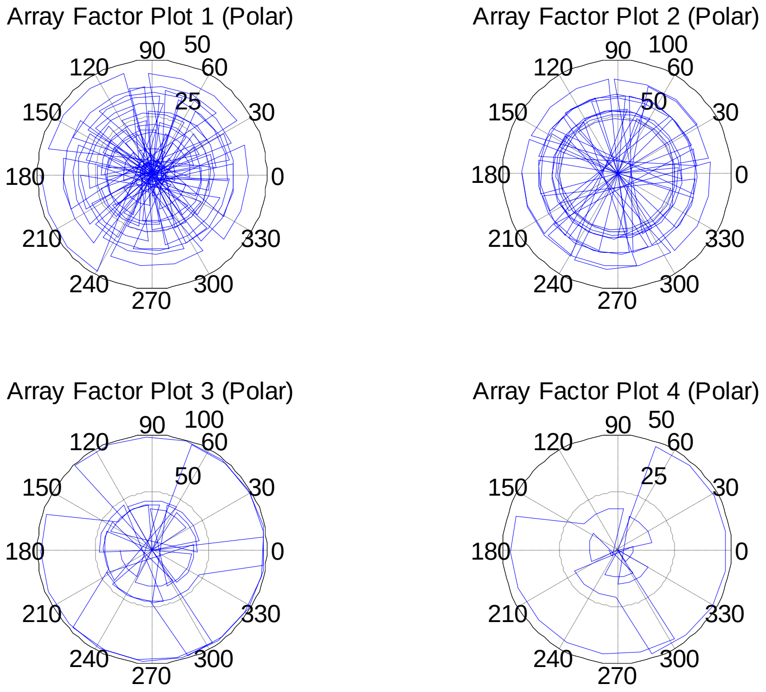

Fig 5: Linear array antenna output with distances 10, 20, 30, 40cms and angle 270^0

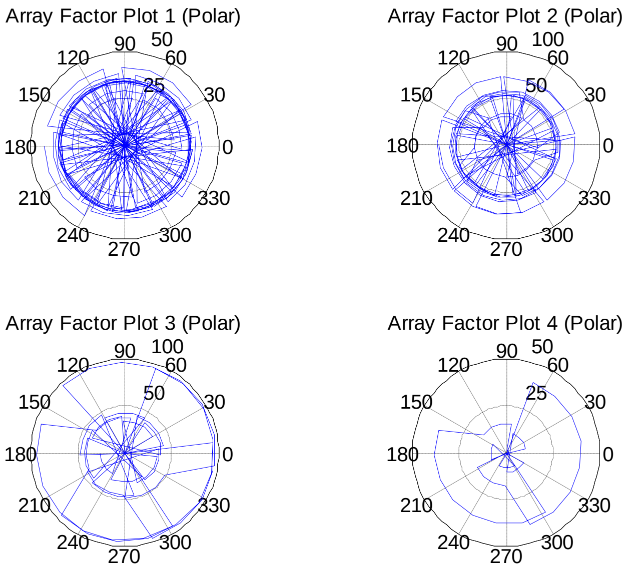

Fig 6: Linear array antenna output with distances 100, 75, 50, 25cms and angle 360^0

Table 1: Comparison of Linear Array Antenna

	Angle 90^0 & Distances 80,40,20, 10cms	**Angle 180^0 & Distances 200, 150, 100, 50cms**	**Angle 270^0 & Distances 10, 20 ,30 40cms**	**Angle360^0 & Distances 100, 75, 50, 25cms**
BER	0.0025	0.0029	0.0025	0.0024
PSNR	39.1726	39.7261	39.1746	38.8743
BEAMWIDTH	104.0000, 12.0000, 64.0000, 116.0000, 40.0000, 76.0000	156.0000, 64.0000, 64.0000, 92.0000, 92.0000, 0.0000	144.0000, 12.0000, 64.0000, 132.0000, 80.0000, 52.0000	120.0000, 96.0000, 44.0000, 24.0000, 76.0000, 52.0000
SLL	51.0000	71.0000	55.0000	55.0000

The analysis of the performance of the system created is on the basis of few parameters like BER, PSNR, BEAMWIDTH, SLL. On the analysis given above, for different values of angles and distances, linear system provides different outputs.

IV. CONCLUSION

Undertaking this project has provided many learning opportunities regarding the smart antenna and its associated technologies. In particular, the architectures are investigated with multiple antenna arrays arranged in a linear pattern that offered the advantages of higher gains, range extension, multi-path diversity, interference suppression, capacity increase and data rate increase. Smart antenna arrays have the ability to form a composite signal with higher performance, which increases the system capacity by reducing interference from other users and increases the signal quality by reducing the fading effects. Adaptive antenna arrays can improve the performance of the received signal to a level that satisfies some preassigned criteria.

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