



AN INTRODUCTION TO SMART ANTENNA SYSTEM

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ABSTRACT

Smart antennas are antenna arrays or group of antenna with smart processing algorithms used to identify spatial signal signature. A smart antenna takes advantage of diversity effect at the source (transmitter), the destination (receiver), or both. Diversity effect involves the transmission and/or reception of multiple radio frequency (RF) waves to increase data speed and reduce the error rate. Smart antenna technology can overcome these capacity limits as well as improve signal quality and let mobile telephones operate on less power. Smart antennas are also known as adaptive array antennas, MIMO & multiple antennas.

Keyword: *Smart antenna, Beam forming, Adaptive array antennas, MIMO & multiple antennas.*

INTRODUCTION

Smart antennas are comprised of a number of individual antennas and associated signal processors which provide the "smart" portion. Smart antennas can use either, or both, for the signal transmission and the signal reception.

The major advantages to using a smart antenna are reduction in overall system power, reduction in communication interference, and increase in system capacity and improve in power efficiency. Smart antenna at the receiver provides reduction of signal loss in multipath fading, which means more overall robust signal quality independent of the variations of the transmitted signal due to the physical environment and other electromagnetic interferences. For mobile applications, there are fewer dropped calls, reduced areas of low-signal / no-signal or dead zones better reception, reduction of bit error rate, reduction in handoff and higher data rates.

FUNCTIONS OF SMARTANTENNA

Direction of Arrival Estimation (DOA):

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.

Beam forming: It is the method used to create the radiation pattern of the antenna array by adding constructively the phases of the signals in the direction of the targets/mobiles desired, and nullifying the pattern of the targets/mobiles that are undesired/interfering targets. This can be done with a simple FIR tapped delay line filter. The weights of the FIR filter may also be changed adaptively, and used to provide optimal beam forming, in the sense that it reduces the MMSE

between the desired and actual beam pattern formed. Typical algorithms are the steepest descent, and LMS algorithms. 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.

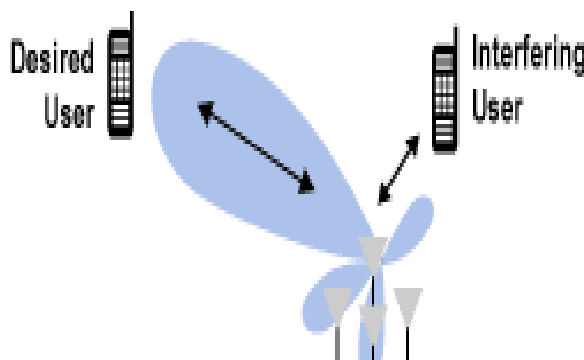


FIG 1: SMART ANTENNA SYSTEM – BEAM FORMING [12]

TYPES OF SMARTANTENNA

There is two type of smart antenna mainly.

Switched Beam:

Switched beam antenna systems form multiple fixed beams with heightened sensitivity in particular directions. These antenna systems detect signal strength, choose from one of several predetermined, fixed beams and switch from one beam to another as the mobile moves throughout the sector. Instead of shaping the directional antenna pattern with the metallic properties and physical design of a single element, switched Beam systems combine the outputs of multiple antennas in such a way as to form finely directional beams with more spatial selectivity than can be achieved with conventional, single-element approaches.

Adaptive Array antennas:

Adaptive antenna technology represents the most advanced smart antenna approach as on date. Using a variety of new signal-processing algorithms, the adaptive system takes advantage of its ability to effectively locate and track various types of signals to dynamically minimize interference and maximize intended signal reception. Both systems attempt to increase gain according to the location of the user, however, only the adaptive system provides optimal gain while simultaneously identifying, tracking and minimizing interfering signals

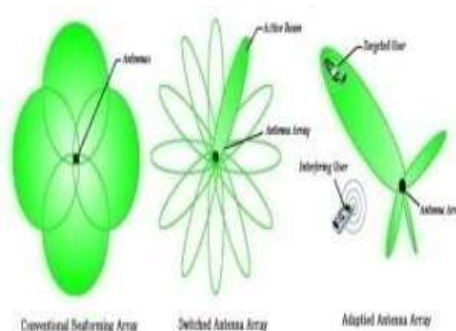


FIG 2: DIFFERENT TYPE OF SMART ANTENNA

Another way of categorizing smart antennas is in the number of inputs and outputs that is used for the device. According to this classification the categories are given below.

