BER Performance of W-CDMA Reciever Using Adaptive Array Antenna Technique in Indoor LOS/NLOS Environments

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Abstract

The wide band code division multiple access(W-CDMA) receiver combined with adaptive array antenna(AAA) technique is developed and used to measure the bit error rate(BER) performances in indoor line of sight(LOS) and non line of sight(NLOS) environments. Since the BER changes with the orientation of the receiving antenna in indoor environment, the mean BER is proposed by averaging all BERs at each orientation of receiving antenna along azimuth direction. Compared with the single antenna when BER is equal to 10^{-2}, the experimental results have demonstrated that signal-to-interference ratio(SIR) can be improved by 10dB in indoor LOS environment and 8dB in indoor NLOS environment, respectively.

I. Introduction

The benefits of using adaptive array antenna (AAA) technique in wireless mobile systems have been thoroughly studied in recent years, showing overcoming multipath fading of the desired signal and suppressing the interfering signals, as a consequence, an increase in the system capacity. Although, most of the applications of AAA have been found in base stations [1]-[3], the application to mobile terminals has been paid more and more attention [4]-[7]. In [4], the authors experimentally analyzed a code division multiple access (CDMA) adaptive system performance by using a 3-element planar inverted F array antenna. In [6], the authors measured signal-to-interference-plus-noise ratio(SINR) to evaluate the adaptive beamforming performance with using six different 4-element array configurations. In the case of mobile terminals, because of the space limitation for locating array antennas, the array spacing is small compared with the case of base station. Therefore, the mutual coupling between array elements should be considered carefully in adaptive array antenna systems [7].

In order to further investigate the effects of the antenna geometry, the adaptive algorithm and the environment on the performance of adaptive array antenna system for mobile terminals, a W-CDMA receiving system combined with AAA technique is developed. In this paper, the effect of the environment on the W-CDMA receiver combined with AAA technique will be focused. In section 2, the system configuration of the receiver and receiving array antenna will be described, then in section 3 the adaptive algorithm will be briefly reviewed. In section 4, the results of the BER performance using AAA technique in indoor multipath propagation scenario will be presented and further compared with the BER performance without using AAA technique to support the validity of application of AAA technique on W-CDMA receiver system.

II. System Configuration of W-CDMA Receiver

The configuration of the W-CDMA receiver is shown in Fig.1. There are 4 RF branches with SMA input ports to connect 4 receiving antennas. The system works at 2.452GHz. Each RF branch consists of a low noise amplifier and a mixer to convert RF signal at 2.452 GHz to IF signal at 15.36 MHz. In the baseband circuit, the IF signal is over-sampled at a clock of 61.44 MHz and converted into digital data by a 14-bit A-D converter (ADC). The baseband signal is received by a digital demodulator and a correlator. The adaptive control is carried out in digital signal processor 2 (DSP2) and its algorithm can be modified very easily. In this paper, the normalized least mean square(N-LMS) is selected as the adaptive algorithm and the pilot symbol for each downlink slot of W-CDMA DPCH is used as the reference signal for N-LMS algorithm. The synthesized output after adaptive control will be finally obtained in the field programmable gate array (FPGA).

In this research, a 4-element monopole array antenna(Fig.2) with $1m \times 1m$ ground plane is used as receiving array antenna. The array spacing and the length of monopole element are both set to be 0.25λ.

III. N-LMS Adaptive Algorithm

Least mean square (LMS) algorithm introduced by Widow [8] has gained much popularity due to its simplicity and ease of implementation. However, its step size choice which is good for certain environments may result in poor performance with a change in environment or even divergence of the algorithm. The normalized LMS(N-LMS) has been presented by Nagumo

