MITIGATION OF CHANNEL FADING IN CDMA20001X NETWORK USING ANTENNA DIVERSITY TECHNIQUE

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ABSTRACT

This paper focuses on the mitigation of channel fading in Code Division Multiple Access (CDMA) 20001x network using antenna diversity technique. During the experimentation, the received signal strength measurement over some distances of 100metres were carried out from a CDMA20001x network. The measurement devices include a TEMS software, Global Positioning System (GPS), *modem, HP Laptop. The field measurement was done for some period of time and the average of the measured data were recorded. The average of data obtained from the field measurement was used in the determination of the pathloss exponent of the investigative network. Also, an empirically propagation model was developed from the measured field data. The implementation of the antenna diversity on the network was done during simulation and the received signal strength was measured again. Result obtained from the field data showed a pathloss exponent of 4.25 while a pathloss exponent of 2.81 was obtained with antenna diversity on the network.*

***Key words**: Antenna diversity, CDMA20001x, pathloss exponent, multipath propagation, Maximum ratio combining technique.*

1.0 INTRODUCTION

In a wireless mobile communication system, the transmitted signals often experience channel fading and time dispersion due to user mobility and multipath propagation (Barry and Messerschmitt, 2009). Channel gain fluctuations can be decomposed into long-term fading and short-term fading. Long term fading is mainly due to shadowing and variations in the distance between the mobile and base station. Long term fading changes with time at a relatively slow rate. Cellular communication systems are mostly interference limited. Mitigation of channel fading by diversity reception can translate into improved interference tolerance which in turn means greater ability to support additional users and therefore greater system capacity (Goldsmit and Varaiya, 2011).

Diversity is a means of combating the effect of multipath fading in a wireless network (Rappaport, 2009). There are many diversity schemes which are used in practice. These include frequency diversity, time diversity and space or antenna diversity (Brennan, 2014). In frequency diversity, the desired message is transmitted simultaneously over several frequency slots. The separation between adjacent frequency slots should be larger than the channel coherence bandwidth such that channel fading over each slot is independent of that in any other slot. By using redundant signal transmission (i.e. frequency diversity) the transmission link quality is improved though at the cost of extra frequency bandwidth. In time diversity, the desired message is transmitted repeatedly over several time periods. The time separation between adjacent transmission should be larger than the channel coherence time such that the channel fading experienced by each transmission is independent of the channel fading experienced by all of the other transmissions. In addition to extra system capacity (in terms of transmission time) due to the redundant transmission, this diversity introduces significant signal processing delay especially when the channel coherence time is large.

Antenna diversity transmits the desired message by using multiple transmitting antennas and/or receiving antennas. The space separation between adjacent antennas should be large enough to ensure that the signals from different antennas are independently faded. This diversity does not require extra system capacity. Antenna diversity is used to compensate for the effect of long-term fading (Bjerke et al., 2014). However, the cost of extra antenna is a disadvantage.

Maximum ratio combining is one of the antenna diversity techniques used in the reduction of multipath fading in wireless network (James, 2009). Maximal Ratio Combining (MRC) is the most effective of the combining techniques because it presents at the output of the receiver a SNR that is the direct sum of all individual SNR's in the branches. The analysis of antenna diversity using Two-Branch maximal ratio combining technique is shown in figure 1.

