Adaptive Beamformer Using Nested Arrays and Multirate Techniques

Vrushali Golhar[#1], Mrs. M.R. Vargantwar[#2]
M.E. (Communication), MIT, BAMU, Aurangabad, Maharashtra, India

Abstract- **The circular adaptive antenna array and linear adaptive antenna array are examined in this thesis 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. We analyzed the performance 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 and established four performance boundaries, viz. BER, PSNR, BEAMWIDTH and SLL. 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.
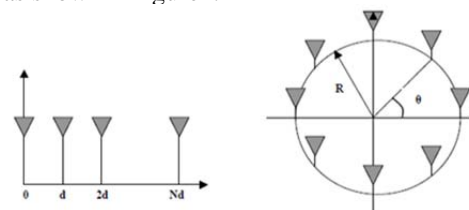

Figure 1: Common Antenna Array Geometries- Uniform Linear Array ULA (left) and Uniform Circular Array UCA (right)

1. IMPEMENTATION

The implementation is divided into two major parts namely CIRCULAR Antenna Implementation and the LINEAR Antenna Implementation. Both of them have the same blocks and the steps, only we have to check the performance of the signal in both antenna types. 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 system is divided into two parts, circular array antenna output and linear array antenna output. The four parameters are measured for both arrays and then compared.

1. Circular Array Antenna Output

The following output shows the Circular Antenna result. In circular array antenna, random 16 signals are taken from different directions having different angles. The different angles chosen are 0^0, 90^0, 180^0, 270^0. The distance of the antenna array is same that is 20 meters for all. Then all the signals are passed through filter and get a single signal. After that the four parameters are calculated as given in table. The first image that is top left shows the signals inputed on the circular space of the antenna. It has more distortions as compared to others. The top right image shows the optimized signal, that is those signal which are easily received. The bottom left diagram shows the density on the basis of the angle. The bottom right diagram shows the most efficient angles of the circular antennas.

2. Linear Array Antenna Output

The following output shows the Linear Antenna result. In linear array antenna, random 16 signals are taken from the direction having angle 0^0. The distances of the antenna array are mapped as 40, 20, 10, and 5 meters. Then all the signals are passed through filter and get a single signal. After that the four parameters are calculated as given in table. The above output shows the Linear Antenna result. The first Image that is top left shows the signals inputed on the Linear Space of the antenna. The top right image shows the optimized signal, that is those signal which are easily received. The bottom left diagram shows the density on the basis of the angle. The bottom right diagram shows the most efficient angles of the linear antennas.
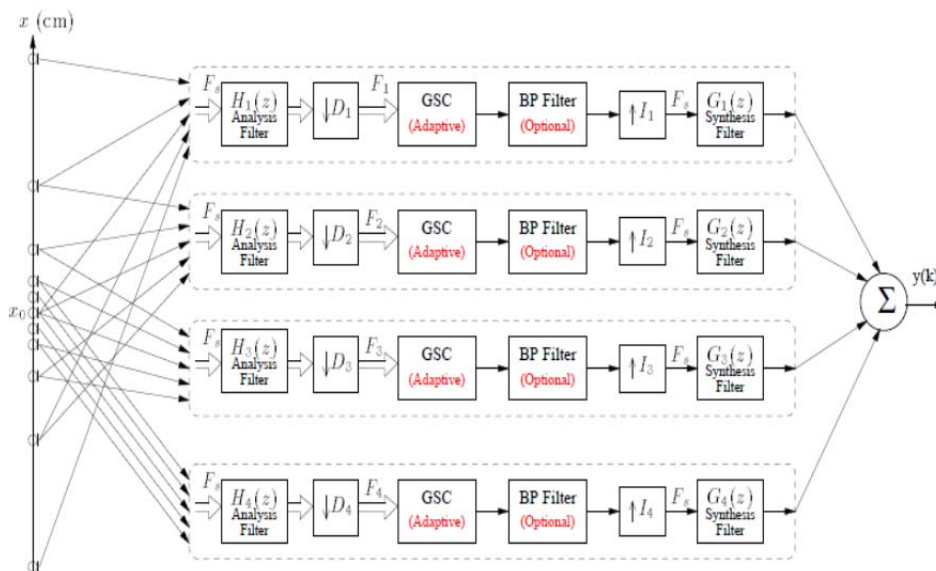

