What are Smart Antennas?

contact@doctoroluwatobiadeogun.com.ng

Christopher Olabisi Olutobi Adeogun

Abstract: **A smart antenna system combines multiple antenna elements with a signal-processing capability to optimize large increase in capacity, increased range, potential to introduce new services, more security and reduce multi path propagation which response to the signal environment in its radiation pattern and reception pattern**.

Key words: Smart Antenna, Dipole, Coverage Pattern, Switched Beam Antenna, Miso, Diversity and Beam forming.

I. OVERVIEW

Wireless systems are undoubtedly an essential part of modern society and are becoming more as we move towards the information society, demand access to more information, more immediately and in more places. Concurrently, technological developments are making new applications possible, opening up new markets, and promising significant economic benefits. In all cases, spectrum is an essential basic resource which although reusable, cannot be created to meet demand. It is therefore, increasingly important to improve the efficiency with which use is made of the spectrum. As an example, the next generation mobile telephone system may require an order of magnitude increase in capacity. Since present day systems are close to the Shannon limit, there is relatively little to be gained by improving the modulation and coding schemes, and smart antennas have been identified as one technique that may close the predicted performance gap. A smart antenna is one that responds in some way to its electromagnetic environment in order toimprove a specified performance metric; inso-doing, they can provide, for example, increased immunity tointerference, or reduced signal level towards a vulnerable receiver. In general, provision of these capabilities requires the use of multi-element array antennas, with control over the excitation of each element. Smart antennas are not new in concept, yet, with a number of notable exceptions, they have not seen widespread adoption. This project, which was awarded as part of the Spectrum Efficiency Scheme, set out to investigate smart antennas and their potential application areas, in an attempt to understand the reasons why they have not been implemented widely. Possible reasons for this may be that their forecast benefits are unobtainable, that the technology for their implementation is not mature,or that they cannot currently be implemented economically. These lead to the overall objectives of the project, namely, to assess and demonstrate the potential of smart antennas for enhancing spectrum efficiency in wireless systems.

II. ADAPTIVE SMART ANTENNAS SYSTEM

A Useful Analogy for an intuitive grasp of how an adaptive antenna system works, close your eyes and converse with someone as they move about the room. We will notice that we can determine their location without seeing them because of the following:

- We hear the speaker's signals through your two ears, your acoustic sensors.
- The voice arrives at each ear at a different time.
- Our brain, a specialized signal processor, does a large number of calculations to correlate information and compute the location of the speaker.

Our brain also adds the strength of the signals from each ear together, so you perceive sound in one chosen direction as being twice as loud as everything else. Adaptive antenna system does the same thing, using antennas instead of ears. As a result, 8, 10, or 12 earcan be employed to help fine-tune and turn up signal information. Also, because antennas both listen and talk, an adaptive antenna system can send signals back in the same direction from which they came. This means that the antenna system cannot only hear 8 or 10 or 12 times louder but talk back more loudly and directly as well going a step further, if additional speakers joined in , your internal signal processor could also tune out unwanted noise (interference) and alternately focus on one conversation at a time. Thus, advanced adaptive array systems have a similar ability to differentiate between desired and undesired signals.

Smart

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 reception of multiple radio frequency (RF) waves to increase data speed and reduce the error rate. The concept of using multiple antennas and innovative signal processing to serve cells more intelligently has existed for many years. In fact, varying degrees of relatively costly smart antenna systems have already been applied in defense systems. Until recent years, cost barriers have prevented their use in commercial systems. The advent of powerful low-cost digital signal processors (DSPs),general-purpose processors (and ASICs), as well as innovative software-based signal-processing techniques (algorithms)have made intelligent antennas practical for cellular communication system. Today, when spectrally efficient solutions are increasingly a business imperative, these systems are providing greater coverage area for each cell site, higher rejection of interference, and substantial capacity improvements.

What are Smart Antennas?

Smart antennas (also known as adaptive array antennas, multiple antennas and, recently, MIMO) are antenna arrays with smart signal processing algorithms used to identify spatial signal signature such as the direction of arrival (DOA) of the signal, and use it to calculate beam forming vectors, to track and locate the antenna beam on the mobile/target. Smart antennas should not be confused with reconfigurable antennas, which have similar capabilities but are single element antennas and not antenna arrays. Smart antenna techniques are used notably in acoustic signal processing, track and scan radar, radio astronomy and radio telescopes, and mostly in cellular systems like W-CDMA, UMTS, and LTE. In a cellular system the radio communication is between the user and a base station,which provide s radio coverage within a certain area,called a cell. The base stations are Omni-directional or sectored. This is waste of power as most of it will be radiated in other directions than toward the user. The power radiated in other directions will be experienced as interference by other users. The ideas of smart antenna is to use base station antenna patters that are not fixed, but adapt to the correct radio conditions. This can visualized as the antenna directing a beam toward the communication partner only.

