Smart Antenna

D.Jayalakshmi[1], Dr. T.V.U. KiranKumar[2], Ms. Racheline Suja[3]

[1]*D.Jayalakshmi, Department of Electronics and Communication Engineering, Bharath University, Selaiyur, Chennai* - 600 073, *Tamilnadu, India.*

[2]*Dr. T.V.U. Kiran Kumar, Professor, & HOD, Department of Electronics and Communication Engineering, Bharath University, Selaiyur, Chennai* - 600 073, *Tamilnadu, India.*

[3]*Ms. Racheline Suja, Asst. Prof. , Department of Electronics and Communication Engineering, Bharath University, Selaiyur, Chennai* - 600 073, *Tamilnadu, India.*

Corresponding author: [1]*D.Jayalakshmi, Department of Electronics and Communication Engineering, Bharath University, Selaiyur, Chennai* - 600 073*, Tamilnadu, India.*

Email: jayabreeze@gmail.com.

Abstract

One of the most rapidly developing areas of communications is Smart Antenna systems. 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 and 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 patterns.

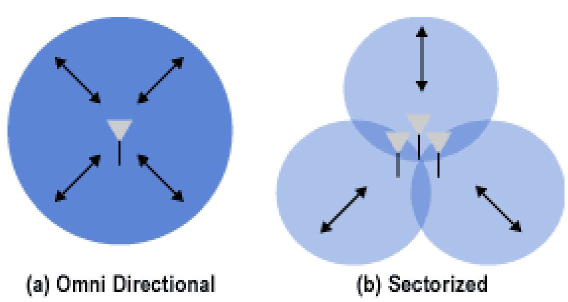
Keywords: Direction of Arrival (DOA), beamforming technique.

1. INTRODUCTION

There is an ever-increasing demand on mobile wireless operators to provide voice and high-speed data services. At the same time, these operators want to support more users per base station to reduce overall network costs and make the services affordable to subscribers. As a result, wireless systems that enable higher data rates and higher capacities are a pressing need. Unfortunately, because the available broadcast spectrum is limited, attempts to increase traffic within a fixed bandwidth create more interference in the system and degrade the signal quality.

Traditional base station antennas are omni-directional, this is actually a waste of power because most of it will be transmitted in other directions than toward the desired user. In addition, other users will experience the power radiated in other directions as interference. A promising technique to increase the spectrum efficiency is using smart antennas. This technique adds a new way of separating users on one base station by space, so called SDMA (Spatial Division Multiple Access). In particular, when omni-directional antennas (see Figure 1) are used at the basestation, the transmission/reception of each user's signal becomes a source of interference to other users located in the same cell, making the overall system interference limited. An effective way to reduce this type of interference is to split up the cell into multiple sectors and use sectorized antennas, as shown in Figure 1.

Figure. 1 *Non-Smart Antennas System*



2. SMART ANTENNA

A smart antenna is a digital wireless communications antenna system that takes advantage of diversity effect at the source (transmitter), the destination (receiver), or both. Diversity effect involves the transmission and/or use of smart antennas can reduce or eliminate the trouble caused by multipath wave propagation. In conventional wireless communications, a single antenna is used at the source, and another single antenna is used at the destination. This is called SISO (single input, single output). Such systems are vulnerable to problems caused by multipath effects. When an electromagnetic field (EM field) is met with obstructions such as hills, canyons, buildings, and utility wires, the wave fronts are scattered, and thus they take many paths to reach the destination. The late arrival of scattered portions of the signal causes problems such as fading, cut-out (cliff effect), and intermittent reception (picket fencing). In a digital communications system like the Internet, it can cause a reduction in data speed and an increase in the number of errors. The A smart antenna system combines multiple antenna elements with a signal-processing capability to optimize its radiation and/or reception pattern automatically in response to the signal environment.

