

A Survey on Smart Antenna System

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Abstract

Smart Antenna system is the One of the most rapidly developing areas of communications. This is the survey of paper which shows 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. The 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 shows required algorithms that are need for the beam forming in the antenna patters.

Keywords

Smart antenna, DOA, Beam forming, switched beam, adaptive array.

I. Introduction

A smart antenna is an array of antenna 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. 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 [1].

A. WHY NEED SMART ANTENNAS

Wireless communication systems, as opposed to their wire line counterparts, pose some unique challenges [2]:

- limited allocated spectrum results in a limit on capacity
- radio propagation environment and the mobility of users give rise to signal
- fading and spreading in time, space and frequency
- limited battery life at the mobile device poses power constraints

In addition, cellular wireless communication systems have to cope with interference due to frequency reuse. Research efforts investigating effective technologies to mitigate such effects have been going on for the past twenty five years, as wireless communications are experiencing rapid growth [2]. Among these methods are multiple access schemes, channel coding and equalization and smart antenna employment. An antenna in a telecommunications system is the port through which radio frequency (RF) energy is coupled from the transmitter to the outside world for transmission purposes, and in reverse, to the receiver from the outside world for reception purposes.

To date, antennas have been the most neglected of all the components in personal communications systems. Yet, the manner in which radio frequency energy is distributed into and collected from space has a profound influence upon the efficient use of spectrum, the cost of establishing new personal communications networks and the service quality provided by those networks. The commercial adoption of smart antenna techniques is a great promise to the solution of the aforementioned wireless communications' impairments.

B. FUNCTIONS OF SMART ANTENNA [1]

- Direction of arrival (DOA) estimation
- Beam forming

1. Direction of arrival estimation

The smart antenna estimates the direction of arrival of the signal, using techniques such as 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.

2. Beam forming [3]

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 beam former can steer its look direction towards a certain signal. Other signals from different directions can reuse the same carrier frequency. Secondly, because the beam former 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 beam former 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 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).

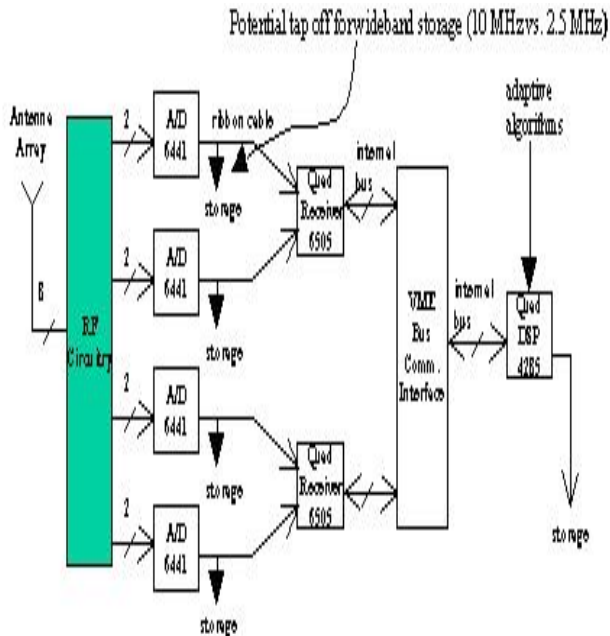


Fig. 1:

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 [1]. 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.

C. TYPES OF SMART ANTENNA SYSTEMS

There are basically two approaches to implement antennas that dynamically change their antenna pattern to mitigate interference and multipath affects while increasing coverage and range. They are

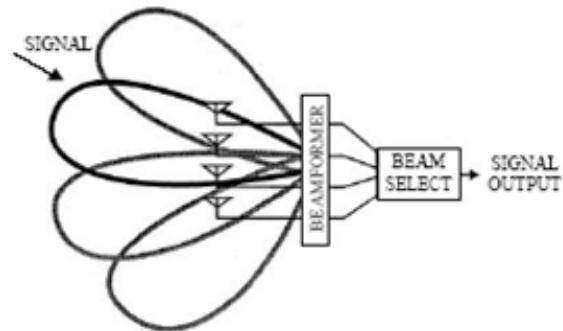
- Switched beam
- Adaptive Arrays

1. Switched beam

The Switched beam approach is simpler compared to the fully adaptive approach. It provides a considerable increase in network capacity when compared to traditional Omni directional antenna systems or sector-based systems. In this approach, an antenna array generates overlapping beams that cover the surrounding area. When an incoming signal is detected, the base station determines the beam that is best aligned in the signal-of-interest direction and then switches to that beam to

communicate with the user.