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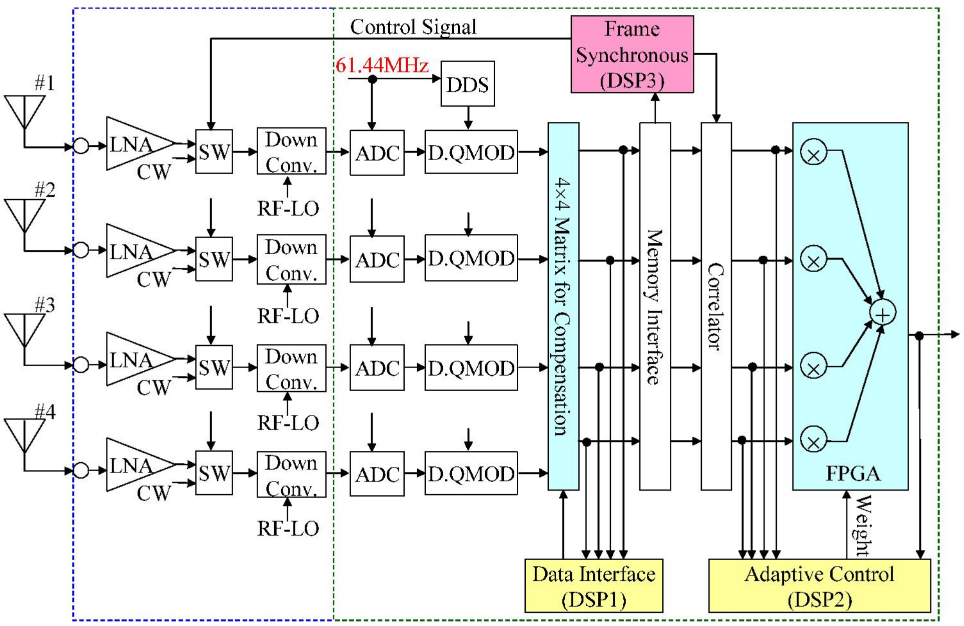


Fig. 1. System configuration of W-CDMA receiver.

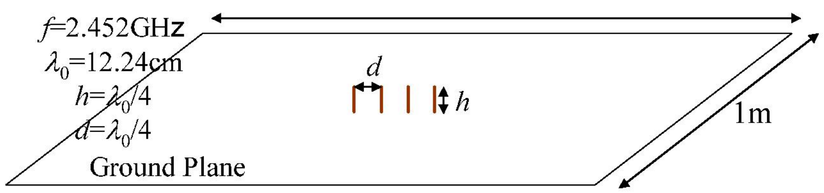


Fig. 2. Configuration of receiving array antenna.

and Noda [9] for overcoming the above disadvantage. Therefore, the N-LMS algorithm is applied to the developed W-CDMA receiver in this paper. The optimum weight vector $[W(t)]$ for each slot is obtained by the following iteration

$$[W(t)] = [W(t - \Delta t)] + \mu e^{*}(t)[X(t)]/ \parallel [X(t)] \parallel^{2}, \tag{1}$$

and further normalized as

$$w_i(t) = w_i(t)/ \parallel [W(t)] \parallel^{2} . \tag{2}$$

In equation (2), $w_i(t)$ denotes the i^{th} element in the weight vector. In equation (1), $[X(t)]$ represents the pilot data in each slot. Δt is the time interval between two slots. μ is the step size which should be selected between 0 and 1. $e(t)$ is the error between the synthesized output and the known reference pilot signal $plt(t)$, and is defined by

$$e(t) = plt(t) - [W(t - \Delta t)]^{T}[X(t)], \tag{3}$$

where the superscript T denotes the transpose, $[W(t-\Delta t)]^{T}[X(t)]$ represents the output signal synthesized by the weight $[W(t)]$ and the input data $[X(t)]$.

IV. BER MESUREMENT IN INDOOR LOS/NLOS ENVIRONMENT

The BER measurement is performed in a indoor LOS environment——a $9m \times 7m$ meeting room with tables and chairs, and in NLOS environment where two $24cm \times 24cm$ metal boxs are placed between the transmitting antenna and receiving antenna in the same meeting room as shown in Fig.3. The metal boxs are used to intercept the direct desired wave or interference wave from the transmitting antenna to receiving antenna. The desired wave and the interference wave generated by vector signal generators are W-CDMA modulated signals whose data formats are shown in detail in Table 1. A logic analyzer is used to collect the output data from the W-CDMA receiver in a required period of time. Every BER value is calculated at off-line mode from 100,000 bits of sample data which are collected by the logic analyzer. The BER measurement is conducted by fixing the transmitting antennas and turning the receiving array antenna along azimuth angle ϕ with every 30^0 step.

