



Performance Improvement Interfering High-Bit-Rate W-CDMA Third-Generation Smart Antenna systems

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ABSTRACT : Performance enhancement of smart antennas versus their complexity for commercial wireless applications. The goal of the study presented in this paper is to investigate the performance improvement attainable using relatively simple smart antenna techniques when applied to the third-generation W-CDMA air interface. Methods to achieve this goal include fixed multi beam architectures with different beam selection algorithms (maximum power criterion, combined beams) or adaptive solutions driven by relatively simple direction finding algorithms. After comparing these methods against each other for several representative scenarios, some issues related to the sensitivity of these methods are also studied, (e.g., robustness to environment, mismatches originating from implementation limitations, etc.). Results indicate that overall, conventional beam forming seems to be the best choice in terms of balancing the performance and complexity requirements, in particular when the problem with interfering high-bit-rate W-CDMA 3g users is considered.

Keywords: Adaptive algorithms, smart antennas, third Generation systems, wavelength code division multiple access (WCDMA).

I. INTRODUCTION

Demand for service provision via the wireless communication bearer has risen beyond all expectations. If this extraordinary capacity demand is put in the context of third-generation systems requirements (UMTS, IMT 2000) [1], then the most demanding technological challenge emerges: the need to increase the spectrum efficiency of wireless networks. While great effort in second-generation wireless communication systems has focused on the development of modulation, coding, protocols, etc., the antenna-related technology has received significantly less attention up to now. In order to achieve the ambitious requirements introduced for future wireless systems, new “intelligent” or “self-configured” and highly efficient systems, will be most certainly required. In the pursuit for schemes that will solve these problems, attention has turned into spatial filtering methods using advanced antenna techniques: adaptive or smart antennas. Filtering in the space domain can separate spectrally and temporally overlapping signals from multiple mobile units, and hence the performance of a system can be significantly improved. In this context, the operational benefits that can be achieved with exploitation of smart antenna techniques can be summarized as follows [2].

1. More efficient power control;
2. Smart handover;
3. Support of value-added services:
 - (a) Better signal quality;
 - (b) Higher data rates;
 - (c) User location for emergency calls;

- (d) Location of fraud perpetrators;
 - (e) Location sensitive billing;
 - (f) on-demand location specific services;
 - (g) Vehicle and fleet management;
4. Smart system planning;
 5. Coverage extension;
 6. Reduced transmit power;
 7. Smart link budget balancing;
 8. Increased capacity.

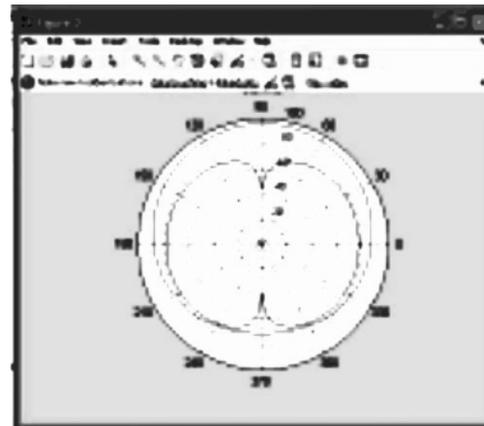


Fig .1. 900 MHz.

Much research has been performed over the last few years on adaptive methods that can achieve the above benefits, e.g., [3–7]. Nevertheless, it has been recognized that communication systems will exploit different advantages or mixtures of advantages offered by smart antennas, depending on the maturity of the underlying system. For

example, at the beginning, costs can be reduced by exploiting the range extension capabilities of simple and cheap.

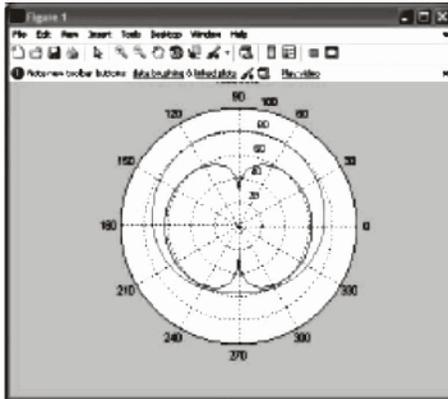


Fig. 2. 1800 MHz.

