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Smart Antennas in 4G

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Abstract

"Smart Antenna" technology is one of the most vital developments in mobile communication.This paper deals with the principle and working of smart antennas and the elegance of their applications in various fields such a 4G -telephony system, best suitability of multi carrier modulations such as OFDMA etc., This paper mainly concentrates on use of smart antennas in mobile communications that enhances the capabilities of the mobile and cellular system such a faster bit rate, multi use interference, space division multiplexing (SDMA), increase in range, Multi path Mitigation, reduction of errors due to multi path fading and with one great advantage that is a very high security. The signal that is been transmitted by a smart antenna cannot tracked or received any other antenna thus ensuring a very high security of the data transmitted. This paper also deals the required algorithms that are need for the beam forming in the antenna patters. The application of smart antennas such as in WI-FI transmitter , Discrete Multi Tone modulation (DMT), OFDMA and TD-SCDMA is already in real world use is also incorporated in this paper.

Keywords: Multipath Fading, Beam forming basics, Switched Beam Antenna, SCDMA.

1. Introduction

A smart antenna is an array of elements connected to a digital signal processor. Such a configuration dramatically enhances the capacity of a wireless link through a combination of diversity gain, array gain, and interference suppression. Increased capacity translates to higher data rates for a given number of users or more users for a given data rate per user. Figure 1 shows a comprehensive view of a smart antenna.

Multipath paths of propagation are created by reflections and scattering. Also, interference signals such as that produced by the microwave oven in the picture, are superimposed on the desired signals. Measurements suggest that each path is really a bundle or cluster of paths, resulting from surface roughness or irregularities. The random gain of the bundle is called Multipath fading.

2. Principle

The smart antenna works as follows. Each antenna element "sees" each propagation path differently, enabling the collection of elements to distinguish individual paths to within a certain resolution. As a consequence, smart antenna transmitters can encode independent streams of data onto different paths or linear combinations of paths, thereby increasing the data rate, or they can encode data redundantly onto paths that fade independently to protect the receiver from catastrophic signal fades, thereby providing diversity gain. A smart antenna receiver can decode the data from a smart antenna transmitter this is the highest-performing configuration or it can simply provide array gain or diversity gain to the desired signals transmitted from conventional transmitters and suppress the interference [1]. No manual placement of antennas is required. The smart antenna electronically adapts to the environment.

3. Space Division Multiple Access (SDMA)

Filtering in the space domain separates spectrally and temporally overlapping signals from multiple MSs. Thus, the spatial dimension can be exploited as a hybrid multiple access technique complementing existing multiple access schemes such as frequency division multiple access (FDMA), TDMA, and CDMA. This approach is usually referred to space division multiple access (SDMA). The realization of this filtering technique is accomplished by using a smart antenna, which is capable of modifying its time, frequency, and spatial response by means of the amplitude and phase weighting and the internal feedback control [4]. SDMA scheme enables multiple users within the same radio cell to be accommodated on the same frequency or time slot. Thus, it will increase the system capacity significantly. The concept of the SDMA scheme is demonstrated by TSUNAMI project. In comparison with a single beam antenna, the frequency reuse is increased by a factor 4/3 using a four-beam antenna and of 12/3 by a 12-beam antenna. In Japan, a six-beam satellite antenna is used for 22 GHz band Satellite broadcasting.