1. SIMO (Single Input – Multiple Output)

In this method one antenna will be used at the source and multiple antennas will be used at the destination.



FIG3:SIMO–SINGLE INPUTMULTIPLEOUTPUT

2. MISO (Multiple Input – Single Output)

In this method, multiple antennas will be used at the source and only one antenna will be used at the receiver.



FIG 4: MISO - MULTIPLE INPUT SINGLE OUTPUTS

3. MIMO (Multiple Input – Multiple Output)

In this method multiple antennas will be used at both the source and the destination. This is the most efficient method amongst all. This method was extended recently in accordance to the IEEE 802.11n standard. This method clearly supports spatial information processing.



FIG 5: MIMO - MULTIPLE INPUT MULTIPLE OUTPUT

WHAT MAKES THEM SMART [7]?

A simple antenna works for a simple RF environment. Smart antenna solutions are required as the number of users, interference, and propagation complexity grow. Their smarts reside in their digital signal-processing facilities. Like most modern advances in electronics today, the digital format for manipulating the RF data offers numerous advantages in terms of accuracy and flexibility of operation. Speech starts and ends as analog information. Along the way, however, smart antenna systems capture, convert, and modulate analog signals for transmission as digital signals and reconvert them to analog information on the other end. In adaptive antenna systems, this fundamental signal-processing capability is augmented by advanced techniques (algorithms) that are applied to control operation in the presence of complicated combinations of operating conditions.

SMART ANTENNASYSTEMS

How Do Smart Antenna Systems Work [8][9][10][11]?

Traditional switched beam and adaptive array systems enable a base station to customize the beams they generate for each remote user effectively by means of internal feedback control. Generally speaking, each approach forms a main lobe toward individual users and attempts to reject interference or noise from outside of the mainlobe.

Switched Beam Systems:

In terms of radiation patterns, switched beam is an extension of the current micro cellular or cellular sectorization method of splitting a typical cell. The switched beam approach further subdivides macro-sectors into several micro sectors as a means of improving range and capacity. Each micro-sector contains a predetermined fixed beam pattern with the greatest sensitivity located in the center of the beam and less sensitivity elsewhere. The design of such systems involves high-gain, narrow azimuthal beam width antennaelements.



FIG 6: BEAM FORMING LOBES AND NULLS THAT SWITCHED BEAM (RED) AND ADAPTIVE ARRAY (BLUE) SYSTEMS MIGHT CHOOSE FOR IDENTICAL USER SIGNALS (GREEN LINE) AND CO-CHANNEL INTERFERERS (YELLOW LINES)

Smart antenna systems communicate directionally by forming specific antenna beam patterns. When a smart antenna directs its main lobe with enhanced gain in the direction of the user, it naturally forms side lobes and nulls or areas of medium and minimal gain respectively in directions away from the main lobe. Different switched beam and adaptive smart antenna systems control the lobes and the nulls with varying degrees of accuracy and flexibility.

1) ADAPTIVE ANTENNA APPROACH:

The adaptive antenna systems approach communication between a user and base station in a different way, in effect adding a dimension of space. By adjusting to an RF environment as it changes (or the spatial origin of signals), adaptive antenna technology can dynamically alter the signal patterns to near infinity to optimize the performance of the wireless system.

