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SMART ANTENNA: BASIC CONCEPTS, SCOPE AND APPLICATIONS

Dr. G.A.E. Satish
Professor, Dept. of Electronics
& Communication Engineering,
Vardhaman College of Engineering,
Shamshabad, Hyderabad, INDIA

Dr. M. Sushanth Babu
Professor, Dept. of Electronics
& Communication Engineering,
Vardhaman College of Engineering,
Shamshabad, Hyderabad, INDIA

ABSTRACT: In recent times, mobile wireless communications is experiencing an explosive growth rate. The demand for service provision via the wireless communications bearer has raised above all the expectations. Some 3.2 billion subscribers to mobile networks are estimated by this year. This high demand for wireless communications services requires increased system capacities. One of the most rapidly developing areas in communication is "Smart Antenna" system. The elegance of their applications in various fields such as 4G telephony systems, best suitability of multi carrier modulations such as OFDMA etc.., 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 gives the brief idea about the smart antenna basic structure, merits, applications and some recent developments.

KEYWORDS: Smart Antennas, Spatial diversity, Beam-forming, Signal to Interference Ratio.

I. INTRODUCTION

Smart antenna technology is one of the key technologies used in wireless communications. Smart (or adaptive) antenna systems are an active research topic nowadays due to the improvements and advantages over Omni-directional systems. A smart antenna system is defined by the IEEE as, an antenna system that has circuit elements associated with its radiating elements such that one or more of the antenna properties are controlled by the received signal [1]. In these systems, each transmitter located at a certain place has its unique pattern, which is also called spatial signature [2].

A. What is smart antenna?

Smart antennas and smart antenna technology using an adaptive antenna array are being introduced increasingly with the development of other technologies including the software defined radio, cognitive radio, MIMO and many others.

Smart antenna technology or adaptive antenna array technology enables the performance of the antenna to be altered to provide the performance that may be required to undertake performance under specific or changing conditions.

The smart antennas include signal processing capability that can perform tasks such as analysis of the direction of arrival of a signal and then the smart antenna can adapt the antenna itself using beam-forming techniques to achieve better reception, or transmission. In addition to this, the overall antenna will use some form of adaptive antenna array scheme to enable the antenna to perform is beam formation and signal direction detection.

B. Functions of smart antenna

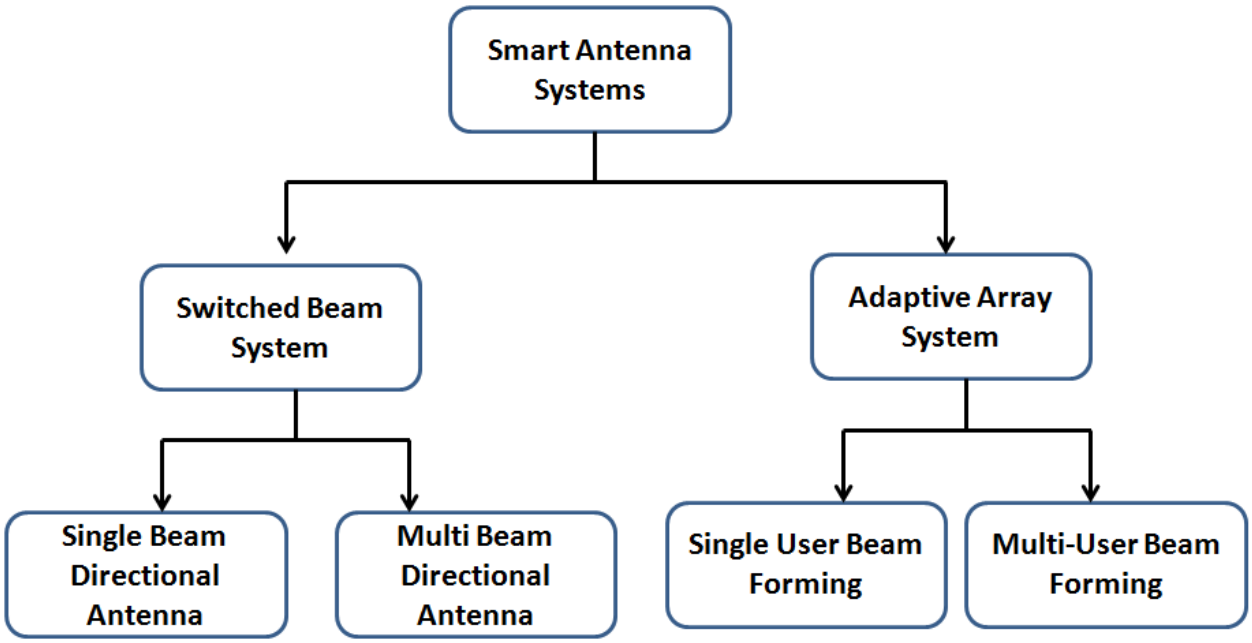
The main purposes of standard antennas are to effectively transmit and receive radio signals, there are two additional functions that smart antennas or adaptive antennas need to fulfil:

- ***Direction of arrival estimation:*** In order for the smart antenna to be able provide the required functionality and optimization of the transmission and reception; they need to be able to detect the direction of arrival of the required incoming signal. The information received by the antenna array is passed to the signal processor within the antenna and this provides the required analysis.