	Desired Wave	Interference
Spread Factor	256	128
Symbol Rate	15 ksps	30 ksps
Spread Code	0	8
data	PN9	Random

TABLE I
SPECIFICATION OF DESIRED WAVE AND INTERFERENCE

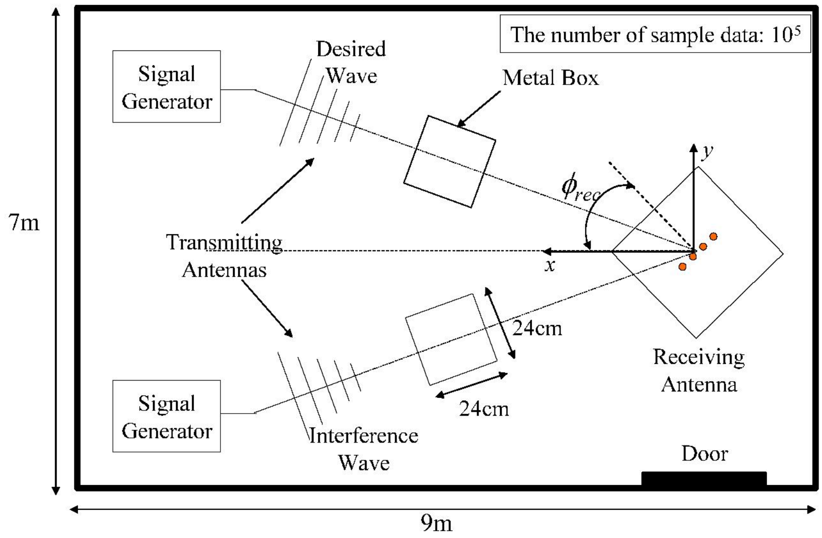


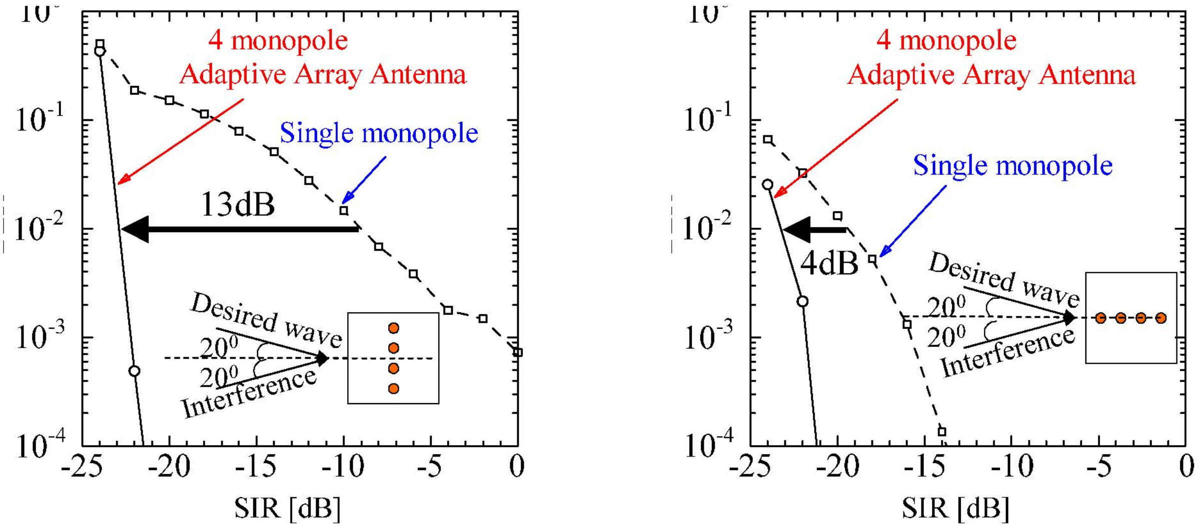
Fig. 3. BER measurement system.

