A Study on Bi-orthogonal Modulation for W-CDMA Higher Bit Rate Transmission

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ABSTRUCT

This paper studies a modulation method for a Wideband Code Division Multiple Access (W-CDMA) system in order to enhance its performance. The modulation method studied here introduce bi-orthogonal modulation instead of multicode transmission in order to suppress the envelope variation which comes from code division multiplexing in multicode transmission. Bi-orthogonal modulation studied here selects a single code in both in-phase and quadrature components, and leads to relaxation of the requirement of HPA linearity. And this relaxation enhances to implement mobile station (MS) with smaller size or lower power consumption. Computer simulation results show that power level of spurious emission in adjacent channel is reduced by approximately 8dB with use of bi-orthogonal modulation, with keeping the required E_b/I_0 almost the same as multicode transmission.

T. INTRODUCTION

Next generation mobile communication systems are required to deal with multimedia communication services that transmit various kind of data with bit rates being from low rate to much higher rate, to use frequency resource with high efficiency. As direct sequence W-CDMA is recognized to satisfy such requirement, this technology is regarded as one of the most promising technologies for IMT-2000 systems, so that there are lots of studies on this technology [1]-[4]. A W-CDMA system shown in [5]-[8] manages variable rate transmission using either single code or multicode depending on bit rate. When it is lower than a specific rate, single code transmission is used. When it is equal to or faster than a specific rate, multicode transmission is used. Multicode transmission adopts code division multiplexing using plural short codes and common long code. Short code is used for channel separation. Long code is used for spreading spectrum.

Multicode transmission can achieve higher bit rate with spreading factor larger than a specific value in order to keep benefit of spread spectrum communication. On the other hand, considering hardware implementation, it requires high power amplifier (HPA) with highly linear characteristics especially on mobile station (MS). That is, higher bit rate transmission requires larger transmission power than lower bit rate data in order to keep a required E_b/I_0. In addition, multicode transmission causes envelope variation due to codes multiplexing. HPA nonlinearity causes not only increase of out-of-band spurious emission, which results in adjacent channel interference, but also BER degradation due to nonlinear distortion. Consequently, the linearity of HPA with higher output power and wider dynamic range is indispensable. However, these kind of HPA result in more cost, or difficulty for MS implementation with smaller size or lower power consumption.

In order to solve the difficulty mentioned above, we propose to introduce bi-orthogonal modulation instead of multicode transmission. In section 2, the modulation scheme is described. In section 3, performances of the bi-orthogonal modulation are given by computer simulation. And section 4 gives a conclusion.

U MODULATION SCHEME

A. Multicode Transmission

Fig. 2.1 shows a multicode transmission scheme [6]. For reverse link, this scheme is used at MS transmitter. In case of multicode transmission, there are plural code channels that are separated by short code. Information data input of 10msec frame is divided into k code channels by a serial-to-parallel (S/P) converter. Each divided data is input to the FEC and slot mapping unit. This unit consists of many functions; convolutional encoding, interleaving, mapping to slot, and inserting pilot bits accompanied with transmission power control (TPC) bits with the aid of time multiplexing.