Switched Multibeam Antenna



2. Adaptive Arrays

The Adaptive array system is the “smarter” of the two approaches. This system tracks the mobile user continuously by steering the main beam towards the user and at the same time forming nulls in the directions of the interfering signal. Like switched beam systems, they also incorporate arrays. Typically, the received signal from each of the spatially distributed antenna elements is multiplied by a weight. The weights are complex in nature and adjust the amplitude and phase. These signals are combined to yield the array output. These complex weights are computed by a complicated adaptive algorithm, which is pre-programmed into the digital signal-processing unit that manages the signal radiated by the base station.

Adaptive Antenna Array

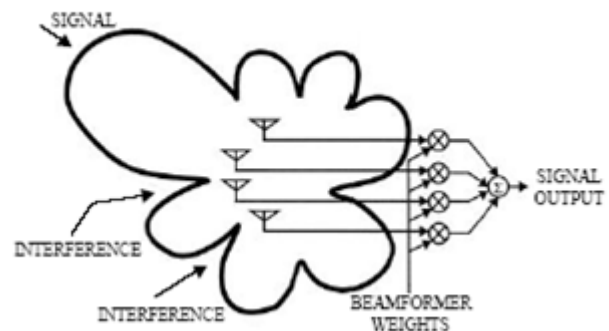


Fig. 2 : Adaptive Antenna Array

II. APPLICATIONS OF SMART ANTENNA

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 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.

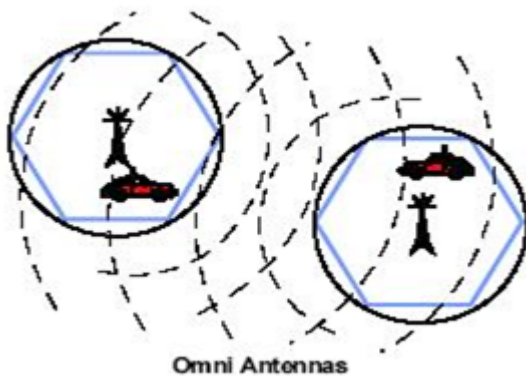


Fig. 3 : Omni Antennas

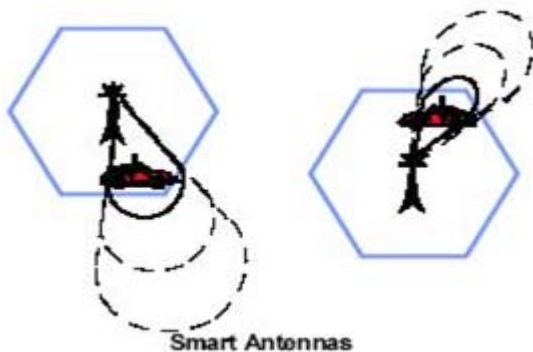


Fig. 4 : Smart Antennas

III. WORKING OF SMART ANTENNA

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).

IV. SMART ANTENNA RELATED WORKS

A. MBPVAA for Smart Antenna Applications in Cellular Systems

In this paper author [4] has used a new array antenna concept for application as smart antenna in cellular systems has been developed. He implemented as a compact, 4 x 4 dual polarized, multiband array together with a calibration network which satisfies the tight tolerances of the system requirements. A three-dimensional radiator structure made of metalized plastic covers more than 20% bandwidth (VSWR<1.5) and allows various polarizations, e.g., dual-slant polarization. A large micro strip board for signal distribution forms a sandwich structure together with a carbon-fiber reinforced back-plate and a foam-filled epoxy radome (radar dome). These measures keep the weight of the array exceptionally low while ensuring high mechanical stability. A broad-band (15dB match over 20% at 2GHz), polarization-versatile, low-weight array antenna has been described. It contains a calibration network for application in smart antenna cellular base-stations. The antenna combines several progressive technologies in order to keep performance, weight, and cost within limits: metalized plastic radiators, printed circuit board networks, sandwich structure with reinforced shells. Particular efforts have been described to keep couplings between antenna columns below -17dB without deterioration of the tilted radiation pattern.