There are Two Major Types of Smart Antenna System:

There are distinctions between the two major categories of smart antennas regarding the choices in transmit strategy:
• Switched beam infinite number of fixed, predefined patterns or combining strategies (sectors)
• Adaptive array an infinite number of patterns (scenario-based) that are adjusted in real time.

III. SWITCHED BEAM ANTENNAS

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 (like a sectorized antenna), switched beam systems combine the outputs of multiple antennas in such a way as to form finely sectorized(directional) beams with more spatial selectivity than can be achieved with conventional, single-element approaches Switched Beam System Coverage Patterns (Sectors).

Fig 1.Switched Beam System Coverage Patterns (Sectors)

IV. ADAPTIVE ARRAY ANTENNAS

An adaptive beam forming system relies on principals of wave propagation and phase relationships. See Constructive interference, and Beam forming. Using the principles of superimposing waves, a higher or lower amplitude wave is created (e.g. by delaying and weighting the signal received). The adaptive beam forming system dynamically adapts in order to maximize or minimize a desired parameter, such as Signal-to-interference-plus-noise ratio.

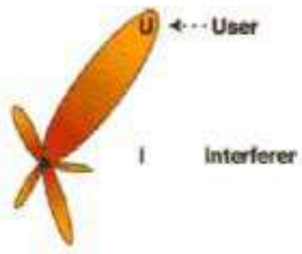

Fig 2. Adaptive Array Coverage

The Aim of a Smart Antenna System:

>More focused transmission of radio signals while enhancing capacity through increased frequency reuse.

>To augment the signal quality of the radio-based system

Effect of Smart Antenna on DCA, Power Control and packet scheduling

A- Effect of smart antenna on DCA

Beam forming of smart antenna can effectively reduce the interference between users. Its essence is to distinguish the signals of different users in space. If the DCA in the channel assignment, as far as possible to the same direction of the users are distributed to different time slots, and at the same time the distribution of users in different directions, so we can give full play to the smart antenna space division multiple access interference effect, to minimize. To achieve this goal, the need to increase the DCA (Dynamic Channel Allocation, dynamic channel allocation) to user space information acquisition and processing functions. Smart antenna to signal the direction of arrival (DOA, Direction Of Arrival) DCA were estimated according to the user every time slot of the location for the new user assigned time slot, the user beam multi access interference as small as possible. In accordance with the principle of time slot interference size distribution of user location diagram.Capacity allocation of space resources increased to DCA algorithm, we must first obtain the user location information, and according to the interference measuring user directed beam location. In accordance with this interference by new users in different time slot size can still choose the slot in the DCA algorithm, this refers to the interference on the direction of interference, rather than the entire residential users in the slot. Baseband processing combined with smart antenna and joint detection. The total output of A generation system matrix data is through the equalization and filtering of airspace, the size can be calculated from the interference beam, as time slot allocation in DCA based on. Further research is needed to interference calculation methods, which can correctly reflect the size of the equivalent baseband beam interference. The baseband signal processing principle, smart antenna and joint detection technology. An ideal target of smart antenna is the realization of space division multiplexing (SDM). The beam forming effect of good enough, can be assigned the same code for different directions of the user (carrier, time slot, the same spreading code), which will make the system capacity doubled. Taking into account the user's mobility, the relative position between the user changes may make the user access the spatial multiplexing scheme that is failure, the co channel interference. Fast DCA code can be adjusted to overcome this problem. When the same code DCA for obtaining user interference is larger than the threshold value, trigger channel adjustment, for the allocation of channel resources with the new code of serious interference to eliminate the interference. Smart antenna with DCA is effective way to realize space division multiplexing.

B- Effect of smart antenna on power control

(1) The power control process changes**.**No smart antenna, power control and target according to the measured SIR value adjustment cycle. A Smart antenna, the main beam alignment adjustment to the user, and then the associated measurement.

(2) Control the power reduced. In the case of smart antenna, when the main beam at the user, because the antenna gain is high, relative to no smart antenna can greatly reduce the transmit power of the user terminal.

(3) In smart antenna, equation of power control is complicated. The traditional power control modeling method is no longer applicable. In this case the power control algorithm and modeling algorithm for smart antenna specific.

C- Effect of smart antenna on packet scheduling

Packet scheduling algorithm is the function of the distribution of packet data services in packet between users, improve the ability of users to use the air interface resource. Packet scheduling in the application is based on the combination of time division and code division. And the introduction of the smart antenna, the beam of resources, thus increasing the air in the one-dimensional packet scheduling mode. Change the air interface resource model, so the algorithm model should be changed. By using the beam resources, by reducing the Mai air separation, but also increase the transmission rate of packet users. At the same time, the use of smart antenna positioning function of UE, can also according to the location information to optimize the user scheduling rate, and thus more effective use of system resources.