3. PRINCPLE OF WORKING

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. No manual placement of antennas is required. The smart antenna electronically adapts to the environment by looking for pilot tones or beacons or by recovering certain characteristics (such as a known alphabet or constant envelope) that the transmitted signal is known to have. The smart antenna can also separate the signals from multiple users who are separated in space (i.e. by distance) but who use the same radio channel (i.e. center frequency, time-slot, and/or code); this application is called Space-division multiple access (SDMA). In shortAfter the digital signal processor receives signals collected from each antenna element, it computes the direction-ofarrival (DOA) of the signal of interest (SOI). It then uses adaptive beamforming algorithms to produce a radiation pattern that focuses on the SOI, while tuning out any signal not of interest (SNOI)

4. FUNCTIONS OF SMART ANTENNA

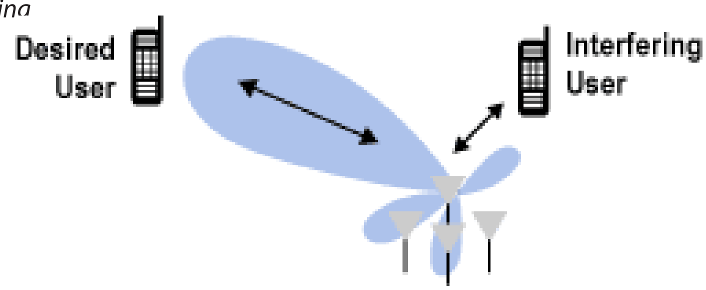
Smart antennas have two main functions: DOA estimation and Beamforming.

4.1 Direction of arrival (DOA) estimation

The smart antenna system estimates the direction of arrival of the signal, using techniques such as MUSIC (Multiple Signal Classification), estimation of signal parameters via rotational invariance techniques (ESPRIT) algorithms, Matrix Pencil method or one of their derivatives. They involve finding a spatial spectrum of the antenna/sensor array, and calculating the DOA from the peaks of this spectrum. These calculations are computationally intensive. Matrix Pencil is very efficient in case of real time systems, and under the correlated sources.

Direction-Of-Arrival (DOA) estimation techniques considered here are broadly divided into four different types: *conventional techniques*, *subspace based techniques*, *maximum likelihood techniques* and the *integrated techniques* which cwmbine property restoral techniques with subspace based approaches. Conventional methods are based on classical beamforming techniques and require a large number of elements to achieve high resolution. Subspace based methods are high resolution sub-optimal techniques which exploit the eigen structure of the input data matrix. Maximum likelihood techniques are optimal techniques which perform well even under low signal-to-noise ratio conditions, but are often computationally very intensive. A promising method for CDMA is the integrated approach which uses property-restoral based techniques to separate multiple signals and estimate their spatial signatures from which their Directions-Of-Arrival can be determined using subspace techniques.

Figure. 2 *Smart Antenna System—Beamforming*



4.2 Beamforming

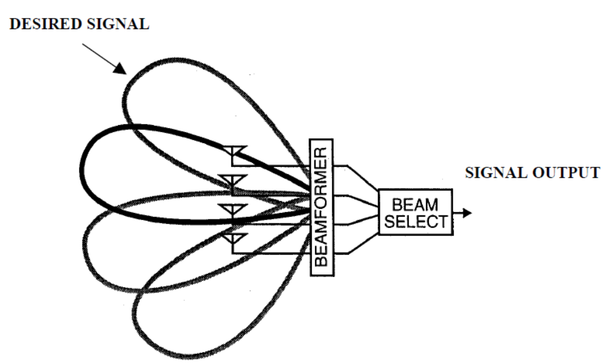
Smart antenna technology offers a significantly improved solution to reduce interference levels and improve the system capacity. With this technology, each user's signal is transmitted and received by the basestation only in the direction of that particular user. This drastically reduces the overall interference in the system. A smart antenna system, as shown in Figure. 2, consists of an array of antennas that together direct different transmission/reception beams toward each user in the system. This method of transmission and reception is called beamforming and is made possible through smart (advanced) signal processing at the baseband. In beamforming, each user's signal is multiplied with complex weights that adjust the magnitude and phase of the signal to and from each antenna. This causes the output from the array of antennas to form a transmit/receive beam in the desired direction and minimizes the output in other directions.

4.2.1 Beam forming basics

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. 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. 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.

One of the foremost advantages offered by the software radio technology is flexibility. 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.While the first reason is important especially when the environment is changing rapidly, the later reason decreases the algorithm dependency on a specific air interface Figure.3.