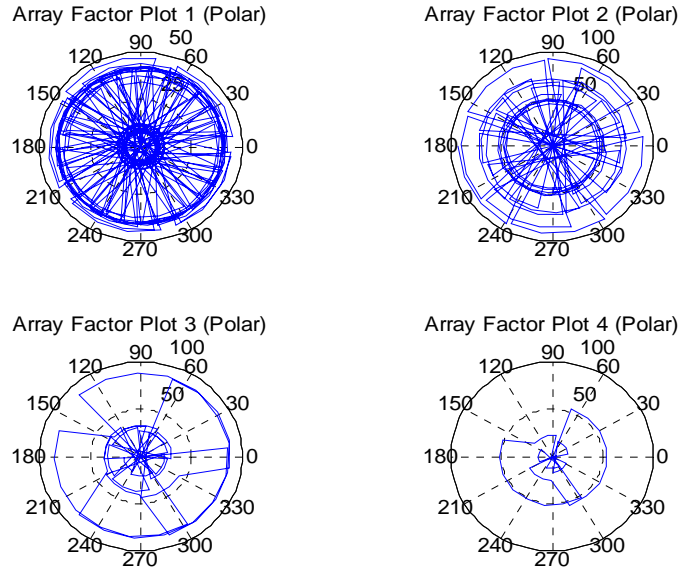Figure 2: Nested Array using Multirate Sampling

Array Factor Plot 1 (Polar)

Array Factor Plot 2 (Polar)

Array Factor Plot 3 (Polar)

Array Factor Plot 4 (Polar)

Figure 3: Circular Array Antenna output

Array Factor Plot 1 (Polar)

Array Factor Plot 2 (Polar)
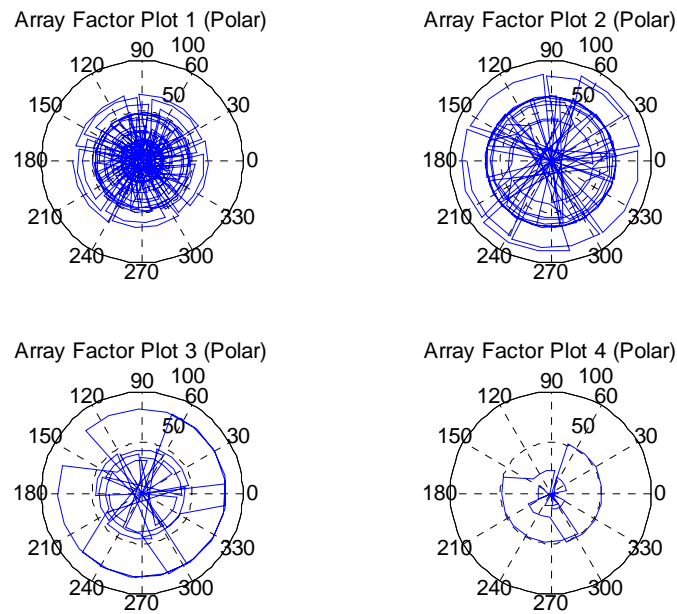
Array Factor Plot 3 (Polar)

Array Factor Plot 4 (Polar)

Figure 4: Linear Array Antenna output

Table 1: Comparison of Linear and Circular Array Antenna

Parameters	Linear Array	Circular Array
BER	0.0029	0.0027
PSNR	39.7261	39.4154
BEAMWIDTH	156.0000, 64.0000, 64.0000, 92.0000, 92.0000, 0.0000	32.0000, 28.0000, 80.0000, 4.0000, 48.0000, 52.0000
SLL	71.0000	35.0000

The analysis of the performance of the system I created is on the basis of few parameters like BER, PSNR, BEAMWIDTH, SLL. On the analysis given above we can observe that in the circular antennas the values are lower therefore we can say that the circular antennas are more performance oriented than the linear antennas.

IV. CONCLUSION

Undertaking this thesis 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 circular 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. As well, it shows that circular adaptive antennas are more beneficial than linear one.

REFERENCES

[1] Theodore S. Rappaport and Joseph C. Liberti, JR, *"Smart Antennas for Wireless Communications,"* 1 Edition, Prentice Hall, Upper Saddle River, New Jersey 1999.

[2] Theodore S. Rappaport, *"Wireless Communications Principle and Practice,"* 2 Edition, Prentice Hall PTR, Upper Saddle River, New Jersey 2002.

[3] Tighe, J.E., *"Modeling and Analysis of Cellular CDMA Forward Channel,"* PhD Dissertation, Naval Postgraduate School, Monterey, CA, March 2001.

[4] Janaswamy Ramakrishna, *"Radiowave Propagation and Smart Antennas for Wireless Communications,"* Kluwer Academic Publishers, Norwell, Massachusetts 2000.

[5] P.P. Vaidyanathan, *"Mutirate Digital filters, filter banks,polyphase networks, and applications: a tutorial,"* Proc. IEEE, Vol.78, No.1, pp.56-93,Jan 1990.

[6] Ng, Kok keng, *"Smart Antenna Application in DS-CDMA Mobile Communication System,"* MSEE Thesis, Naval Postgraduate School, Monterey, CA, September 2002.

[7] Michael, Zatman, *"Circular Array STAP,"* MIT Lincoln Laboratory, Seventh Annual ASAP'99 Workshop, New Jersey 1999.