Smart antennas. Then costs can be further decreased by avoiding extensive use of small cells where there is increased capacity demand, by exploiting the capability of smart antennas to increase capacity, with relatively simple (more complex than the previous phase) adaptive methods. Finally, more advanced systems (third generation) will be able to benefit from smart antenna systems, but it is almost certain that more sophisticated space/time filtering approaches [6] will be necessary to achieve the goals of universal mobile telecommunications service (UMTS), especially as these systems become mature too. Recognizing that full exploitation of smart antennas, and in particular in future-generation systems, requires the growth of radio-frequency and digital signal-processing technology, this paper focuses on studying the performance of a UMTS-type system [wireless code-division multiple access (W-CDMA)], with relatively simple (in terms of complexity), smart antenna methods [9]. The next section will describe the simulation method that was employed in order to achieve this goal. Then simulation results will be presented and discussed in the context of the achieved performance under different conditions.

II. LOW-COMPLEXITY SMART ANTENNA

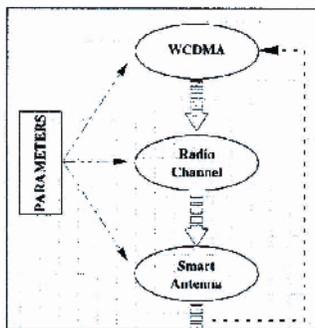


Fig .3. Smart Antenna Block.

A. The W-CDMA System

(1) General Description: The universal mobile telecommunications system (UMTS UTRA) FRAMES mode-2 W-CDMA proposal (FMA2) is based on W-CDMA, with all the users sharing the same carrier under the direct-sequence CDMA (DSSSS) principle. The frequency-division duplex (FDD) mode; however, a time division duplex (TDD) mode for W-CDMA is also included in the specification. The FMA2 is asynchronous with no base station dependence upon external timing source (e.g., global positioning system).

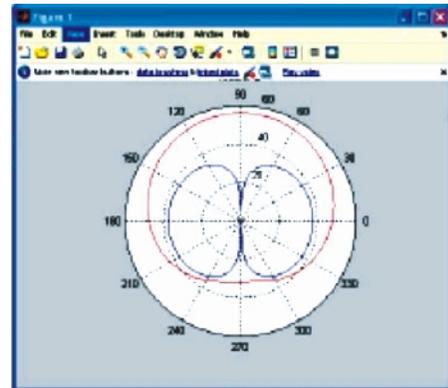


Fig. 4. 1900 MHz.

It employs 10-ms frame length, which, although it is different from the global system for mobile communications (GSM), also allows making intersystem handoffs, since 12 FMA2 frames are equal to a single GSM frame. FMA2 defines two types of dedicated physical channels on both uplink and downlink: the dedicated physical control channel (PCCH) and the dedicated physical data channel (PDCH). The PCCH is needed to transmit pilot symbols for coherent reception, power-control signaling bits, and rate information for rate detection. The FMA2 downlink is similar to second-generation DS-SS systems like IS-95. The PDCH and PCCH are time multiplexed within each frame and fed to the serial-to-parallel converter. Then, both I and Q branches are spread by the same channelization orthogonal variable spreading factor (OVSF) codes and subsequently scrambled by a cell-specific code. The downlink scrambling code is a 40 960 chip segment (one frame) of a Gold code of length 21. The channelization codes are OVSF codes that preserve orthogonality between channels with different rates and spreading factors. Each level of the tree corresponds to a different spreading factor.

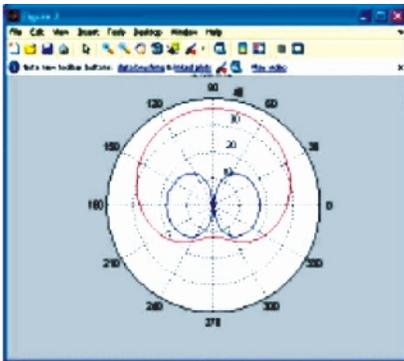


Fig. 5. 2100 MHz.

A code from the tree can be used if and only if no other codes are used from an underlying branch or the path to the root of the tree. All codes from the tree cannot be used simultaneously if orthogonality is to be preserved [10]. In essence, codes generated with this method are Walsh-Hadamard codes, with small differences in the permuting rows of each level, in order to preserve interlevel orthogonality. Two basic options for multiplexing physical control channels are: time multiplexing and code multiplexing. In FMA2, a combined IQ and code-multiplexing solution (dual-channel quaternary phase-shift keying) is used to avoid audible interference problems with discontinuous transmission. This solution also provides robust rate detection since rate information is transmitted with fixed spreading factor on the PCCH. In terms of the uplink spreading and scrambling concepts of the PDCH and PCCH physical channels, the physical channels are mapped onto I and Q branches, respectively, and then both branches are spread by two different OVFS channelization codes and scrambled by the complex code. Each part of the complex scrambling code is a short Kasami code 256 chips long. As a second option, long-code complex scrambling may also be used. Such a long code is an advantage for the conventional receiving scheme (single-user matched filtering), since it prevents consecutive realization of bad multiple-access interference (MAI). However, it is a disadvantage from the point of view of implementing multi-user detection, since the detector must be time-varying and explicit knowledge of interference is required.