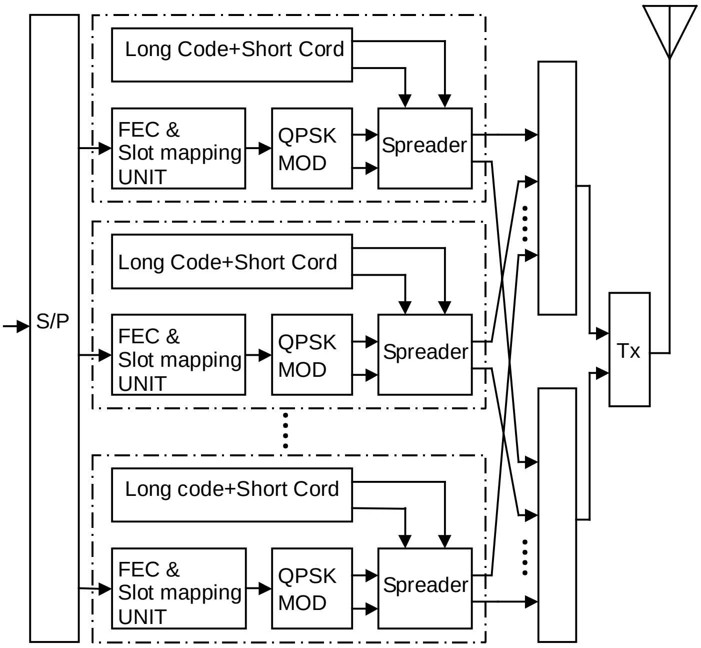


Figure 2.1 Multicode Transmission Scheme

As these bits are commonly used among code channels in reverse link, insertion of pilot and TPC bits is done for the first code channel only. The other code channels do not transmit any bit in this duration. QPSK modulator makes QPSK symbol from the output of the FEC and slot mapping unit by S/P converter. Next, QPSK spreader using in-phase and quadrature spreading codes spreads QPSK symbol. Each spreading code is generated from an orthogonal short code and long codes for in-phase and quadrature component. Finally, the output of each QPSK spreader are added, where it causes envelope variation, and then transmitted to the base station (BS).

B. Bi-orthogonal Modulation

Fig.2.2 shows the bi-orthogonal modulation scheme studied here. In Fig.2.2 (a), the configuration is the same as multicode transmission up to QPSK modulator. The output of QPSK modulator is separately fed to two bi-orthogonal modulators, which are corresponding to in-phase and quadrature components. Each bi-orthogonal modulator selects one of the bi-orthogonal codes corresponding to combination of the input data, where bi-orthogonal codes are polarized orthogonal codes. Namely, orthogonal code (short cord) is used for modulation instead of code multiplexing in multicode transmission. As for pilot bits and TPC bits, bi-orthogonal modulation is not applied. They are only passed through this modulator. At the demodulator, received signal is demodulated to detect transmitted bi-orthogonal code.

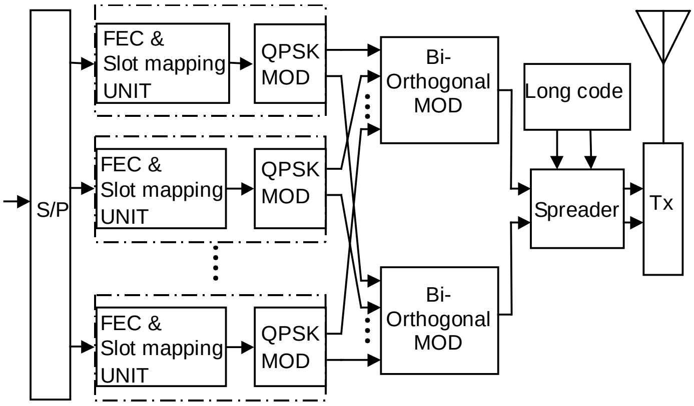
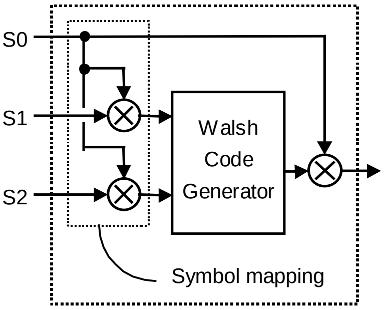


Figure 2.2(a) Bi-orthogonal Modulation Scheme



S0 S1 S2	Bi-orthgonal
+1 +1 +1	+W4(0)
+1 +1 –1	+W4(1)
+1 –1 +1	+W4(2)
+1 –1 –1	+W4(3)
–1 +1 +1	–W4(3)
–1 +1 –1	–W4(2)
–1 –1 +1	–W4(1)
–1 –1 –1	–W4(0)

Figure 2.2(b) Bi-orthogonal Modulator (k=3)

The detailed scheme of bi-orthogonal modulator is shown in Fig.2.2 (b). The orthogonal code used here is Walsh code. When k bits are put into the modulator, the first bit determines the polarity of the selected orthogonal code. The first bit is also put into the symbol mapping function. Another bits are also put into the symbol mapping function. In the mapping function, each bit is multiplied by the first bit. The outputs of the symbol mapping function are put into Walsh code generator. This symbol mapping is very similar to Gray mapping in QPSK modulation. With this function, two groups of input bits having complementary relationship select the same Walsh code but with opposite polarity, as also shown in Fig. 2.2(b) in the case of k=3.

V. PERFORMANCE EVALUATION

A. Conditions for Computer Simulation

Performance of W-CDMA system using bi-orthogonal modulation is evaluated by computer simulation. Simulation conditions are shown in Table 3.1 for power spectral density (PSD) and Table 3.2 for required E_b/I_0. Fig. 3.1 shows input-output characteristics of HPA used for this simulation. The HPA is developed for a 1.5GHz mobile phone.