B. The WWRF and SAS Technology

In this paper Members [5] of the WWRF are typically manufacturers, network operators/service providers, R&D centers, universities and small and medium enterprises. In particular, the WWRF identify and scope research issues relevant to future mobile and wireless communications, including pre-regulatory impact assessments and invite world-wide participation. As such, the Forum provides a global platform for discussion of results, exchange of views to initiate global cooperation towards systems beyond 3G. In particular, smart antenna technology has become one of the most dominant technologies for future wireless systems. This paper gives an overview of the WWRF and smart antenna technologies being developed within the WWRF.

C. MLA for High Frequency RFID Smart Shelf Application

In This paper author [6] has presented a patent-pending multi-loop antenna for HF (13.56MHz) RFID smart shelf applications. The proposed antenna prototype has been able to generate magnetic field with uniform magnitude for a larger interrogation region. In addition, the low profile structure makes it very easy

for implementation and not necessary for any modification to the shelf. Hence, the system installation cost has been reduced significantly. The patent-pending multi-loop antenna has been used for RFID smart shelves which are implemented in library for book management with achieved detection accuracy of 95-100%.

D. ATET Using an Interactive and Movie-based E-Book

In this paper author [7] has used a virtual tool (electronic book) for antenna theory and electromagnetic propagation is presented. A variety of radiation and electromagnetic problems ranging from linear antennas to arrays, radiation in time domain, micro strip antennas, smart antennas, and reflectors can be simulated. The material is useful both at undergraduate and graduate engineering courses. The education tool uses a user-friendly interface thanks to MathCAD® software package which has been used to develop the electronic book. Moreover, navigation throughout the book follows the same rules used by internet users, therefore, no extra knowledge have to be introduced on how to use the present tool. Besides the user-friendly interface, the book also features visualization capabilities, 3D representations and videos, which play a significant role in teaching. The electronic book comes with several exercise sections having twofold objectives: first, students can check their own progress, and second, data from such exercises is provided to professor/mentor. This data is extremely useful to determine whether a given section can be considered completely understood or some extra emphasize needs to be done. All the material presented in the book can be complemented by extra peer review scientific papers given at the end of each section, most of them can be downloaded (obviously, depending on the contract between university and editorial). The book has been tested using objective data resulting in good acceptance. We have presented an e-book for antenna theory, electromagnetic radiation and propagation based on MathCAD® software. The e-book takes advantage of hypertext, interactivity and multimedia files to enhance comprehension and motivate the student. The e-book contents and structure have been presented: eight chapters for undergraduate and graduate level. The e-book has been objectively tested where results encourage for further improvement of the present edition.

E. RC and EI to Smart Antenna

In this Research author [8] has actual working conditions influence to communication ability with common and similar smart antenna. Methods: Experimental research, data comparison and the results analysis comprehensively. Test received and sent data-packets successful ratio, and its reception intensity with antenna in USB network device in Windows 98 system, under AP (infra structure) mode with wireless broadband routers at several channels. It is greatly changing the similar smart antenna position indoors of crowd residential area, under 1 to most several BSs at the same channel. Results: The reception intensity is 70~76%, even over 90% out of the door, the successful reception packets 14~20%, even below 10%; sending packets below 10% even 2% between wireless router and adapter only, while signal penetrating through the much impediment walls and buildings. Uplink error is much more than Omni ones. A large reflector cannot efficiently raise the performance of similar smart antenna with its own indicate software. Conclusion: It is stronger than commons in the field and less penetrating through impediments that

main-directional pattern self-fit antenna for its reception and sending. Synchronous uplink for smart one keeps unblocked communication to overcome wave front distortion and multi-path interference. The reflector is very effectual method strong signal for common antenna, but not suitable for smart one. Unidirectional antenna concentrates energy for long distance point-to-point fixed communication and weakening signal, so that it suits and penetrates through multi impediments.

V. Conclusions

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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