- ***Beam steering:*** With the direction of arrival of the required and any interfering signals analysed, the control circuitry within the antenna is able to optimise the directional beam pattern of the adaptive antenna array to provide the required performance.

II.TYPES OF SMART ANTENNA SYSTEMS

There are several techniques of implementing smart antennas. Figure 1 shows a generalized classification. With considerable levels of functionality being required within smart antennas, two main approaches or types of smart antenna technology have been developed. The first one is Switched beam antenna systems and adaptive array antenna systems. The switched beam antenna system comprises only basic switching between separate directional antennas or predefined beams of an array while enabling high directivity and gain [2]. Switched beam systems can be further divided into two groups: single beam and multi beam directional antennas. In single beam directional antenna systems, only one beam is active at a given time. No simultaneous transmissions are allowed, because in this system there is only one transceiver as shown in Fig.1 (a). The switched beam smart or adaptive antennas are designed so that they have several fixed beam patterns. The control elements within the antenna can then select the most appropriate one for the conditions that have been detected. Although this approach does not provide complete flexibility it simplifies the design and provides sufficient level of adaptivity for many applications. On the other hand, multiple beam directional antenna system is an example of Spatial Division Multiple Access (SDMA) system. Here, each directional antenna can be used and transmissions are allowed at the same time and frequency. The number of beams is equal to the number of transceivers as shown in Fig.1 (b).



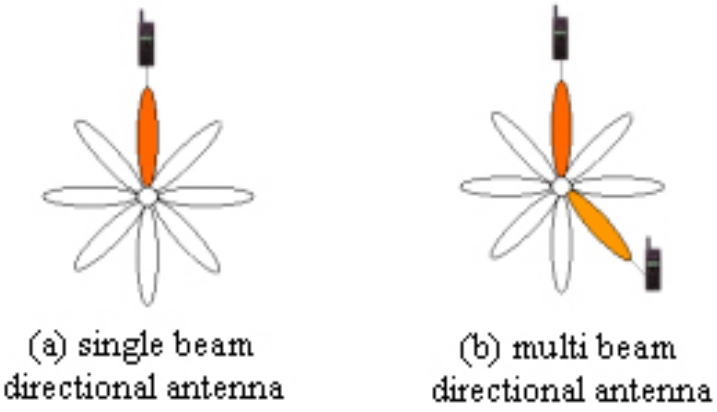


Figure 1. Switched Beam Smart Antenna

The second technique is adaptive beam forming (array) antenna systems, where a Direction of Arrival (DoA) algorithm is used to determine the direction of the signal received from the user. By this way continuous tracking of users can be achieved. Also, the detection of the interferers can be added to these systems, so that interference is cancelled by adjusting the radiation pattern nulls to increase the Signal to Interference Ratio (SIR). Clearly, adaptive beam forming is more complex than switched beam systems. There are two kinds of adaptive beam forming: In single user beam forming, the antenna beam is adjusted to track a user and cancel interferers. In this case, a single transceiver is sufficient where only one user is active at a given time as shown in Fig.2 (a). In multi user beam forming, there are different beam patterns, and each beam tracks one user. Therefore, simultaneous transmissions are allowed and SDMA is achieved. As shown in Fig.2 (b), there is more than one transceiver-beam pair in multi user beam forming.

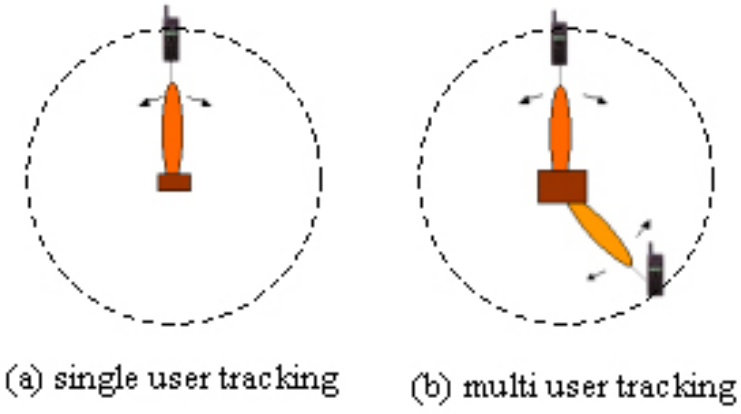


Figure 2. Adaptive Arrayt Smart Antenna

A. Evolution of smart antenna

Application of antennas, reconfigurable antennas and antenna arrays has been suggested in recent years for mobile communications systems to overcome the problem of limited channel bandwidth, thereby satisfying an ever growing demand for a large number of mobiles on communications channels. Wireless systems are also evolving towards multi functionality options of connecting to different kinds of wireless services for different purposes at different times. To reach their full potential, modern wireless systems require agile antennas, antenna arrays with adaptive signal processors, and reconfigurable antennas.