B. Performance of power spectrum density

Fig. 3.2 shows PSD of W-CDMA signals with the parameter of k. For an operating point of output power back-off (OBO) =6dB, we can see that adjacent channel interference

Table 3.1 Simulation Conditions for PSD

Parameter	Condition
Evaluation Link	up link
Chip Rate	4.096 Mcps
Data Modulation	Multicode QPSK / Bi-orthogonal QPSK
Spreading Modulation	QPSK
Spreading Code	Long (Gold 2^{42}-1) code + Short (Walsh) code
Spreading Factor	16 chip/symbol
Number of Multicodes (k)	1,2,3,4 (= number of coded symbols beared by a Bi-orthogonal signal)
User Data Rate	128 - 512 kbps (k x 128 kbps : k = 1,2,3,4)
QPSK Symbol Rate	256 - 1024ksps (k x 256 ksps : k = 1,2,3,4)
Low Pass Filter	Square Root Nyquist Filter(Roll-off 0.22)
HPA Characteristics	HPA Developed for 1.5 GHz Mobile Phone (See Fig 3.1)

Table 3.2 Simulation Conditions for Required E_b/I_0

Parameter	Condition
Evaluation link	up link
Chip Rate	4.096Mcps
User Data Rate	128k - 512kbps (k x 128 kbps : k = 1,2,3,4)
FEC	Convolutional(R=1/3,K=9)
Antenna Diversity	2branch Space Diversity
Rake	4finger/branch
Channel	Vehicular Channel A
TPC	Ideal Closed Loop, 1dB step, command with 1.6kbps
Viterbi Decoder Input	Hard Decision Input
HPA Characteristics	HPA Developed for 1.5GHz Mobile Phone
OBO	6 dB

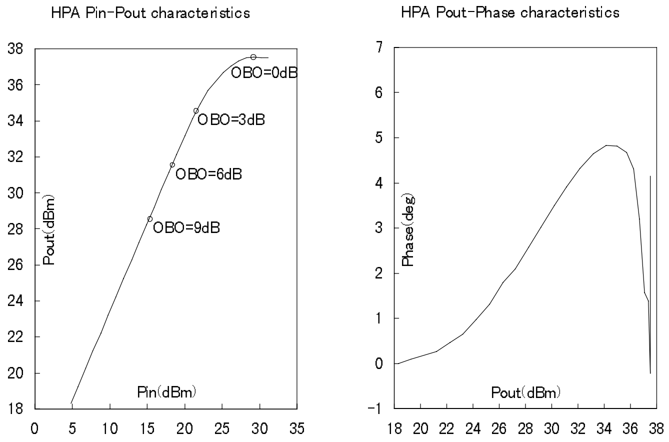


Figure 3.1 HPA characteristics

can be effectively reduced using bi-orthogonal modulation, that has the same PSD as multicode transmission with k=1.

For example, at the center frequency of adjacent channel (5MHz separation point), interference level of bi-orthogonal modulation is reduced by approximately 8dB. Fig. 3.3 and Fig. 3.4 show PSD with the parameter of OBO for bi-orthogonal modulation and multicode transmission (k=4). In these figures we can see that the bi-orthogonal modulation limits a maximum level of interference to approximately 40dB at the 5MHz separation point. On the other hand, this result is not achieved by multicode transmission (k=4) even with OBO 9dB.

