Fading Mitigation with Diversity Schemes in WCDMA: Technical Review

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Abstract: Wide Code Division Multiple Access (WCDMA)a third generation wireless communication system that has high bandwidth and offers multimedia communication capabilities for global mobile communications but the performance of WCDMA is degraded with various factors such as interference, fading and scattering. Diversity is a technique which is used to mitigate the fading problem in wireless channel at a relatively low cost .This paper gives the review of different diversity techniques to mitigate the fading problem and for improving the overall performance of the communication system. In different diversity techniques, space diversity technique is an important technique and maximum ratio combining (MRC) is the most effective technique which is a part of space diversity technique.MRC produces an output signal to noise ratio (SNR) equal to the sum of the individual SNRs.

Keywords: WCDMA, Diversity Techniques, Selection Combining, Maximum Ratio Combining

I. INTRODUCTION

Wireless communication is the fastest growth period in the history of communication technologies. Advance Mobile Phone System (AMPS) was the first cellular system. It allocates bandwidth of 60KHzto each user. This allocation consisted of two 30KHz Channels: One is the uplink channel and another is downlink channel [1]. In the AMPS system spectrum is shared amongst users and this technology is called Frequency Division Multiple Access (FDMA) [2]. The first digital cellular phone was standard IS-54. It supported three users in each 30 KHz of bandwidth. Which is used in AMPS system [3].

This improves the users three times per channel along with other advantages such as error-correction and security. This improvement in the number of supportable voice channels was due to speech coding, compression, digital modulation and time Division Multiple Access (TDMA). The multiple access schemes in GSM were TDMA structure that is implemented on multiple frequency sub-bands. Two frequency bands of 25 MHz each at around 900MHz (GSM 900) had been allocated for the use in GSM: 890–915MHz for the uplink and 935-960MHz for the downlink. The GSM system in also operates in the 1800MHz(GSM 1800) frequency band[4]. Each uplink and downlink GSM frequency band was divided into 124 pairs of carriers spaced by 200 kHz and each carrier was divided into 8 time slots using TDMA[5][6]. In CDMA the narrowband message signal is multiplied with a large bandwidth signal that is called the spreading signal. In spread spectrum technique each users is multiply with pseudo-noise code sequence hence increase the bandwidth of users[7]. The pseudo-noise code sequence generates using shift register and repeat after known period. The CDMA system is two types: non-orthogonal and orthogonal. The TDMA, FDMA and orthogonal CDMA all have the same capacity in an additive noise channel[8]. In CDMA, each user uses one of the ten available orthogonal codes that can be transmitted all the time over all of the frequency.[9]. The increasing demand for internet and wireless services such as voice, video and data highlights the need of increase in the capacity of the

system. The 3rd generation partnership project (3GPP) and 3rd generation partnership project two (3GPP2) had developed the wideband code-division multiple access (WCDMA) technologies and CDMA2000 respectively[10].

II. WIDEBAND CDMA

Wideband CDMA (WCDMA) is the second 3Gairinterfacestandard which is based on CDMA. It is an asynchronous scheme and it uses a 5MHz carrier frequency. The use of a wider carrier frequency is to provide high data rates. WCDMA is considered to be wideband technology which is based on the direct sequence spread spectrum transmission scheme. In direct sequence spread spectrum user information bits are spread over a wide bandwidth and user data multiplied with the quasi-random bits called chip. In order to support very high bit rates (up to 2 Mbps), the use of a variable spreading factor and multi code connection is required. In WCDMA the chip rate of 3.84 Mcps leads a carrier bandwidth of 5MHz [11].

2.1 WCDMA KEY FEATURES

The key features of the WCDMA are[12], [13]:
- It provides high service flexibility□□
- It supports the high data rate transmission: 2mbps for local area coverage and 384 kbps for wide area coverage.
- Support of inter frequency hand over and hand over to other systems including hand over to GSM.
- Efficient packet access
- It supports both time division duplex (TDD and frequency division duplex (FDD)

2.2 PROTOCOL ARCHITECTURE

The design of modern wireless networks is based on a layered architecture and each layer is associated with specific functions and communicates with other layers through a particular interface. The advantage of this technique is that each layer can be redesigned without affecting the rest of the layers as long as it keeps the same

interface[14]. Fig.1 shows the radio interface protocol Model. The radio interface protocol architecture of WCDMA consists of the three layers [1].