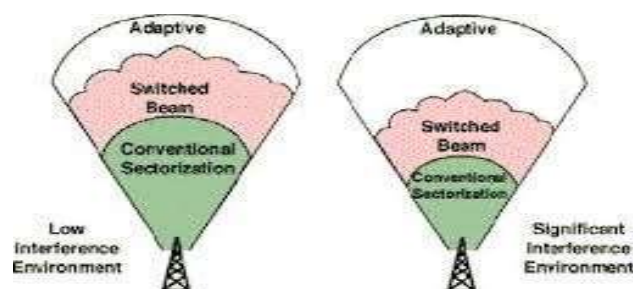


FIG 7: COVERAGE PATTERNS FOR SWITCHED BEAM AND ADAPTIVE ARRAY ANTENNAS

Adaptive arrays utilize sophisticated signal-processing algorithms to continuously distinguish between desired signals, multipath, and interfering signals as well as calculate their directions of arrival. This approach continuously updates its transmit strategy based on changes in both the desired and interfering signal locations. The ability to track users smoothly with main lobes and interferers with nulls ensures that the link budget is constantly maximized because there are neither micro sectors nor predefined patterns. Both types of smart antenna systems provide significant gains over conventional sectorized systems. The low level of interference on the left represents a new wireless system with lower penetration levels. The significant level of interference on the right represents either a wireless system with more users or one using more aggressive frequency reuse patterns. In this scenario, the interference rejection capability of the adaptive system provides significantly more coverage than either the conventional or switched beam system [1][2].

RELATIVE BENEFITS/TRADEOFFS OF SWITCHED BEAM AND ADAPTIVE ARRAYS SYSTEMS

- **Integration-** Switched beam systems are traditionally designed to retrofit widely deployed cellular systems. It has been commonly implemented as an add-on or appliqué technology that intelligently addresses the needs of mature networks. In comparison, adaptive array systems have been deployed with a more fully integrated approach that offers less hardware redundancy than switched beam systems but requires new build-out.

- **Range/Coverage-** Switched beam systems can increase base station range from 20 to 200 percent over conventional sectorized cells, depending on environmental circumstances and the hardware/software used. The added coverage can save an operator substantial infrastructure costs and means lower prices for consumers. Also, the dynamic switching from beam to beam conserves capacity because the system does not send all signals in all directions. In comparison, adaptive array systems can

Cover a broader, more uniform area with the same power levels as a switched beam system.

- **Interference suppression-** Switched beam antennas suppress interference arriving from directions away from the active beam's center. Because beam patterns are fixed, however, actual interference rejection is often the gain of the selected communication beam pattern in the interferer's direction. Also, they are normally used only for reception because of the system's ambiguous perception of the location of the received signal (the consequences of transmitting in the wrong beam being obvious). Also, because their beams are predetermined, sensitivity can occasionally vary as the user moves through the sector. Switched beam solutions work best in minimal to moderate co-channel interference and have difficulty in distinguishing between a desired signal and an interferer. If the interfering signal is at approximately the center of the selected beam, and the user is away from the center of the selected beam, the interfering signal can be enhanced far more than the desired signal. In these cases, the quality is degraded for the user. Adaptive array technology currently offers more comprehensive interference rejection. Also, because it transmits an infinite, rather than finite, number of combinations, its narrower focus creates less interference to neighboring users than a switched-beam approach.

- **Spatial division multiple access (SDMA)** - Among the most sophisticated utilizations of smart antenna technology is SDMA, which employs advanced processing techniques to, in effect, locate and track fixed or mobile terminals, adaptively steering transmission signals toward users and away from interferers. This adaptive array technology achieves superior levels of interference suppression, making possible more efficient reuse of frequencies than the standard fixed hexagonal reuse patterns. In essence, the scheme can adapt the

frequency allocations to where the most users are located.



FIG 8: FULLY ADAPTIVE SPATIAL PROCESSING, SUPPORTING TWO USERS ON THE SAME CONVENTIONAL CHANNEL SIMULTANEOUSLY IN THE SAME CELL

Utilizing highly sophisticated algorithms and rapid processing hardware, spatial processing takes the reuse advantages that result from interference suppression to a new level. In essence,

Spatial processing dynamically creates a different sector for each user and conducts a frequency/channel allocation in an ongoing manner in real time.