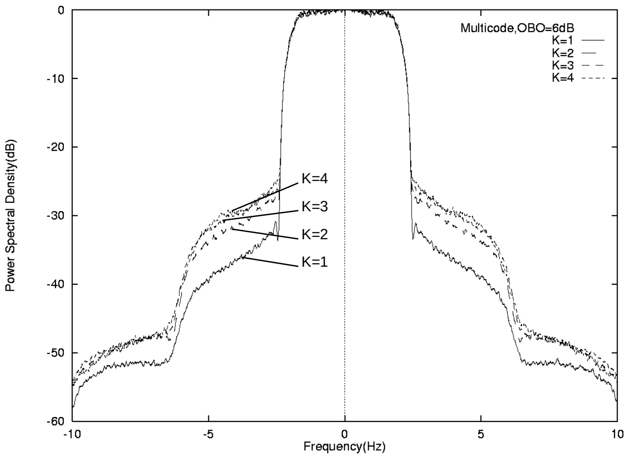


Figure 3.2 Power Spectral Density comparison at OBO=6dB

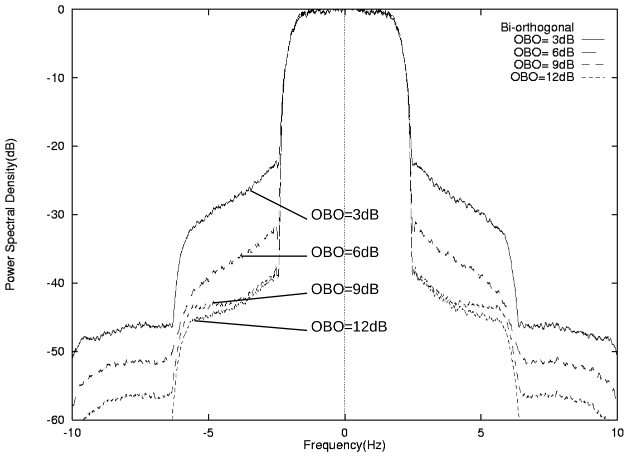


Figure 3.3 PSD for Bi-orthogonal Modulation

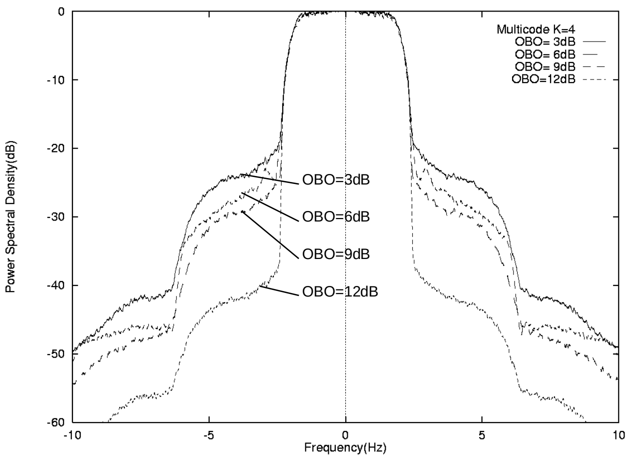


Figure 3.4 PSD for Multicode Transmissions(K=4)

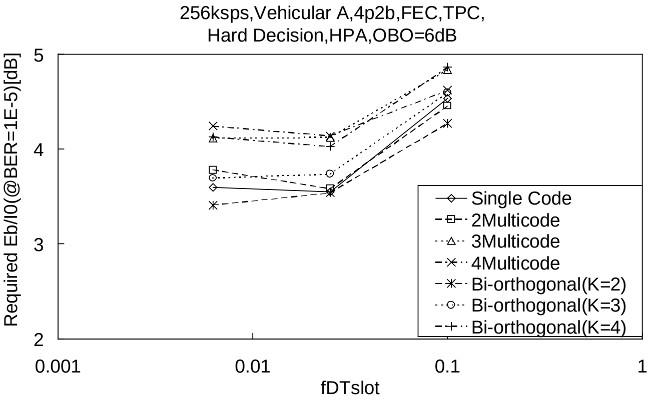


Figure 3.5 Performance Comparison over Multipath Fading Channel(Vehicular

C. Required E_b/I_0 Performance

Required E_b/I_0 per branch for BER=10^{-5} are evaluated for performance comparison considering HPA characteristics near saturation (OBO=6dB) under Vehicular Channel A [9]. Fig. 3.5 shows the results with parameter k. Better performance should not be expected with bi-orthogonal modulation for low SIR (coded signal to interference Power ratio). Namely, introducing a convolutional encoder with r=1/3 reduces coded signal power by 4.8dB. In low SIR region, BER improvement might not be expected theoretically, especially for large number of k. For k=4, both systems have almost the same performance. For k=2 and 3, the required E_b/I_0 of bi-orthogonal modulation is better than that of multicode transmission by a factor of 0.2 to 0.4dB. These results show that required E_b/I_0 per branch for BER=10^{-5} for bi-orthogonal modulation is almost the same as multicode transmission. Considering the hardware complexity, and performance degradation with large number of k, it is convenient using k being equal to or less than 4.