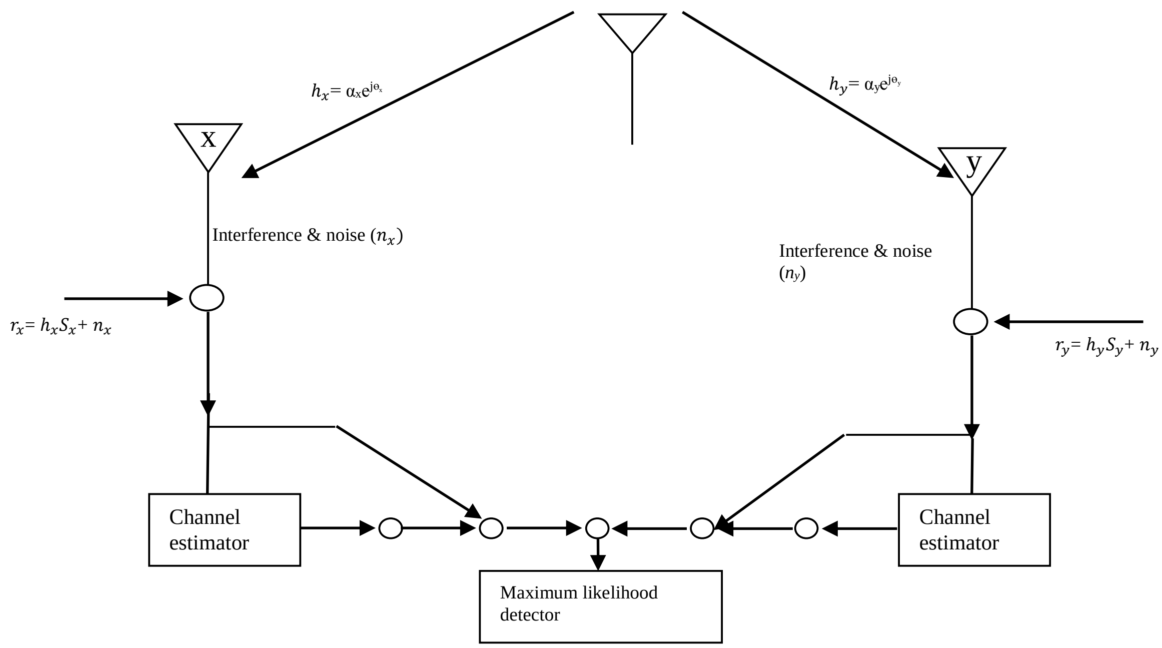

Figure 1. Baseband representation of the classical two-branch MRC

Source: Cox (2010)

Figure 1 shows the baseband representation of a typical two-branch maximal ratio combining. The mathematical analysis of the two branch maximal ratio combining is as follows:

Let the channel between the transmit antenna and receive antenna x be denoted by h_x and the channel between the same transmit antenna and receive antenna y be denoted by h_y. These channels at time,t, can be modelled by a complex multiplicative distortion $h_x(t)$ for receiver antenna x and $h_y(t)$ for receiver antenna y. Thus, the channels $h_x(t)$ and $h_y(t)$ are given by the expressions:

$$h_x(t) = h_x = \alpha_x e^{j\theta_x} \quad (1)$$

$$h_y(t) = h_y = \alpha_y e^{j\theta_y} \quad (2)$$

It is observed that as the signals $s_x, and\ s_y$ transverse these channels, noise and interference are added to the signals reaching the two receivers x and y. Therefore, the resulting received baseband signals on the x and y antennas are expressed as:

$r_x = h_x\ s_x + n_x$ (3)

$r_y = h_y\ s_y + n_y$ (4)

Where

s_x are the signals reaching the antenna x and antenna y respectively. Also, n_x and n_y represent receiver noise and interference on the x and y channels respectively. Assuming n_x and n_y are Gaussian distributed, the maximum likelihood decision rule at the receiver for the received signals is to choose signal if and only if:

$$d^2(r_x, h_x\ s_i) + d^2(r_y, h_y\ s_i) \le d^2(r_x, h_x\ s_k) + d^2(r_y, h_y\ s_k) \quad (5)$$

But, the expression d^2(x, y) is the squared Euclidean distance between signals x and y and is expressed as follows:

$$d^2(x, y) = (x-y)\,(x^*- y^*) \quad (6)$$

Therefore, the receiver combining scheme, $\hat{S}_o$, for two branch MRC is determine as follows:

$$\hat{S}_o = h_x^* r_x + h_y^* r_y \quad (7)$$

Substituting the values of r_x and r_y into equation (17)

$$\hat{S}_o = h_x^*(h_x\ s_x + n_x) + h_y^*(h_y\ s_y + n_y) \quad (8)$$

$$\hat{S}_o = (\alpha_x^2 + \alpha_y^2) S_x + h_x^*\ n_x + h_y^*\ n_y. \quad (9)$$

Expanding equation (19) and using equation (15) and (16), we choose the highest signal, S_i, if and only if :

$$(\alpha_x^2 + \alpha_y^2)|\ S_i|^2 - \hat{S}_o S_x{}^* - S_x{}^* S_i \le (\alpha_x^2 + \alpha_y^2)|\ S_k|^2 - \hat{S}_o S_k{}^* - S_x{}^* S_k, \text{ for } i \ne k \quad (10)$$