Figure. 3 *Phased array*



4.2.2 Advantages for beamforming

a) Processing Speed

Smart antenna technology requires high processing bandwidth, with computational speeds approaching several billion multiply and accumulate (MAC) operations per second. Such computationally demanding applications quickly exhaust the processing capabilities of digital signal processors. Altera FPGAs, with enhanced DSP blocks and TriMatrix memory, provide throughputs in excess of 50 GMACs, offering a high-performance platform for beamforming applications.

b) Flexibility

There are a number of beamforming architectures and adaptive algorithms that provide good performance under different scenarios such as transmit-receive adaptive beamforming and transmit-receive switched beamforming. With embedded processors and easy-to-use development tools such as DSP Builder and the Qsys system integration tool. Altera® FPGAs offer a high degree of flexibility in implementing various adaptive signal processing algorithms.

c) Lower Risk

The standards for next-generation networks are continuously evolving, and this creates an element of risk for beamforming ASIC implementation. Transmit beamforming, for example, utilizes the feedback from the mobile terminals. The number of bits provided for feedback in the standards can determine the beamforming algorithm that is used at the basestation. Moreover, future basestations are likely to support transmit diversity including space-time coding and multiple-input multiple-output (MIMO) technology. Because Altera FPGAs are remotely upgradeable, they reduce the risk involved with designing for evolving industry standards while providing the option for the gradual deployment of additional transmit diversity schemes.

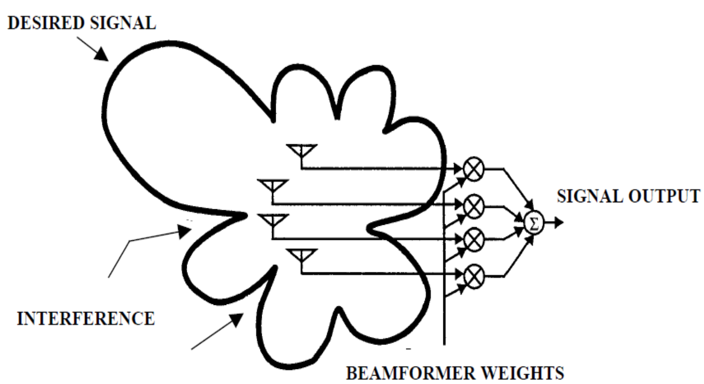
d) Cost Reduction Path

Mobile wireless service providers would likely deploy smart antennas technology initially at certain "hot spots"— such as densely populated urban areas—where there is more demand for high-speed wireless data services. The high NRE costs and long development cycles associated with ASICs cannot be justified for such low volume requirements. Along with a significant time-to-market advantage over ASICs, Altera's HardCopy® ASICs offer a seamless migration process that supports the high-density Stratix series FPGAs and can offer up to 70 percent cost reduction for relatively low minimum order quantities (MOQs).

5. TYPES OF SMART ANTENNA

There are two basic types of smart antennas. Phased Array/Multibeam Antenna.Adaptive Antenna array. As shown in Fig. 3, the first type is the phased array or multibeam antenna, which consists of either a number of fixed beams with one beam turned on towards the desired signal or a single beam (formed by phase adjustment only) that is steered toward the desired signal. The other type is the adaptive antenna array as shown in Figure. 4, which is an array of multiple antenna elements, with the received signals weighted and combined to maximize the desired signal to interference plus noise power ratio.

Figure. 4 *Adaptive array*



This essentially puts a main beam in the direction of the desired signal and nulls in the direction of the interference. A smart antenna is therefore a phased or adaptive array that adjusts to the environment. That is, for the adaptive array, the beam pattern changes as the desired user and the interference move; and for the phased array the beam is steered or different beams are selected as the desired user moves. Another way of categorizing smart antennas is in the number of inputs and outputs that is used for the device.

Smart antennas fall into three major categories:

SIMO (single input, multiple output)

MISO(multiple input, single output)

MIMO (multiple input, multiple output).

In SIMO technology, one antenna is used at the source, and two or more antennas are used at the destination.

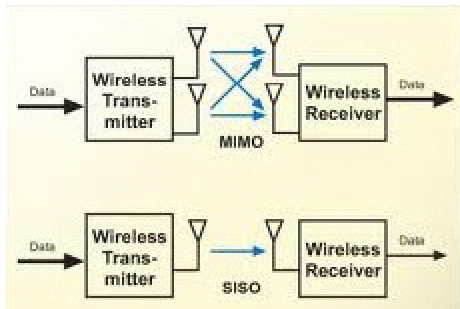
In MISO technology, two or more antennas are used at the source, and one antenna is used at the destination.

In MIMO technology, multiple antennas are employed at both the source and the destination. MIMO has attracted the most attention recently because it can not only eliminate the adverse effects of multipath propagation, but in some cases can turn it into an advantage.