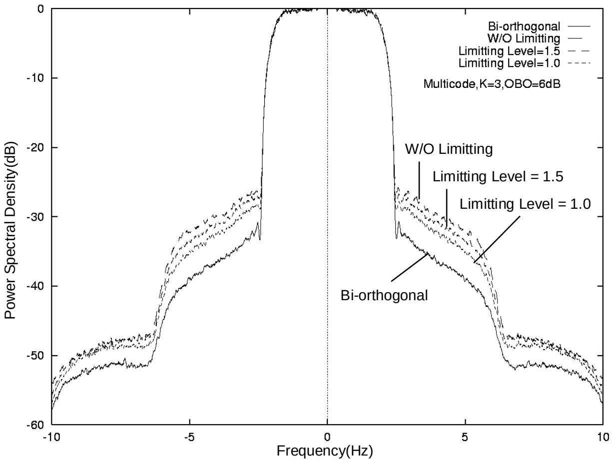


Figure 3.6 Impact of Peak Power Limitation on PSD(K=3)

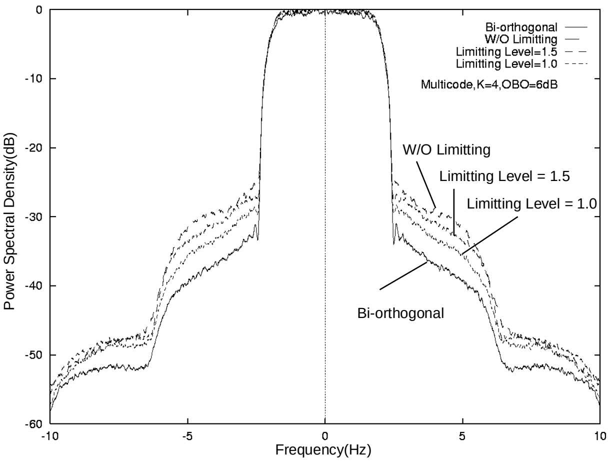


Figure 3.7 Impact of Peak Power Limitation on PSD(K=4)

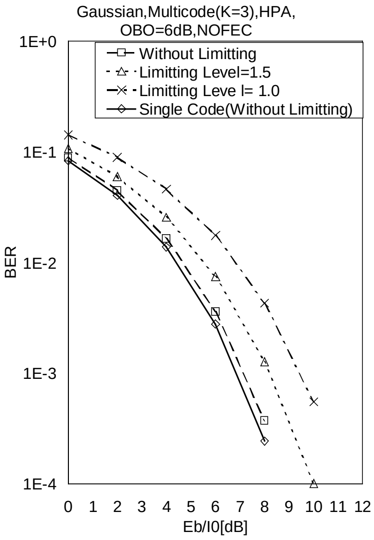


Figure 3.8 Impact of Peak Power Limitation on BER(K=3)

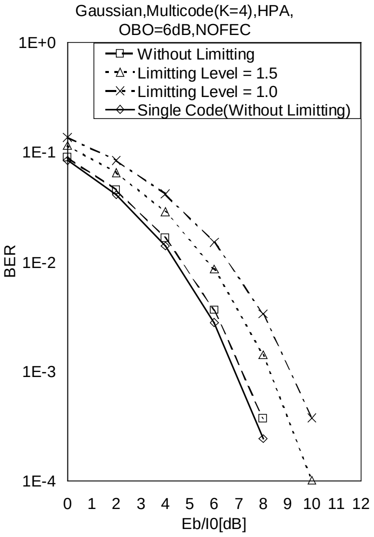


Figure 3.9 Impact of Peak Power Limitation on BER(K=4)

D. Performance of Multicode Transmission with Peak Power Limitation

One of the solutions to relax the requirement of HPA linearity in case of multicode transmission is peak power limitation before baseband low pass filter [10]. This limitation may degrade the performance of multicode transmission in terms of BER performance even on additive white Gaussian noise (AWGN) channel. The parameter newly introduced here is limiting level, which indicates peak-to-average power ratio before the low pass filter. As shown in Fig. 3.6 and Fig. 3.7, out-of-band spurious emissions can be effectively suppressed using sufficient peak power limitation on the multicode transmission signal. However Fig. 3.8 and Fig. 3.9 show that the limitation seriously degrades BER performance. It means that it is difficult for multicode transmission to keep good BER performance with small out-of-band spurious emission. In multicode transmission systems, highly linear HPA, which is very expensive, should be introduced in order to keep sufficient linearity. On the other hand, bi-orthogonal modulation can keep the envelope constant so that cheaper HPA can be applied which can realize lower cost, lower power consumption and smaller terminals.

Ⅳ CONCLUDION

This paper studied bi-orthogonal transmission for high bit rate transmission in order to enhance the performance of W-CDMA system. This method is applicable with only minor modification to a system proposed before. Computer simulation results show that the out-of-band spurious emission is reduced while BER performance is the same as multicode transmission. Optimization of soft decision method for metric calculation in the Viterbi decoding is a further study.

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