For Phase Shift Key (PSK) signals (equal energy constellations)

$$|\ S_i|^2 = |\ S_k|^2 = E_s \quad (11)$$

Where E_s is the energy of the signal. Therefore, for PSK signals, the decision rule in equation may be simplified to choose S_i if and only if:

$$d^2(\hat{S}_o, S_i) \le d^2(\hat{S}_o, S_k), \text{ for } i \ne k \quad (12)$$

2.0 MATERIALS AND METHOD

2.1 Materials

Determination of the Pathloss Exponent of the Propagation Channel

Pathloss occurs when the received signal becomes weaker and weaker due to increasing distance between the mobile station and base station. The extent to which signal degradation occurs in a communication channel can be known by determining the pathloss exponent of the environment (Kumar, 2011). Therefore, pathloss exponent, n, of an environment shows the variation of signal loss in an environment. The pathloss exponent and the received signal strength obtained from field measurement can be used to completely characterize a propagation environment under consideration. The mean path loss, $P_L(d_i)$ [dB] at a transmitter receiver separation, d_i, is given by ((Rappaport, 2009):

$$P_L(d_i)\ [\text{dB}] = P_L(d_0)\ [\text{dB}] + 10n \log_{10}\left(\frac{d_i}{d_o}\right) \quad (13)$$

Where n = pathloss exponent, $P_L(d_0)$ = pathloss at known reference distance d_0.

For free space model *n* is regarded as 2 and the pathloss exponent of urban cellular environment is in the range 2.7 to 4.0 (Alor M., 2015). The free-space model however is an over idealization, and the propagation of a signal is affected by reflection, diffraction and scattering. These effects are environment (indoors, outdoors, rain, buildings, etc) dependent. However, it is accepted on the basis of empirical evidence that it is reasonable to model the pathloss, $P_L(d_i)$ at any value of *d* at a particular location as a random and log-normally distributed random variable with a distance-dependent mean value as shown in equation (14):

$$P_L(d_i)\ [\text{dB}] = P_L(d_0)\ [\text{dB}] + 10n \log_{10}\left(\frac{d_i}{d_o}\right) + S \quad (14)$$

Where *S*, the shadowing factor is a Gaussian random variable with values in deciBel (dB). The path loss exponent, *n*, is an empirical constant which depends on propagation environment.

In order to determine the pathloss coefficient, *n,* of the test bed environment, equation (1) can be used to manually compute it as:

$$n = \frac{\{P_L(d_i) - P_L(d_0)\}}{10log_{10}\left(\frac{d_i}{d_0}\right)}. \quad (15)$$

But, using linear regression, the value of *n* can be determined from the measured data by minimizing total error R^2as follows (Azubogu A.C.O.,*et al.,* 2011):

$$R^2 = \sum_{i=1}^{M}\left[P_L(d_i) - P_L(d_0) - 10nlog_{10}\left(\frac{d_i}{d_0}\right)\right]^2. \quad (16)$$

Differentiating equation (4) with respect to *n*,

$$\frac{\partial R^2(n)}{\partial n} = -20log_{10}(d)\sum_{i=1}^{M}\left[P_L(d_i) - P_L(d_0) - 10nlog_{10}\left(\frac{d_i}{d_0}\right)\right] \quad (17)$$

Equating $\frac{\partial R^2(n)}{\partial n}$ to zero,

$$0 = -20log_{10}(d)\sum_{i=1}^{M}\left[P_L(d_i) - P_L(d_0) - 10nlog_{10}\left(\frac{d_i}{d_0}\right)\right] \quad (18)$$

$$\sum_{i=1}^{M}[P_L(d_i) - P_L(d_0)] - 10nlog_{10}\left(\frac{d_i}{d_0}\right) = 0 \quad (19)$$

$$\sum_{i=1}^{M}[P_L(d_i) - P_L(d_0)] - \sum_{i=1}^{M}\left[10nlog_{10}\left(\frac{d_i}{d_0}\right)\right] = 0. \quad (20)$$

$$\sum_{i=1}^{M}[P_L(d_i) - P_L(d_0)] = \sum_{i=1}^{M}\left[10nlog_{10}\left(\frac{d_i}{d_0}\right)\right] \quad (21)$$

Therefore, $n = \frac{\sum_{i=1}^{M}[P_L(d_i) - P_L(d_0)]}{\sum_{i=1}^{M}\left[10log_{10}\left(\frac{d_i}{d_0}\right)\right]}$. (22)

Equation (22) can be used in determining the pathloss exponent, n, of the test bed environment which is essential in characterizing the propagation environment.