1. Perfect power control.
2. Perfect channel estimation.
3. One chip is represented by one sample hence no pulse shaping.
4. All users [including low bit rate (LBR)] are modeled according to the W-CDMA UTRA frame format, and also spreading/despreading and scrambling/descrambling are incorporated in the simulator. This is done to take into account site-specific radio channel models (ray tracing) where even LBR interfering users color the spatial structure of MAI.

(5) Interfering users from other than the central cells are modeled as space-time white noise. depicts the simulation schematic of the desired user. Since the data from

other users are of no interest (single-user detection), the interfering users from the same cell are further simplified. Same-cell interferers are constructed to account for MAI only; hence only scrambling codes are transmitted. This can be viewed also as a stream of “1” spread by the first OVFS code depicts one way to visualize or model the transmission of such signals through the radio channel with the help of a bank of tapped delay lines. The values of the parameters shown in are taken from the results produced with the help of the ray-tracing propagation model described in the next section. The reception process discussed above can be described as

$$x(t) = \sum_{k=1}^K \sum_{l=1}^L \sqrt{p_{k,l}} s(t - T_{k,l}) g_{k,l}(t - T_{k,l}) a_{k,l} + n(t)$$

where $x(t)$ is the received signal vector by the element antenna array, K is the number of users, L is the number of multi paths, $p_{k,l}$ is the power of the l th multipath component from the k th user, $s(t - T_{k,l})$ is the scrambling code, $g_{k,l}(t - T_{k,l})$ is the antenna response vector, and $n(t)$ is the noise vector, and is

$$s(t - T_{k,l}) = C_{k,l}^{PDCH}(t - T_{k,l}) b_{k,l}^{PDCH}(t - T_{k,l}) + j \cdot C_{k,l}^{PCCH}(t - T_{k,l}) b_{k,l}^{PCCH}(t - T_{k,l})$$

III. THE SMART ANTENNA

Conventional Beam forming Fourier Method (FM): This classic method is based on the fact that the spatial Fourier transform of an observed signal vector across an array defines the spatial spectrum. The resulting antenna weights can be expressed as

$$w_n = \exp\left(j(n-1) \frac{2\pi}{\lambda} d \sin(\varphi)\right)$$

It is a straightforward technique, and since it is fairly insensitive to parameter variations, it is inherently robust. In the presence of wide signal separations, this method may offer more robust Performance than the high-resolution methods, and since it is far easier to compute, it is a favored candidate in real system implementations.

Switched Beams (SB): This method uses a number of fixed steered beams, calculates the power level at the output of each of the beams, and in its simplest form the beam with the highest output power is selected for reception. Although it is believed that this algorithm is best suited to environments in which the received signal has a well defined direction of arrival, i.e., the angular spread of the environment should be less than the beam width of each of the beams, even in environments where the angular spreading is high, there can be benefit from this algorithm. It is not efficient when co channel interference is present, but it may cope with frequency-selective channels provided

the channel consists of narrow clusters at widely separated directions. For both of the above cases, a linear array with eight elements was used. The weights that generate the beams for the SB methods (as for the weights of all the algorithms that are employed in the simulation results shown here) are normalized to the absolute value of the weight vector. In an attempt to balance the conflicting requirements not to consider ideal situations (60 dB) and at the same time not to bias the analysis at this level with high sidelobe and null depth levels (15 dB), the minimum null depth was chosen to be limited to 30 dB. The complexity associated with adaptively scanning the beam-pointing direction by varying complex weights in a beam forming network is avoided by switching between fixed beam directions. The weights that produce the desired grid of beams can be calculated and saved for future use; hence the beam switching approach allows the multi beam antenna and switch matrix to be easily integrated with existing cell site receivers as an applique [5]. Also, tracking is performed at beam switching rate (compared to angular change rate for direction finding methods and fading change rate for optimum combining [2]). Disadvantages include low gain between beams, limited interference suppression and false locking with shadowing, interference, and wide angular spread [2].