Antenna arrays can be classified as basic arrays, phased, adaptive, and smart antennas. In adaptive array the phase and gain of the signals induced on each element are changed before combining to adjust the gain of the array in dynamic fashion, as required by the system. The term adaptive array is used for phased array when the amplitude and also direction of the pattern is controlled. This is accomplished by multiplying the induced signal at the output of each element by a complex quantity, which is referred to as weight. As the weight is complex quantity which has magnitude and phase part, it controls the amplitude pattern as well as the direction. The weights are adjusted in such a way, the array adapts to the situation and the adaptive process is normally under the control of the system. For example, to obtain maximum output signal to interference plus noise ratio (SINR) by canceling unwanted interferences and receiving the desired signal without distortion may be one way of adjusting gains and phase of elements. Whereas smart antenna combines the antenna array with signal processing to optimize automatically beam pattern in response to the received signal.

Smart antennas hold great promise for increasing the capacity of wireless communications because they radiate and receive energy only in the intended directions, thereby greatly reducing interference. The primary goal of smart antennas in wireless communications is to integrate and exploit efficiently the extra dimension offered by multiple antennas at the transceiver in order to enhance the over-all performance of the network. Smart antennas systems use modems which combine the signals of multi-element antennas both in space and time. Smart antennas can be used for both receive and transmit both at the base station and the user terminal

A reconfigurable antenna is one that has selectable or tunable fundamental characteristics, including operating frequency, impedance bandwidth, radiation pattern, and polarization. Typically, the goal is to change one or more of these characteristics independently of the others. There are various methods of changing these characteristics, such as electrical, mechanical and electromechanical. These antennas find applications in Software defined radio, Cognitive radio, Multiple-input multiple-output (MIMO) systems, Multi-function consumer wireless devices and high performance phased arrays. In addition to these, many other antennas such as fractal antennas, active antennas, conformal arrays have been reported and finding applications in modern wireless communication.

III. MERITS OF SMART ANTENNA SYSTEMS

Wireless local area networks (WLANs) are becoming ubiquitous with rapid growth in both the home and enterprise markets. However, users are often not satisfied with the coverage and performance of these networks for several reasons. Two key techniques that can be used to overcome these problems are smart antennas [3] and ad hoc networking [4]. A smart antenna [3] is a multi-element antenna where the signals received at each antenna element are intelligently combined to improve the performance of the wireless system. Smart antennas at base stations can be used to enhance mobile communication systems in several ways: increased BS range, less interference within the cell, less interference in neighboring cells,_ increased capacity by means of SFIR or SDMA [5].The first advantage noted, the increased BS range can be useful in some specific scenarios where the cell sizes are limited not by the traffic needs in the respective area but by the BS range. Here, smart antennas can be used to bundle the radiated power and thus achieve higher BS ranges. However, the aspects of reduced interference within the cell as well as in neighboring cells are of even higher interest [6-7].

A. Major Research issues for smart antenna

The major research issues for smart antennas are the following: cost (including power and electronics), size, diversity, tracking, spatial-temporal processing, hooks in international standards to include provisions for smart antennas, vertical integration/interdisciplinary research. Of these, interdisciplinary research incorporating smart antennas was considered to be the key to the greatest gains, but very little of this type

of research is currently being conducted because of the difficulty of the required interactions. For future wireless systems to be viable, substantial research on smart antennas in the above areas will be required, with emphasis on interdisciplinary approaches.

B. Technology Assessment

Smart antenna technology varies substantially among companies, and since many of these companies are multinational, it is difficult to make a comparative assessment of the technology among regions. However, the emphasis of the research on phased or adaptive arrays varies by application. Specifically, Japanese companies emphasize WCDMA and higher frequencies, and thus the major focus of their work is on phased arrays. On the other hand, U.S. and European companies tend to emphasize lower frequencies (850 and 1900 MHz), and TDMA systems (GSM, EDGE, ANSI-136) as well as WCDMA, and therefore focus on adaptive arrays in addition to phased arrays. Thus, Japan leads in smart antenna research and technology for phased arrays, particularly at higher frequencies (5 GHz and above), whereas the United States and Europe lead in adaptive array research and technology (see Table 1).

	U,S	Japan	Europe
Smart antennas Over all	*****	*****	*****
Phased arrays	***	*****	***
Adaptive arrays	*****	***	*****

Table.1

IV. ADVANTAGES OF SMART ANTENNA

With many applications including MIMO, Software Defined Radio - SDR, and Cognitive Radio - CR requiring antenna systems to be more adaptive and provide greater levels of adaptivity, Smart antenna technology or adaptive antenna technology will become more widely used

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.

A. What Makes Them So Smart

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 algorithms that are applied to control operation in the presence of complicated combinations of operating conditions.

VI. CONCLUSION

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. With better range and coverage, increased bandwidth, increased capacity and multi-path rejection smart antennas have increased bit-rates and reduced overall expenses, thus improving world communication technology. New technologies and algorithms are helping us to optimize the usage of smart antenna in our daily life. The smart antenna was universally recognized as a critical component. Smart antennas can provide increased capabilities/performance to wireless networks (range, robustness, battery life, capacity). Combination of smart antennas and wireless networks can provide gains that are greater than the sum of the gains, but only if used properly. Further research is needed (with standards development), but the potential is substantial

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