2.2 Method

Figure 2 shows a framework used for data collection during the experimentation. First, the TEMS investigation software (Dingli Panorama) was loaded on the HP Laptop. The measuring equipment used include Samsung x 199 which is the Mobile Station (MS), Global Positioning System (GPS), Modem (Visafone network), General Packet Radio Service (GPRS) equipment, digital street map. All these measuring equipment were connected to the computer via Universal Serial Bus (USB) port. The Dingli Panorama software helped the modem to be operated on the 3G network such as the Visafone network. The Visafone network is a CDMA20001x carrier and also the investigative network. The specifications of the CDMA20001x investigative network include: Transmitting Frequency: 800MHz, base station height: 36m, Minimum transmit power:-50dBm, Maximum Power: 20W, Noise Figure:8dB, Interference Margin:5.5dB. After connecting all equipment to the computer and loading the Map and the cell file on the TEMS application, the measurement of the received signal strength over some distances of 100m intervals were carried out during drive test. At all measurement point, the GPS shows the location on TEMS with support for navigation and movement at the site. The cell file usually contains the coordinate of the site but one can take the coordinates on site to confirm the location of the test-bed.

Figure 2. Measurement Equipment

3.0 RESULTS AND DISCUSSION

3.1. Results

The result obtained during the measurement periods is shown in Table 1 while the pathloss model obtained from the measured field data and pathloss model obtained with antenna diversity is showed in Table 2. Also, the graphical presentation of the average result obtained from field data is shown in figure 2. The comparison of the result obtained from field data and simulation is shown in figure 3

.

Table 1: Received Signal Strength (RSS) carried out on Visafone Network

D(m)	RSS (dBm)	RSS (dBm)	RSS (dBm)	RSS (dBm)	RSS (dBm)	RSS (dBm)	RSS (dBm)	RSS (dBm)	RSS (dBm)	RSS (dBm)	AVERAGE RSS (dBm)
100	-68.21	-68.10	-67.94	-67.50	-68.10	-68.00	-67.84	-67.89	-68.30	-67.52	-67.94
200	-74.50	-73.75	-74.50	-73.75	-75.05	-73.80	-73.75	-73.70	-75.05	-73.75	-74.16
300	-87.25	-87.24	-87.00	-88.00	-84.05	-87.000	-87.36	-87.00	-86.50	-87.00	-86.84
400	-87.50	-88.00	-85.50	-87.25	-87.00	-87.25	-88.00	-84.90	-87.40	-87.10	-87.04
500	-90.53	-92.25	-91.50	-93.00	-90.53	-91.50	-93.00	-90.53	-92.00	-91.56	-91.64
600	-100.00	-99.24	-99.45	-99.07	-99.10	-99.25	-99.50	-99.27	-99.17	-99.05	-99.33
700	-104.00	-103.25	-103.24	-103.25	-104.00	-103.00	-102.66	-102.65	-102.60	-102.65	-103.13

Table 2: Path loss model obtained from field data when conventional antenna is in use and pathloss model when antenna diversity is employed on CDMA20001x network.

Distance from Tx [m]	Field data pathloss: $(L_p(d_i) = 94.74 + 42.5\text{Log}(d_i))$	Antenna diversity pathloss - $(L_p(d_i) = 94.74+28.1\text{Log}(d_i))$
100	94.74	94.74
200	107.53	103.20
300	115.02	108.14
400	120.33	111.66
500	124.45	114.38
600	127.81	116.61
700	130.68	118.48