D- Effect of smart antenna on switching control

The use of smart antenna technology, will inevitably involve some network properties, such as user mobility management etc. At the same time, the spatial location of the user in the mobile communication system has become a new available wireless physical resource including frequency, time slot, code and space angle four elements. This will give to the admission control and resource reservation brings a lot of flexibility in the switching process. In addition, the smart antenna can provide some useful reference information to improve the position of system resource utilization rate and shorten the time and reduce the handoff dropping rate, reduce signaling interaction, improve the success rate of handover and handover. The smart antenna in the system to bring the benefits of the switch, also increased the complexity of the switching, switching uncertainty and instability. As in the process of allocation of physical channels, the conflict of the need for adjustment and channel switching, because the decision dimension increases, the switching algorithm is more complicated than only 3 kinds of resources, handoff management of mobile users is much more complicated. The smart antenna is that the relationship between some criteria in the switching algorithm becomes fuzzy and complex, measurement parameters such as more random factors, the location of mobile users, the smart antenna effect etc. The respiratory effect of the area more randomized switching region is random.

V. FEATURES OF SMART ANTENNA SYSTEM

a- Signal gain
b- Interference rejection
c- Spatial Diversity and
d- Power Efficiency.

VI. BENEFITS OF SMART ANTENNA SYSTEM

a- Better range /coverage
b- To increase capacity
c- Multipath rejection and
d- Reduce expense.

VII. WORKING OF SMART ANTENNA

Smart antenna patterns are controlled via algorithms based upon certain criteria. These criteria could be maximizing the signal-to-interference ratio (SIR), minimizing the variance, minimizing the mean-square error (MSE), steering toward a signal of interest, nulling the interfering signals, or tracking a moving emitter to name a few. The implementation of these algorithms can be performed electronically through analog devices but it is generally more easily performed using digital signal processing. This requires that the array outputs be digitized through the use of an A/D converter. This digitization can be performed at either IF or baseband frequencies. Since an antenna pat-tern (or beam) is formed by digital signal processing, this process is often referred to as digital beam-forming. Contrasts a traditional electronically steered array with a DBF array or smart antenna. When the algorithms used are adaptive algorithms, this process is referred to as adaptive beam forming. Adaptive beam forming is a sub-category under the more general subject of digital beam forming. Digital beam forming has been applied to radar systems, sonar systems, and communications systems to name a few. The chief advantage of digital beam forming is that phase shifting and array weighting can be performed on the digitized data rather than by being implemented in hardware. On receiving, the beam is formed in the data processing rather than literally being forming in space. The digital beam forming method cannot be strictly called electronic steering since no effort is made to directly shift the phase of the antenna element currents. Rather, the phase shifting is computationally performed on the digitized signal. If the parameters of operation are changed or the detection criteria are modified, the beam forming can be changed by simply changing an algorithm rather than by replacing hardware. Adaptive beam forming is generally the more useful and effective beam forming solution because the digital beam former merely consists of an algorithm which dynamically optimizes the array pattern according to the changing electromagnetic environment. Conventional array static processing systems are subject to degradation by various causes. The array SNR can be severely degraded by the presence of unwanted interfering signals, electronic countermeasures, clutter returns, reverberation returns (in acoustics), or multipath interference and fading. An adaptive array system consists of the antenna array elements terminated in an adaptive processor which is designed specifically to maximize certain criteria.

VIII. USES OF SMART ANTENNA TECHNOLOGY

Smart antenna technology can significantly improve wireless system performance and economics for a range of potential users. It enables operators of PCS, cellular, and wireless local loop (WLL) networks. To realize significant increases in signal quality, capacity, and coverage. Operators often require different combinations of these advantages at different times. As a result, those systems offering the most flexibility in terms of configuration and upgradeability are often the most cost-effective long-term solutions.

REFERENCES

[1] Hansen, R. C., Microwave Scanning Arrays. Academic Press, 1966.Using Baseband Antenna Array Outputs," 1999 IEEE Vehicular Technology ConferenceProceedings, vol. 3, pp. 1759-1763, 1999.

[2] L. Godara, "Applications of Antenna Arrays to Mobile Communications, Part I:Performance Improvement, Feasibility and System Consideration," Proceedings of the IEEE,July 1997, pp. 1029-1069.

[3] Christopher Adeogun, "Antenna Height and Radio Communications Effectiveness", January, 2022.

[4] Hansen, R. C., Phased array antennas. John Wiley & Sons, 1988.