3.1 Beam Forming Basics

Beam forming is the term used to describe the application of weights to the inputs of an array of antennas to focus the reception of the antenna array in a certain direction, called the look direction or the main lobe. More importantly, other signals of the same carrier frequency from other directions can be rejected**.** These effects are all achieved electronically and no physical movement of the receiving antennas is necessary. In addition, multiple beam formers focused in different directions can share a single antenna array one set of antennas can service multiple calls of the same carrier. It is no coincidence that the number of elements in the above diagram equals the number of incoming signals. A beam former of L antenna elements is capable of accepting one signal and reliably rejecting L-1 signals. A greater number of interfering signals will diminish the performance of the beam former. Beam forming presents several advantages to antenna design. Firstly, space division multiple access (SDMA) is achieved since a beamformer can steer its look direction towards a certain signal. Other signals from different directions can reuse the same carrier frequency. Figure 2 shows the beam that is formed out of a four element linear antenna array. Secondly, because the beamformer is focused in a particular direction, the antenna sensitivity can be increased for a better signal to noise ratio, especially when receiving weak signals. Thirdly, signal interference is reduced due to the rejection of undesired signals. For the uplink case of transmitting from the antenna array to a mobile telephone, system interference is reduced since the signal is only transmitted in the look direction. A digital beamformer is one that operates in the digital domain. Traditionally, beam formers were implemented in analog; the weights were determined and applied to the antenna inputs via analog circuitry. With digital beam forming, the antenna signals are individually translated from Radio Frequencies (RF) to Intermediate Frequencies (IF), digitized and then down-converted to base-band I and Q components [3]. A beam forming algorithm implemented on one or more digital signal processors then processes the I and Q components to determine a set of weights for the input signals. The input signals are then multiplied by the weights and summed to output the signal of interest (SOI).

One of the foremost advantages offered by the software radio technology is flexibility [5]. Because beam forming is implemented in software, it is possible to investigate a wide range of beam forming algorithms without the need to modify the system hardware for every algorithm. Consequently, researchers can focus their efforts on improving the performance of the beam forming algorithms rather than on designing new hardware, which can be a very expensive and time consuming process. A complete description of the RLS algorithm can be found in. This algorithm was chosen for its fast convergence rate and ability to process the input signal before demodulation. Figure 3 shows the significance of smart antennas.

4. Switched-Beam Antenna

It is possible, using array antennas, to create a group of overlapping beams that together result in omni directional coverage. It is the simplest technique, and comprises only a basic switching function between separate directive antennas or predefined beams of an array. Beam-switching algorithms and RF signal-processing software are incorporated in smart antenna designs. For each call, software algorithms determine the beams that maintain the highest quality signal and the system continuously updates beam selection, ensuring that customers get optimal quality for the duration of their call. One might design overlapping beam patterns pointing in slightly different directions similar to the ones shown in figure. Figure 4 contemplates on the beam patterns for the cover of the earth surface.

5. Application in Mobile Communications

A space-time processor (smart 'antenna') is capable of forming transmit/receive beams towards the mobile of interest. At the same time it is possible to place spatial nulls in the direction of unwanted interferences. This capability can be used to improve the performance of a mobile communication system.

5.1Increased Antenna Gain

The 'smart' antenna forms transmit and receive beams. Therefore, the 'smart' antenna has a higher gain than a conventional omni-directional antenna. The higher gain can be used to either increase the effective coverage, or to increase the receiver sensitivity, which in turn can be exploited to reduce transmit power and electromagnetic Radiation in the network [2].

5.2 Decreased inter symbol interference

Multipath propagation in mobile radio environments leads to ISI. Using transmit and receive beams that are directed towards the mobile of interest reduces the amount of Multipath and ISI. Figure 5 shows the interference reduction.

6. Spatial Structure Methods

As mentioned before, *spatial structure* methods exploit the information in the *steering vector*.. The *spatial structure* is used to estimate the *direction of arrivals* (DOAs) of the signals impinging on the sensor array. The estimated *directions of arrivals are* then used to determine the weights in the *pattern forming network*. This is called beam forming. Spatial structure methods only exploit *spatial structure* and *training signal*s and the *temporal structure* of the signals is ignored. In the following an overview will be given about the three main *spatial structure* methods, namely conventional beam forming methods, maximum likelihood estimation and the so-called subspace-based methods. For simplicity, the vector channel model used here (and everywhere in the array processing literature for ***spatial structure*** methods) is a spatial-only vector channel. Figure 6 shows a perspective view of the TD-SCDMA Smart Antenna.

7. Conclusion

In conclusion to this paper "Smart Antenna" systems are the antennas with intelligence and the radiation pattern can be varied without being mechanically changed. With appropriate adaptive algorithms such as Recursive Least Square Algorithm (RLS) the beam forming can be obtained. As the system uses a DSP processor the signals can be processed digitally and the performance is with a high data rate transmission and good reduction of mutual signal interference.