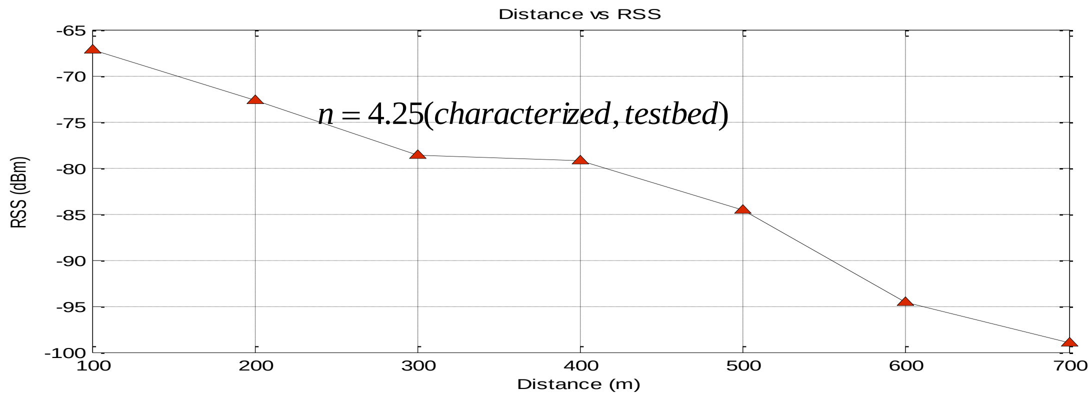

Figure 3. Field data measurement of received signal strength over 100 metres interval distances

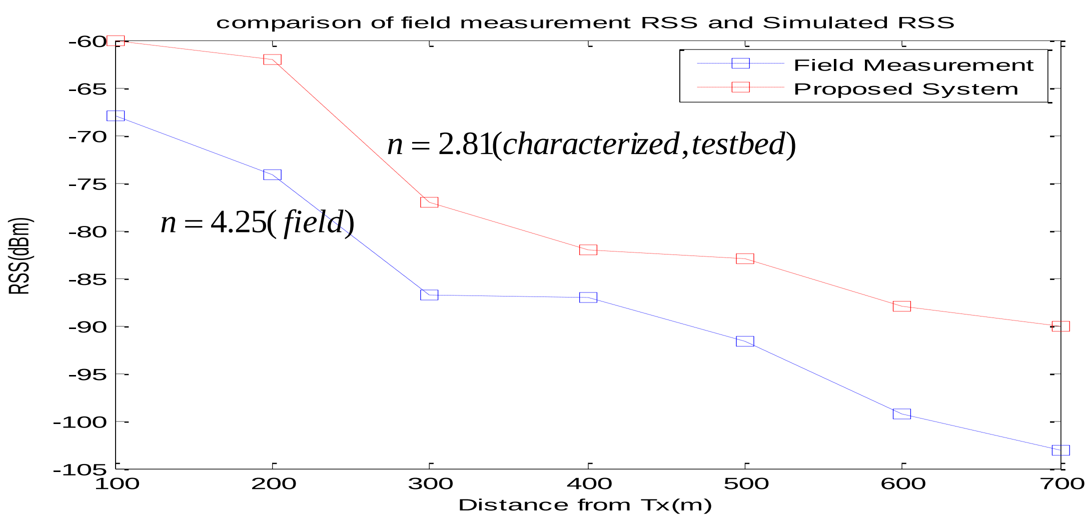

Figure 4. Field path loss exponent (without antenna diversity) compared with pathloss exponent with antenna diversity.

3.2 Discussion

Figure 2, the data obtained from the field measurement of received signal strength showed that as the distance from the cell site increases the signal quality depreciates. But, the extent of signal degradation can be determined by the pathloss exponent. But, for cellular CDMA network, a pathloss exponent in the range of 2.7 to 4.0 shows a satisfactory network . Figure 2 shows a pathloss exponent of 4.25 which implies that the signal quality obtained on the network in the said environment is strongly affected by channel fading.

Figure 3, it is observed that the pathloss exponent obtained with antenna diversity is 2.81 unlike that obtained without antenna diversity which is 4.25. The pathloss exponent of 2.81 shows that the rate at which signal losses occur in the investigative network is lesser and also the network can perform optimally since the pathloss exponent obtained when antenna diversity is used on the network falls within the standard threshold for urban cellular environment compared to the pathloss exponent of 4.25.

5.0 CONCLUSION

This paper has shown that channel fading can be mitigated on the CDMA 20001x network using antenna diversity. Thus, in using antenna diversity, deep channel fades are absent and limited amount of transmitted power is enough to compensate for fading. The technique does not require any feedback from the receiver to the transmitter. Therefore, mitigation of channel fading by diversity reception can translate into improved interference tolerance which in turn means greater ability to support additional users and therefore greater system capacity.

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