- Radio physical layer (layer 1, L1)
- Radio data link layer (layer 2, L2)
- Radio network layer (layer 3, L3)

2.3 W-CDMA RADIO PARAMETERS
The main radio parameters that define in WCDMA radio interface are given in Table1 [1]

Fig.1 Radio Interface Protocol Model

Table 1 Radio parameter of WCDMA system[15]

WCDMA		PARAMETERS
Channel bandwidth		5,10, 20 MHz
Chip rate		3.84 *(1,2,4) Mcps
Multiple Access		DS CDMA
Frame length	Variable-rate speech	10 or 20ms
	Packet Data	10-80 ms
Modulation	Spreading	Balanced QPSK (downlink)
		QPSK (Uplink)
		Complex spreading circuit
	Data	QPSK (downlink)
		BPSK (Uplink)
Coherent detection		Pilot Symbol assisted
Channel Coding		Convolutional and turbo coding
Scrambling code		10ms
Interleaving		10/20/40/80 ms
Multirate		Variable spreading and multicode
Spreading factor		4-512
Spreading	Downlink	Variable length orthogonal sequences for channel separation. Gold sequence2¹⁸ for user and cell separation
	Uplink	Variable length orthogonal sequences for channel separation. Gold sequence 241 for user separation
Inter base station timing		Asynchronous

III. PROBLEMS ASSOCIATE WITH WCDMA
When a signal is transmitted from source to destination through the channel, there are some factors which degrade the performance of signal and these degradation factor are discuss here:

3.1 PATH LOSS
In a point-to-point wireless communication system, when a transmitter communicates with a receiver by sending an electromagnetic signal through a wireless medium, the strength of the signal attenuates as it traverses the medium and becomes weaker as the propagation distance increases. Path loss phenomenon is given by following equation[16].

$$P_r = P_0 \left(\frac{1}{4\pi d / \lambda} \right)^2 \left| 1 + a_v e^{j\Delta\Phi} \right|^2 \qquad (1)$$

Where, a_v = the reflection coefficient
$\Delta\Phi$ = the phase difference between a direct path and a reflected path
P_o = the transmitted power
d = the distance
λ = the wavelength

3.2. NOISE
It is an undesired signal in a communication system or unwanted disturbances superimposed on a useful signal which tends to obscure its information content.

3.3 INTERFERENCE
Interference is created due to another mobile in the same cell [17]. It is the major limiting factor in the performance of cellular system. It causes cross talk on voice channel. Interference is more in urban areas, due to the greater RF noise floor and the large number of base stations and mobiles. Co-channel interference and adjacent channel interference are the two types of cellular interference. Co-channel interference (intra-cell) is due to the signal from the other users in the home cell [18]. Co-channel interference is estimated by Carrier-to-interference ratio which is given below [16].

$$\frac{C}{I} = \frac{1}{\sum_{K=1}^{K_I} \left(\frac{D_K}{R} \right)^{-\gamma}} = \frac{1}{\sum_{K=1}^{K_I} (q_k)^{-\gamma}} \qquad (2)$$

Where q_k is the co channel interference reduction factor with *kth* co channel interference cell

$$q_k = \frac{D_K}{R} \qquad (3)$$

Where , D= frequency reuse distance
D= $(3K)^{1/2}$ R   (4)

R= Radius of cell
γ= propagation path loss constant

3.4 FADING
In a typical wireless communication environment multiple propagation paths often exist from a transmitter to a receiver due to scattering by different objects. Signal copies following different paths can undergo different attenuation, distortions, delays and phase shifts. Constructive and destructive interference occurs and if destructive interference occurs, the signal power can be significantly diminished and the phenomenon is called fading [6].In wireless systems, fading may either be due to multipath propagation, referred to as multipath induced fading, or due to shadowing from obstacles affecting the wave propagation, sometimes referred to as shadow fading. In a wireless mobile system a signal can travel from transmitter to receiver through multiple reflective paths which is known as multipath propagation and is illustrated in Fig.2. To overcome the fading effect diversity technique is used[19]. Thus, the idea behind diversity is to send the same data over independent fading paths. These independent paths are combined in some way such that the effect of fading on the resultant signal is reduced.
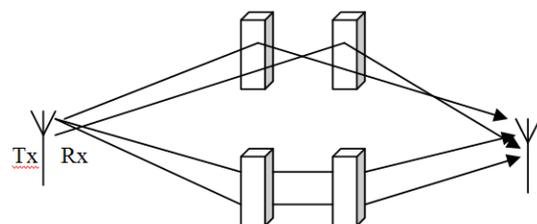
Fig. 2 Multipath Propagation

IV.   ERROR COMPENSATION TECHNIQUES

To remove the error in WCDMA can be used some error compensation techniques such as forward error correction, adaptive equalization, interference cancellation techniques and diversity techniques [20][21].