The BERs versus SIR (signal-to-interference ratio) with/without AAA technique when ϕ_{rec} is 0^0 are shown in Fig. 4(a), and those when ϕ_{rec} is 0^0 are shown in Fig. 4(b), where ϕ_{rec} represents the orientation of the receiver array antenna. In these two figures, the measurement is carried out in LOS environment, the arrival angle of desired wave is -20^0 and that of interference is 20^0. BER with single antenna means the BER without AAA technique and is the average value of BERs of four element antennas when they are used individually. The improvement on SIR when BER is 10^{-2} for the case when orientation angle ϕ_{rec} is 0^0 achieves 13dB, while that for the case when ϕ_{rec} is 90^0 only achieves 4dB. It is because when the orientation angle of the receiving array antenna is near to 90^0, the array antenna has the smallest aperture and its pattern in that direction is quite difficult to be adapted.

Since the BER changes with the orientation of the receiving antenna, the mean BER is proposed by averaging all BERs at each orientation along azimuth direction. These results for indoor LOS environment and for indoor NLOS environment are shown in Fig. 5(a) and Fig. 5(b), respectively. Compared with the BER of single monopole antenna without AAA technique, the BER result with AAA technique offers 10dB SIR improvement when BER is 10^{-2} in indoor LOS environment, and 8dB SIR improvement in indoor NLOS environment. All these results support the effective of AAA technique when it is applied to a W-CDMA receiver.

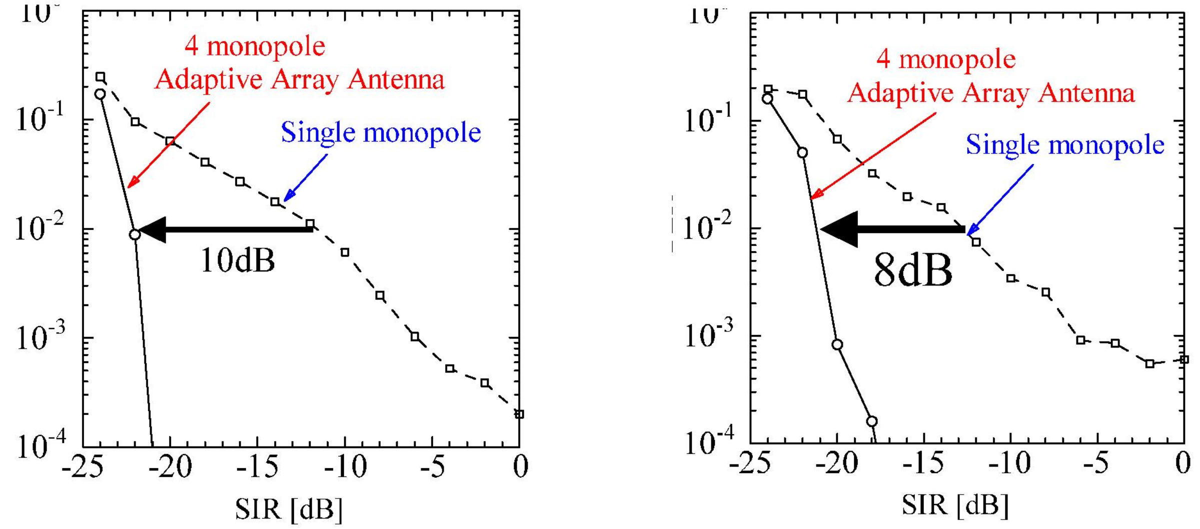
V. CONCLUSIONS

The W-CDMA receiver combined with AAA technique has been developed and used to measure the BER performances for different indoor environments. Since the BER changes with the orientation of the receiving antenna, the mean BER has been proposed by averaging all BERs at each orientation of receiving array antenna along azimuth direction. Compared with the single antenna when BER is equal to 10^{-2}, the experimental results have demonstrated that SIR can be improved by 10dB in indoor LOS environment and 8dB in indoor NLOS environment.



(a) ϕ_{rec} = 0^0 (b) ϕ_{rec} = 90^0

Fig. 4. BER of W-CDMA receiver in LOS environment when SF=256.



(a) indoor LOS environment (b) indoor NLOS environment

Fig. 5. Mean BER of W-CDMA receiver in indoor LOS/NLOS environments when SF=256.

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