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Biodata

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I am currently pursuing my B.Tech final semester in SSN College of Engineering
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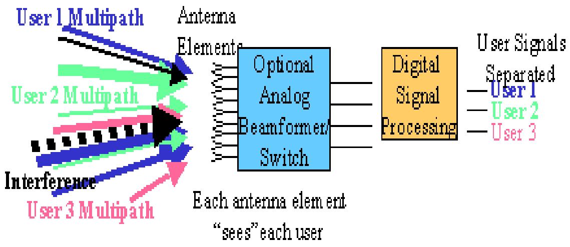

Figure 1 . Comprehensive view of a smart antenna

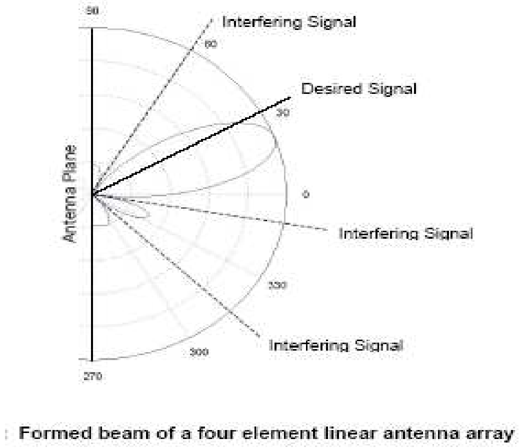

Figure 2 . Beam Formation

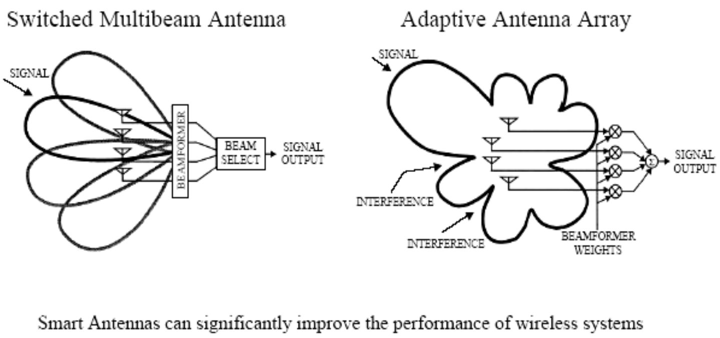

Figure 3 . Significance of smart antennas

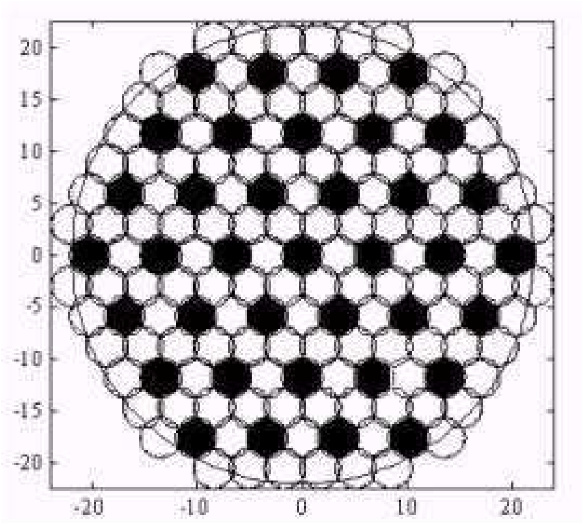

Figure 4 . Beam Patterns for the cover of the earth surface

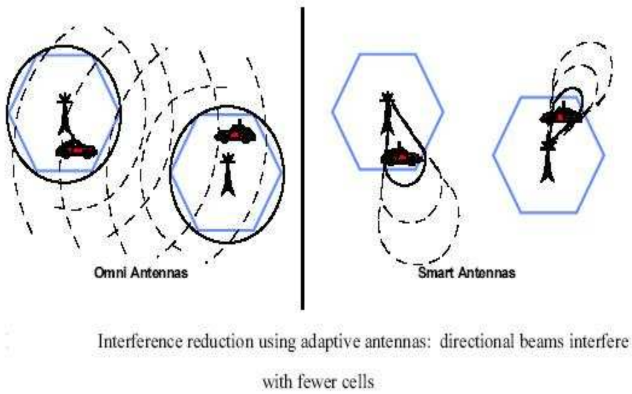

Figure 5 . Interference reduction

Figure 6 . Perspective View of the TD-SCDMA Smart Antenna