V.   DIVERSITY

Diversity is the technique which is used to mitigate the fading problem in wireless communications systems due to multipath propagation. In the diversity if one signal path contains a deep fade at a particular point of time, in this condition there is a chance to get the strong signal in the another independent path.[22].

5.1 SIMPLE DIVERSITY TECHNIQUES

The different types of diversity techniques, used in wireless communication systems, are reviewed here:

5.1.1. FREQUENCY DIVERSITY

In frequency diversity the information signal is transmitted over multiple frequency slots and these frequency slots are separated by a bandwidth Δf_c of the channel as shown in Fig.3 [23]. Spread spectrum modulation and orthogonal frequency division multiplexing (OFDM) are the frequency diversity techniques.
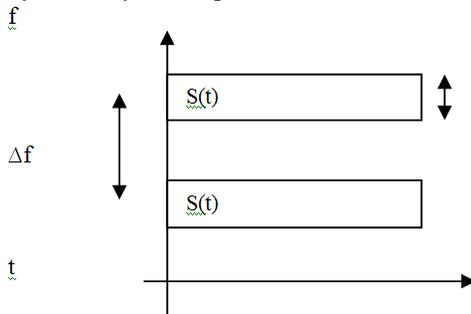
Fig.3 Frequency diversity

When the coherence bandwidth of the channel is larger than the spreading bandwidth or equivalently, then spread spectrum techniques are useless. Xiaoya et.al [24] proposed the complex quadratic spreading sequences to achieve full frequency diversity order through maximum ratio combining (MRC) reception in the frequency domain. Li et.al [25] proposed a frequency diversity technique for blue tooth that used dual channel transmission to deal with both dynamic and static co-channel interferences.

5.1.2. TIME DIVERSITY

In time diversity the same information signal is transmitted in different time slots. The separation between the time slots has to be at least the coherence time Δt_c as shown in Fig 4. The time interval depends on the fading rate and increases with the decrease in the rate of fading[6]. A coding structure known as interleaving is often used to realize time diversity where the receiver knows the code before any transmission takes place. Time interleaving, together with error correction coding can provide diversity improvement[26].
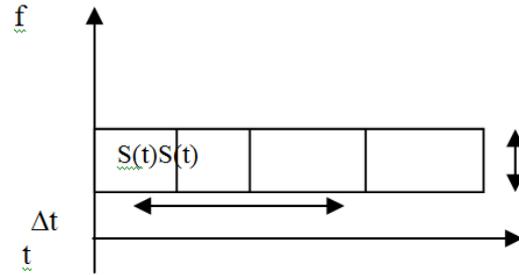
Fig.4 Time diversity

This technique is mostly used in fast fading environment where the coherence time of the channel is small .For slow fading environment, a large time delay is required, which may create significant problems for delay sensitive applications such as voice transmission [27].Awoseyila et.al[28] proposed an improved time diversity technique for short transmission time interval (TTI)and achieve significant time diversity gain in a wideband fading channel without reduction in the user data rate. Papaleo et.al [29].

5.1.3. SPACE DIVERSITY

Antenna diversity technique is also called space diversity. In space diversity two or more antenna can be used at the transmitter or receiver to improve the quality and reliability of a wireless system [30].This technique basically used in urban and indoor area..When signal is effected due to fading this technique is used to remove that fading which is present in the signal due to multipath propagation. When more than two antenna are used at the receiver, this is called receive diversity and more than two antenna are used at the transmitter, is called transmit diversity. Which is shown in Fig. 5 and Fig.6[31],[23].
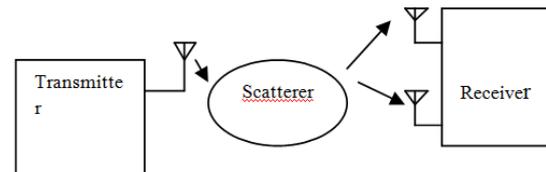
Fig.5 Receive diversity
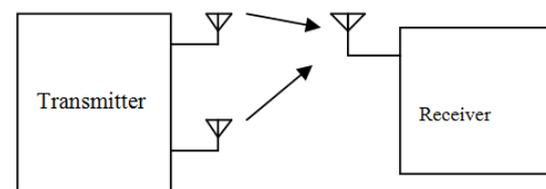
Fig.6 Transmit diversity

In receive diversity the independent fading paths associated with multiple receive antennas are combined to obtain a resultant signal which is passed through a standard demodulator. The major problem with using the receive diversity approach is the cost, size and power of the remote units. The use of multiple antennas and radio frequency (RF) chains (or selection and switching circuits) makes the remote units larger and more expensive. As a result diversity techniques have   been applied to base stations to improve their reception quality. A base station often serves hundreds to thousands of remote units.