Adaptive spatial processing integrates a higher level of measurement and analysis of the scattering aspects of the RF environment. Whereas traditional beamforming and beam-steering techniques assume one correct direction of transmission toward a user, spatial processing maximizes the use of multiple antennas to combine signals in space in a method that transcends a one user-one beam methodology.

TABLE 1: FEATURES AND BENEFITS OF SMART ANTENNA SYSTEMS [7]

S. No.	Feature	Benefit
1	Signal Gain- Inputs from multiple antennas are combined to optimize available power required to establish given level of coverage	Better Range / Coverage- Focusing the energy sent out into the cell increases base station range and coverage. Lower power requirements also enable a greater battery life and smaller/lighter handset size.
2	Spatial Diversity- Composite information from the array is used to minimize fading and other undesirable effects of multipath propagation.	Multipath Rejection- can reduce the effective delay spread of the channel, allowing higher bit rates to be supported without the use of an equalizer, improved bit error rate (due to decreased amount of Multipath and ISI).
3	SDMA- SDMA continually adapts to the radio environment through intelligent / smart antenna	Providing each user with uplink and downlink signals of the highest possible quality and can adapt the frequency allocation to where the most users are located
4	Power Efficiency- combines the inputs to multiple elements to optimize available processing gain in the downlink (toward the user)	Reduced Expense- Lower amplifier costs, power consumption, and higher reliability will result. Lower power consumption reduces not only interferences but also reduces RF pollution (ease health hazard). It will also result in reduction of scarce energy resource (diesel consumption) and save foreign Currency.

5	Interference Rejection- Antenna pattern can be generated toward co-channel interference sources, Improving the signal-to-interference	Increased Capacity- Precise control of signal nulls quality and mitigation of interference combine to frequency reuse reduce distance (or cluster size), improving capacity. Certain adaptive technologies (such as space
	ratio of the received signals.	division multiple access) support the reuse of frequencies within the same cell.

DISADVANTAGES

The main disadvantages are:

Cost: The cost of such a device will be more, not only in the electronics section, but also in the power. That is the device is way too expensive and will also decrease the life of battery of mobiles. The receiver chains that are used must be reduced in order to reduce the cost. Also the costs rise up due to the RF electronics and A/D converter used for each antenna.

- Mobilevideo
- Mobilebroadband/gaming
- Satellite/digitalradio
- GPS
- 3GWireless
- WiMAX
- RFID
- UWBetc.

CONCLUSION

This paper gives the brief idea about the smart antenna systems and their types which we are using to avoid the multipath and co-channel interference. These antennas have advance features like higher efficiency, higher reliability than the normal to reduce the size.

Diversity: When multiple mitigation is needed, diversity becomes a big problem. The terminals and base stations must have multiple antennas. There are mainly three types of diversities. They are spatial, polarization, and angle.

Spatial separation of the antennas that are used is practically impossible when it is applied on mobile phones. It is also difficult to be achieved in point-to-point systems where a near line-of-sight exists between the transmitter and receiver. By using polarized diversity, the above problem can be avoided to a certain point. Dual polarization can be easily instigated without the use of spatial separation.

Angular diversity is the most commonly used method nowadays. The signals which have the maximum signal power are selected from multiple beams and are used to maintain diversity. But the gain depends on the angular spread. That is, if the spread is small, the diversity will also be small.

Tracking

Spatial-temporal processing Hooks in international

Standards to include provisions for smart antennas Vertical integration

Size: For this method to be efficient large base stations are

Needed. This will increase the size. Apart from this multiple external antennas are needed on each terminal.

This is not practical. But companies are trying methods like dualpolarization Antennas **APPLICATION**[13]

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.

SMART ANTENNA TECHNOLOGIES CAN BE USED TO IMPROVE MOST WIRELESS APPLICATIONS, INCLUDING:

- Wi-Fi a/b/g access points and clients
- In-vehicle DBS entertainment systems, such as:

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