Efficient Smart Antenna Systems (4G) For CDMA Wireless Communication

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ABSTRACT:
Today, mobile communications play a central role in the voice/data network arena. With the deployment of mass scale 3G just around the corner, new directions are already being researched. In this paper we address about the 4TH G mobile communications.
The Fourth Generation (4G) Mobile Communications should not focus only on the data-rate increase and new air interface. 4G Mobile should instead converge the advanced wireless mobile communications and high-speed wireless access systems into an Open Wireless Architecture (OWA) platform which becomes the core of this emerging next generation mobile technology. Based on this OWA model, 4G mobile will deliver the best business cases to the wireless and mobile industries, i.e. cdma2000/WLAN/GPRS 3-in-1 product, WCDMA/OFDM/WLAN 3-in-1 product, etc.
The advent of 4G wireless systems has created many research opportunities. The expectations from 4G are high in terms of data rates, spectral efficiency, mobility and integration. Orthogonal Frequency Division Multiplexing (OFDM) is proving to be a possible multiple access technology to be used in 4G. But OFDM comes with its own challenges like high Peak to Average Ratio, linearity concerns and phase noise. This paper proposes a solution to reduce Peak to Average Ratio by clipping method.
With a number of 3G systems using CDMA as the preferred transmission scheme, extensive research has been done into ways of improving performance in a CDMA system. To this end, a lot of research has been done in coding, modulation, handoff protocols and so on. One of the avenues of possible performance improvement that has not received as much attention is the use of multiple antennas at the base station (and possibly at the mobile handset as well). Multiple antennas can be used for beam steering, diversity combining, range improvement, reduction in interference etc. for obtaining performance gains, thus leading to the concept of Smart Antennas

INTRODUCTION
The first operational cellular communication system was deployed in the Norway in 1981 and was followed by similar systems in the US and UK. These first generation systems provided voice transmissions by using frequencies around 900 MHz and analogue modulation.

The objective of the 3G was to develop a new protocol and new technologies to further enhance the mobile experience. In contrast, the new 4G framework to be established will try to accomplish new levels of user experience and multi-service capacity by also integrating all the mobile technologies that exist (e.g. GSM - Global System for Mobile Communications, GPRS - General Packet Radio Service, IMT-2000 - International Mobile Communications, Wi-Fi – Wireless Fidelity, Bluetooth). In spite of different approaches, each resulting from different visions of the future platform currently under investigation, the main objectives of 4G networks can be stated in the following properties:

• Ubiquity;
• Multi-service platform;
• Low bit cost

To achieve the proposed goals, a very flexible network that aggregates various radio access technologies, must be created. This network must provide high bandwidth, from 50-100 Mbps for high mobility users, to 1Gbps for low mobility users, technologies that permit fast handoffs, an efficient delivery.

Smart antenna systems allow for more efficient use of the overburdened cellular spectrum. Smart antennas provide greater capacity from existing cell
sites, more consistent coverage with improved call quality, and a reduction in the number of antennas. Smart antennas allow service providers the ability to elegantly clear spectrum for digital services, and, in the deployment of co-located CDMA systems, allow the analog and digital networks to use the same antennas without having the same sector orientations and sector beamwidths.

SWITCHED-BEAM ANTENNA

The Switched beam approach is simpler compared to the fully adaptive approach. The Switched beam approach is simpler compared to the fully adaptive approach. It provides a considerable increase in Simulation and field testing results of smart antennas system show that a significant increase in carrier to interference (C/I) over a conventional omni or 3-sector system are achievable. This presentation addresses how to practically take advantage of the reduction in interference that smart antennas provide.

Using switched narrow-beam antenna systems allows a frequency planner greater flexibility in designing a cellular system. In addition to supporting flexible sector sizes, smart antennas provide more precise traffic data. By studying the amount of time particular beams or antennas are being used, the probability of having an unacceptable interference condition can be determined. As a result of having improved interference reduction and more detailed system information, aggressive frequency reuse is possible. Field results confirm theoretical calculations and show that it is possible to increase system capacity by tightening frequency reuse without degrading network switch statistics.

II System Analysis

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 network capacity when compared to traditional omnidirectional antenna system or sector-based system.

It is possible, using array antennas, to create a group of overlapping beams that together result in omnidirectional coverage. It is simplest technique, and comprises only a basic switching function between separate directive antennas or predefined beams of an array. Beam-switching algorithms and RF signal-processing software are incorporated in smart antenna designs. For each call, software algorithm determine the beam that maintain the highest quality signal and the system continuously updates beam selection, ensuring that customers get optimal quality for the duration of their call. One might design overlapping beam patterns pointing in slightly different directions similar to the ones shown in figure 1.