Therefore it is more economical to add equipment to base stations rather than the remote units. For this reason transmit diversity schemes are very attractive and in transmit diversity there are multiple transmit antennas with the transmit power divided among these antennas. Transmit diversity is desirable in systems such as cellular systems where more space, power, and processing capability is available on the transmit side[32]. Wittneben et.al[33]proposed a delay diversity scheme for base station simul casting[34]. Seshadri et.al[35]suggested a similar scheme for a single base station in which copies of the same symbol were transmitted through multiple antennas at different times, hence it create an artificial multipath distortion[36]. Alamouti et. Al[32] proposed a new transmit diversity scheme using two transmit antennas and one receive antenna, the new scheme provides the same diversity order as maximal-ratio receiver combining (MRRC) with one transmit and two receive antennas. The disadvantage of space diversity is that it requires significant antenna separation, at least in the very high frequency and lower ultra high frequency bands. In the case where multipath signals arrive from all directions, antenna spacing should be in the order of $.5\lambda$ to $.8\lambda$ for independent or decor related channels.

5.1.4 POLARIZATION DIVERSITY

The space diversity technique is often used in the base station but polarization technique requires two horizontally separated antennas per sector. It contains a dual polarized antenna, in which only one antenna per sector is required shown in Fig[7].The main polarization in the two branches of the antenna system is oriented in the +/- 45 degrees direction or aligned in the horizontal/vertical-0/90 degrees directions [37].
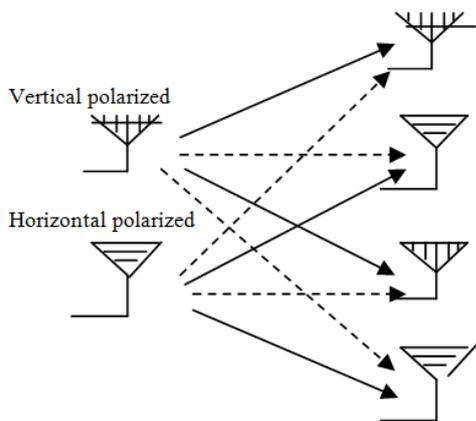
Fig.7 Polarization diversity

In this technology the electric and magnetic fields of the signal carrying the information are modified and many such signals are used to send the same information. Thus orthogonal type of polarization is obtained. Polarization diversity is used as an alternative as the same antenna can be used for different polarizations [38].Smith et.al [39] found that polarization diversity showed a marginally better performance than space diversity for the compact configurations used and it offers a very compact diversity arrangement with good antenna isolation. Buzzi et.al [40] focused on the use of polarization diversity techniques for

multiuser non-orthogonal multipulse modulation and observed that polarization diversity was suitable to improve detection performance in wireless mobile communications. Correal et.al [41] proposed receiver architecture for the uplink of a DS-CDMA system and showed that the effects of flat fading could be significantly mitigated by combining multistage interference cancellation and polarization diversity. Fukushig et.al [42] proposed the analytical method for base station (BS) polarization diversity gain in a WCDMA system. The feature of this method wasthat the diversity gain would be treated as a transmission power value, which increases or decreases when Transmit Power Control (TPC) was applied [43].

5.2 DIVERSITY COMBINING METHODS

Diversity combining methods is used to combine several copies of the transmitted signal, which contain deep fading[44].The three types of diversity combining methods are discussed here [45].

5.2.1 SELECTION COMBINING

In selection combining, the branch that contains the largest signal-to-noise ratio is selected at any time at the receiver from a collection of antennas and the output of the receiver is connected to the demodulator, as shown in Fig.8 [46].
The signal to noise ratio at the input of each diversity branch is the ratio of instantaneous signal power to noise power.

$$SNR_{P_s} = \max\left(SNR_{P_1}, SNR_{P_2}\right) = \max\left(\frac{r_1^2}{N}, \frac{r_2^2}{N}\right) = \frac{1}{N}\max\left(r_1^2, r_2^2\right)$$

$$SNR_{V_s} = \sqrt{SNR_{P_s}} = \max\left(\frac{r_1}{\sqrt{N}}, \frac{r_2}{\sqrt{N}}\right) = \frac{1}{\sqrt{N}}\max\left(r_1, r_2\right)\ (5)$$