3) *Combined Switched Beam Approach (SBc)*: The difference between this method and the basic switched beam approach is that in this case, the calculated power levels at the output of each of the beams are considered in the context of a power window threshold (from the maximum power), and all the beams with output power within the employed power window are selected. The default power windows were chosen to be 3 and 5 dB for SB13 and SB9, respectively. These default values were chosen 1) bearing in mind the measurements reported in [4] and also in an attempt to balance the different beam spacing between the two methods as well as the conflicting requirements of capturing as much desired energy as possible and avoiding interference. As a result, two different cases are considered: SB13c and SB9c. Combining the best beams from a grid of beams is slightly more complex than the basic grid of beams approach. It requires processing the outputs from all the beams in order to find which beams give power within the chosen power window, and then summation of the chosen output signals.

IV. BEAM SPACE OPTIMUM COMBINING (BOPC)

This method works with the eigenvalues of the calculated correlation matrix. The eigenvalues of a correlation matrix indicate how dispersive (spatially) the received signal is. If there are a few eigenvalues with similar amplitudes, then the variability of the signal will tend to be confined to the subspace spanned by the corresponding eigendirections.

If the eigenvalues are approximately equal, then the signal spans the full multidimensional space. If a power window is employed for the eigenvalues of the correlation matrix, then a mechanism is automatically generated to control how many degrees of freedom will be used. The chosen power window can be fixed to some predefined value, or can be adaptive to each scenario considered. After the calculation of eigenvalues, the corresponding eigenvectors of the covariance matrix are simply combined in an optimum manner. From [8], for the eigenvalue solution in array space for maximum signal-to-(interference plus noise) ratio (SINR) at the output of a smart antenna.

$$w_{\text{opt}} = R_{xx}^{-1} v_{\text{max}}$$

Where v_{max} is the associated eigenvector to the largest eigenvalue of R_{xx} . It was shown in [3] that the eigenvector that corresponds to the maximum eigenvalue of the correlation matrix is approximately equal to the steering vector of the target signal source (desired signal) when the desired signal is much stronger than the interferers at the receiver. As a result, this technique is particularly applicable to CDMA systems due to the available processing gain. This technique is suboptimal in that it does not null out interference. Although it is rather complex $N \times N$, it is very promising since there have been ways suggested in [2] to reduce its complexity down to $(11 N)$. Smart antenna system combines an antenna array with the digital signal-processing capability to transmit and receive in an adaptive, spatially sensitive manner. Such a system automatically changes the directionality of its radiation pattern in response to the signal environment [1]. The main objective of a smart antenna is to implement an adaptive algorithm to achieve the optimal weights of antenna elements dynamically. Optimality criteria, such as minimum mean square error (MMSE), least square error (LSE), maximum signal-to-noise-ratio (SNR) can be used to yield a winning solution [2]. Based on these criteria, several adaptive algorithms have been proposed. Smart antenna can be used at both base station and mobile stations to achieve transmit and receive diversity. Receive diversity uses one or more antenna at the receiver to dynamically combine the received signals. This does not demand more power compared to the conventional antenna. Use of a smart antenna at mobile station is not practical. It increases the weight and power consumption of the mobile and the cost [3]. Therefore, we only consider a smart antenna at the base station on the reverse link.

V. RESULTS

We use 900 to 2100 MHz beam forming for 3g smart antenna system and provide simulation results from these matlab 7.8. We also demonstrate the results with the conventional single-element antenna. We also examine the effects of different design parameters in smart antenna system performance.

VI. CONCLUSION

We study the smart antenna technologies for GSM systems. Using Computer simulation, we show that smart antenna has powerful capabilities to reduce co channel interference by forming deep nulls in the directions of interference. We summarize the results of simulation. Smart antenna (using four to six elements) can provide an average gain of 6–8 dB as compared to conventional single element antenna. Smart antenna has best performance with four and six elements. Six-element system has been proposed for systems, whereas four-element for the UMTS. Most suitable spacing for antenna elements is half the wavelength. However, element spacing of less than a wavelength increases. The user data rate does not affect the performance. This means the system can accommodate any kind of user, voice, or data. Adding additional output modules can easily scale the smart antenna system. The number of elements does not limit the number of users it can accommodate. The smart antenna can distinguish different users even if they are from the same direction. This is achieved by exploring inherent orthogonality of the Gold code of different users. The bit error tends to be clustered to some particular user. That is, when error occurs, most of them usually occur on one or two users, instead of spreading out over all users.

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