ADAPTIVE ARRAY

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 as shown in figure II. 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.
OPEN WIRELESS ARCHITECTURE (OWA)

Multi-technology Approach:
- Orthogonal Frequency Division Multiplexing (OFDM)
- Open wire less Architecture (OWA)
- Multiple-input multiple-output (MIMO)

GENERIC MIMO AND OFDM:
Increasing demand for high performance 4G broadband wireless mobile calls for use of multiple antennas at both base station and subscriber ends. Multiple antenna technologies enable high capacities suited for Internet and multimedia services and also dramatically increase range and reliability. This design is motivated by the growing demand for broadband wireless Internet access. The challenge for wireless broadband access lies in providing a comparable quality of service for similar cost as competing wire line technologies. The target frequency band for this system is 2 to 5 GHz due to favorable propagation characteristics and low radio-frequency (RF) equipment cost. The broadband channel is typically non LOS channel and includes impairments such as time selective fading and frequency-selective fading. Multiple antennas at the transmitter and receiver provide diversity in a fading environment. By employing multiple antennas, multiple spatial channels are created and it is unlikely all the channels will fade simultaneously. OFDM is chosen over a single carrier solution due to lower complexity of equalizers for high delay spread channels or high data rates. A broadband signal is broken down into multiple narrowband carriers (tones), where each carrier is more robust to multipath. In order to maintain orthogonality amongst tones, a cyclic prefix is added which has length greater than the expected delay spread. With proper coding and interleaving across frequencies, multipath turns into an OFDM system advantage by yielding frequency diversity. OFDM can be implemented efficiently by using FFTs at the transmitter and receiver. At the receiver, FFT reduces the channel response into a multiplicative constant on a tone-by-tone basis. With MIMO, the channel response becomes a matrix. Since each tone can be equalized independently, the complexity of space time equalizers is avoided. Multipath remains an advantage for a MIMO-OFDM system since frequency selectivity caused by multipath improves the rank distribution of the channel matrices across frequency tones, thereby increasing capacity.

OPEN WIRELESS ARCHITECTURE

The 4G Mobile communications will be based on the Open Wireless Architecture (OWA) to ensure the single terminal can seamlessly and automatically connect to the local high-speed wireless access systems when the users are in the offices, homes, airports or shopping centers where the wireless access networks (i.e. Wireless LAN, Broadband Wireless Access, Wireless Local Loop, HomeRF, Wireless ATM, etc) are available. When the users move to the mobile zone (i.e. Highway, Beach, Remote area, etc.), the same terminal can automatically switch to the wireless mobile networks (i.e. GPRS, W-CDMA, cdma2000, TD-SCDMA, etc.). This converged wireless communications can provide the following advantages.

- Greatly increase the spectrum efficiency
- Mostly ensure the highest data-rate to the wireless terminal
- Best share the network resources and channel utilization
- Optimally manage the service
quality and multimedia applications. Figure 1 shows the wireless evolution to 4G mobile communications based on OWA platform, where 3G, Wireless LAN and other wireless access technologies will be converged into 4G mobile platform to deliver the best infrastructure of mobile communications with optimal spectrum efficiency and resource management. In fact, this OWA model had already been accepted by most wireless industries, for example, the W-CDMA/W-LAN/Bluetooth 3-in-1 terminal is being designed in many companies.

**Arbitrary Signal Combining Techniques For 4G wireless comm.system**

As antenna array has to process a number of signals which may be corrupted by unwanted noise. If there are P significant channels and N are the array elements then there are PN separate data samples to be considered. This requires multichannel receiver. So best approach to solve this problem is to weight each channel approximately and combine them together, before making a data decision. Difficulty comes in scaling of the data samples before combining them.

Four fundamental approaches for signal combining are:

- **Selection Diversity**—This is a quite simple approach for combining signals if the receiver has to process multichannels simultaneously. Receiver simply switches to the channel which has the highest signal power.

- **Maximal Ratio Combining**—This technique is used to maximize the SINR of the combined signals when interference on each multichannel is uncorrelated.

- **Noncoherent Combining**—If the receiver employs DPSK detection, the carrier phase reference is simply the data samples obtained for the previous symbol. The magnitude of the previous data sample also provide an estimate of the amplitude Al.

- **Wiener Filtering**—It attempts to suppress the interference and maximize the SINR at the combiner output. Other three techniques discussed are based on maximizing the signal power at the combiner output.

**Receiver Structure Of smart Antenna**

Receiver should be capable of estimating the data samples from the interference enabled sequence. Two approaches should be considered for combining the data samples.

- **1D RAKE Filter**—It is used for non-coherent combining of P channel taps in a single antenna CDMA receiver.

- **2D RAKE Filter**—It is a more effective and compact approach to dealing with the channel tap vectors is to apply a spatial filter to each tap vector. This permits the receiver to perform coherent combining of the tap vector elements and improving performance over the 1D RAKE filter. This approach is called “2D RAKE Filter ” because the receiver operates two separate sets of combiners in time and space. Receiver picks up the largest channel taps and selects appropriate spatial filter in each case, and output from the filter banks are combined in a conventional RAKE filter ready for decision making. Base stations are frequently split into three sectors, to provide 120 degree coverage.