Selection combining output in (dB) = $\max\left(SNR_1, SNR_2\right)$
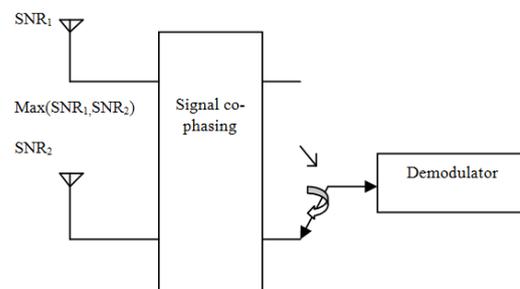
Fig.8 Block diagram of a two-branch selection combining system for equal noise powers in both branch

5.2.2 MAXIMUM RATIO COMBINING

In maximum ratio combining(MRC),each of the branch signals is weighted with a gain factor which is proportional to its own SNR. Then co-phasing and summing is done and summed signal is connected to the receiver and output signal of the receiver is connected to the demodulator. Shown in Fig.9[47]. In a Rayleigh fading channel MRC performance is best followed by equal gain combining and then selection diversity[48].

5.2.3 EQUAL GAIN COMBINING

In Equal gain combining (EGC) the outputs of different diversity branches are first co-phased and equally weighted and after that summing is done and summed signal is connected to the receiver and output signal of the receiver is connected to the demodulator [49].
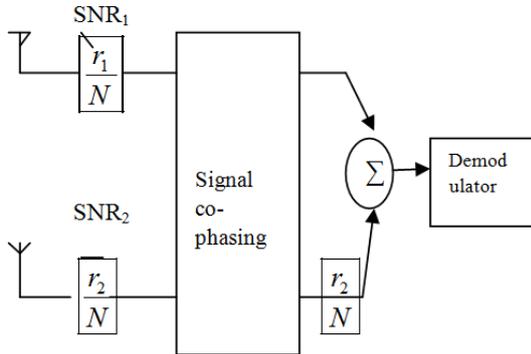
Fig.9 Block diagram of a two-branch maximal ratio combiner for equal noise powers in both branches

$$SNR_{P_M}(t_0) = \frac{r_1(t_0)^2 + r_2(t_0)^2}{N} = \frac{1}{N}\left(r_1(t_0)^2 + r_2(t_0)^2\right) \text{MRC}$$

$$\text{output (dB)} = SNR_1 + SNR_2$$

$$SNR_{V_M}(t_0) = \sqrt{SNR_{P_M}(t_0)} = \frac{1}{\sqrt{N}}\sqrt{r_1(t_0)^2 + r_2(t_0)^2}$$

EGC can be viewed as a special case of MRC which is shown in Fig.10.Ngamjaroen et.al[50] studied the comparison between co-phase and non co-phase EGC diversity techniques and the performance of non co-phase EGC diversity through the problem of limited space on wireless LAN terminal.
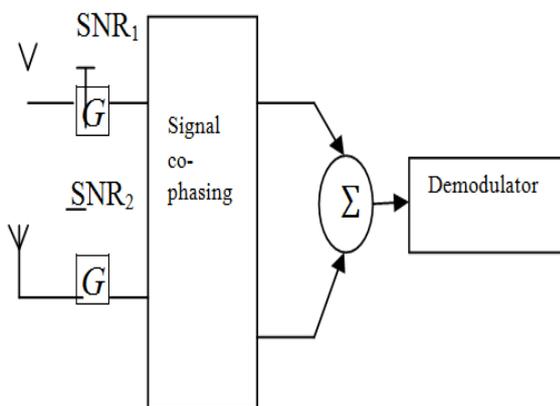
Fig.10Block diagram of a two-branch equal gain combiner for equal noise powers in both branches

$$SNR_{P_E}(t_0) = \frac{1}{2N}\left(r_1(t_0) + r_2(t_0)\right)^2$$

$$\text{EGC output (dB)=}$$

$$0.5SNR_1 + 0.5SNR_2 + \sqrt{SNR_1}\cdot\sqrt{SNR_2}$$

$$SNR_{V_E}(t_0) = \sqrt{SNR_{P_E}} = \frac{1}{\sqrt{2N}}\left(r_1(t_0) + r_2(t_0)\right)$$

VI. CONCLUSION

For high data rate transmission WCDMA is used and but performance of WCDMA is limited by fading and other factors such as interference, scattering etc. Different diversity techniques are used to mitigate fading. In this paper different diversity techniques are reviewed to reduce the fading problem. In all diversity techniques maximum ratio combining is mostly used due to high diversity gain and high signal to noise ratio compare to other diversity techniques.

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