6. SMART ANTENNA ADVANTAGES

Smart antennas can help systems meet these requirements in the following manner: First, both phased and adaptive arrays provide increased power by providing higher gain for the desired signal. Phased arrays use narrow pencil beams, particularly with a large number of antenna elements at higher frequencies, to provide higher gain (power) in the direction of the desired signal. Adaptive arrays place a main beam in the direction of the desired signal for an M-fold power gain with M antenna elements In terms of interference suppression, phased arrays reduce the probability of interference with the narrower beam, and adaptive arrays adjust the beam pattern to suppress interference. For multipath mitigation, smart antennas can provide diversity, of which there are three basic types: spatial, polarization, and angle (or pattern) diversity. Increased Range and Users he range of a smart antenna is larger than that of a regular antenna because it focuses on specific communication devices. With a high number of frequencies available, the antenna can be used by more users. It takes fewer smart antennas than regular antennas to service the same area. More secure Because the signals from smart antennas are specifically focused rather than transmitting in a random way, they offer more security for the user. Anyone wanting to intercept a communication would need to be in the exact location as the antenna and the communication device it was connected to. Less Interference and more Bandwidth As the smart antenna does not emit signals in different, random directions there is less interference. Also, because they have the ability to reuse frequencies, it frees more bandwidth to users Figure. 5.

Figure. 5 *SISO and MIMO*



7. USE OF SMART ANTENNAS

Phased arrays are mainly being studied for point-to-point wireless systems, e.g., for wireless local loops.They are also being considered for macrocellular base stations. For example, in Europe there is work on using 8-element phased arrays on GSM base stations. In Japan, there is work on using very large phased arrays on satellites, as well as on satellite terminals such as on car tops. Adaptive arrays are being studied for indoor systems, i.e., systems with wide angular spread where the received signals arrive via widely separated paths where a phased array may not be useful in achieving gain. Also they are being studied in microcells and in some cellular base stations. For example, currently in the TDMA system ANSI-136 adaptive antenna algorithms have been widely deployed commercially in the United States. Also adaptive arrays are being considered on cellular terminals where local scattering causes wide angular spread.

8. APPLICATIONS 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.

a) Increased 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.

b) Decreased Inter-Symbol Interference (ISI)

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.

c) Decreased Co-Channel Interference (CCI)

Smart antenna transmitters emit less interference by only sending RF power in the desired directions. Furthermore, smart antenna receivers can reject interference by looking only in the direction of the desired source. Consequently smart antennas are capable of decreasing CCI. A significantly reduced CCI can be taken advantage of by Spatial Division Multiple Access (SDMA). The same frequency band can be re-used in more cells, i.e. the so called frequency re-use distance can be decreased. This technique is called Channel Re-use via Spatial Separation. Several mobiles can share the same frequency within a cell. Multiple signals arriving at the base station can be separated by the base station receiver as long as their angular separation is bigger than the transmit / receive beam widths .The beams that are hatched identically use the same frequency band. This technique is called channel re-use via angular separations.

9. FUTURE APPLICATIONS ARE BASED ON BEARER SERVICES

Real-time applications like voice, video conferencing or other multimedia applications require minimum delay during the transmission and generate symmetric traffic. This type of communication is nowadays carried via circuit switching systems. For non real-time applications like e-mail, Internet and Intranet access timing constraints are less strict. In addition, the generated traffic is asymmetric. This type of communication is relayed via packet switched systems. Future pattern of use will show a mix of real-time and non real-time services at the same time and same user terminal. Based on the TDD principle, with adaptive switching point between uplink and downlink, TD-SCDMA is equally adept at handling both symmetric and asymmetric traffic. Wireless Multi Media requires high data rates. With data rates of up to 2 Mbit/s TD-SCDMA offers sufficient data throughput to handle the traffic for Multi Media and Internet applications. With their inherent flexibility in asymmetry traffic and data rate TD-SCDMA-based systems offer 3G services in a very efficient way. Although it is optimally suited for Mobile Internet and Multi Media applications, TD-SCDMA covers all application scenarios: voice and data services, packet and circuit switched transmissions for symmetric and asymmetric traffic, pico, micro and macro coverage for pedestrian and high end mobility. In order to further improve the system robustness against interference, TD-SCDMA base stations are equipped with smart antennas, which use a beam-forming concept. Using omni directional antennas, the emitted radio power is distributed over the whole cell. As a consequence, mutual inter cell interference is generated in all adjacent cells using the same RF carrier. On the other hand, smart antennas direct transmission and reception of signals to and from the specific terminals, improving the sensitivity of the base station receivers, increasing the transmitted power received by the terminals and minimizing inter and intra cell interference.

10. 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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