**Computational Algorithms for computing the optimum weights at the receiver**

This paper focused on algorithms that are not-only computationally efficient but also take into account the fact that future CDMA based systems would want to operate in low-SIR environments. All the techniques mentioned in this paper are blind techniques, i.e. they or inverse matrices. Also, it differs from the previous algorithm in how the don’t need any prior spatial channel information. All these algorithms apply the weight vectors after PN-processing to exploit the advantage of DS-CDMA over other systems.

The direction of arrival angles of N users and L multipaths are assumed to be independent. Channel estimation is done using pilot channels. The smart antenna adaptation rate is assumed to be equal to the symbol rate. Finally, while a real system might use a Viterbi decoder for soft-decision, this paper employs a hard decision for simplicity and simulates symbol (bit) error probability without the Viterbi decoder. The 4 smart antenna algorithms are briefly described below [4]–

1. **Smart Antenna based on Maximum Output Power with Lagrange Multiplier**—If the power of the undesired user is higher than that of the desired user, then this algorithm might end up tracking the undesired user leading to higher BER. The computational load of the smart antenna is on the order of O(4M).
2. **Smart Antenna Based on Maximum SINR Output with Eigenvector Solution** – In this method, the antenna array response vector is estimated as the eigenvector with maximum eigenvalue of the matrix \((R_{xx}(k) - R_{yy}(k))\), where \(R_{xx}\) is the autocorrelation of the desired signal and \(R_{yy}\) is the autocorrelation of the received signal.

3. **Smart Antenna Based on Maximum SINR Output Without Eigenvector Solution** – This algorithm also uses the maximum SINR criteria. However, it does so without calculating any eigenvectors. Autocorrelation matrices are updated.

### Technology

4.5.1 **Reduction in co-channel interference**

Smart antennas have a property of spatial filtering to focus radiated energy in the form of narrow beams only in the direction of the desired mobile user and no other direction.

4.5.2 **Range improvement**

Since smart antennas employ collection of individual elements in the form of an array, they give rise to narrow beam with increased gain when compared to conventional antennas using the same power. The increase in gain leads to increase in range and the coverage of the system. Therefore fewer base stations are required to cover a given area.

4.5.3 **Increase in capacity**

Smart antennas enable reduction in co-channel interference, which leads to increase in the frequency reuse factor.

4.5.4 **Reduction in transmitted power**

Ordinary antennas radiate energy in all directions leading to a waste of power. Comparatively smart antennas radiate energy only in the desired direction. Therefore less power is required for radiation at the base station. Reduction in transmitted power also implies reduction in interference towards other users.

4.5.5 **Reduction in handoff**

To improve the capacity in a crowded cellular network, congested cells are further broken into micro cells to enable increase in the frequency reuse factor. This results in frequent handoffs, as the cell size is smaller. Using smart antennas at the base station, there is no need to split the cells since the capacity is increased by using independent spot beams. Therefore, handoffs occur rarely, only when two beams using the same frequency cross each other.

4.5.6 **Mitigation of multipath effects**

Smart antennas can either reject multipath components as interference, thus mitigating its effects in terms of fading or it can use the multipath components and add them constructively to enhance system performance.

4.5.7 **Compatibility**

Smart antenna technology can be applied to various multiple accents and add them constructively to enhance system performance.

### Conclusions

In this paper we present the evolution of mobile communications through all its generations. From the initial speech vocation to an IP-based data network, several steps were made. From the analog voice centric first generation to the digital second generation, the goal was to enhance the voice experience of a user, by improving the quality of the communication while using more efficiently the installed capacity. At the same time the enhanced mobility provided by seamless handover and the additional data communications capacity (although very small) advanced and opened the doors to future developments. Some of the developments was brought by generation 2.5 namely by GPRS, which improved data communications by supporting IP in the GSM infrastructure. With the third generation the goal changed from voice-centric to data-centric. Moreover total mobility became an objective to pursue. In this generation it is possible to combine voice, inter media applications and mobility in a never experienced manner. However, the global mobility, while an important objective, was never really reached. At the same time new applications demand more bandwidth and lower costs. The newcomer fourth-generation tries to address this problem by integrating all different wireless technologies. In spite of all the evolving technologies the final success of new mobile generations will be dictated by the new services and contents made available to users.

Smart Antenna technology has been introduced which is used for reducing interference.
Use of switched beam and adaptive antenna arrays has been discussed to mitigate interference and multipath effects while increasing coverage and range.

The topic of antenna array discusses that employing M antennas can multiply the reverse link capacity by a factor of roughly by M.

Different signal combining techniques and different algorithms have been used for optimum weight calculation.

Due to number of benefits discussed so far in the paper smart antenna technology can be used for numerous applications in wireless communication like in MIMO systems, 802.11 standard, mobile communication etc.

References


Seamless handover and the additional data communications.