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CDMA vs. OFDM- Comparison and Hybrid OFDM- the Solution for the Next Generation

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***Abstract*— This paper investigates the effectiveness of OFDM and proven in other conventional (narrowband) commercial radio technologies (e.g. DS-CDMA in cell phones) (e.g. OFDM in IEEE 802.11a/g). The main aim was to assess the suitability of OFDM as a modulation technique for a fixed wireless phone system for rural areas. However, its suitability for more general wireless applications is also assessed. Most third generation mobile phone systems are proposing to use Code Division Multiple Access (CDMA) as their modulation technique. For this reason, CDMA is also investigated so that the performance of CDMA could be compared with OFDM on the basis of various wireless parameters. At the end it is concluded that the good features of both the modulation schemes can be combined in an intelligent way to get the best modulation scheme as a solution for wireless communication high speed requirement, channel problems and increased number of users.**

***Index Terms*— CDMA, OFDM, PN Sequence, Peak Power Clipping.**

I. INTRODUCTION

As far as the multiple user access is concerned we have FDMA, TDMA and CDMA, these three are very well known schemes which shares the available bandwidth to multiple users in wireless systems. There are many extensions and hybrid techniques for these methods, such as OFDM and hybrid TDMA-FDMA. CDMA and OFDM both are wide-band wireless digital communication systems in general. CDMA is a spread spectrum technique that uses neither frequency channels nor time slots. With CDMA, the narrow-band messages (typically digitized voice data) are multiplied by a large band width signal that is a unique pseudo random noise code (PN code). All users in a CDMA system use the same frequency band and transmit simultaneously with different codes. The transmitted signal is recovered by correlating the received signal with the PN code used by the transmitter.

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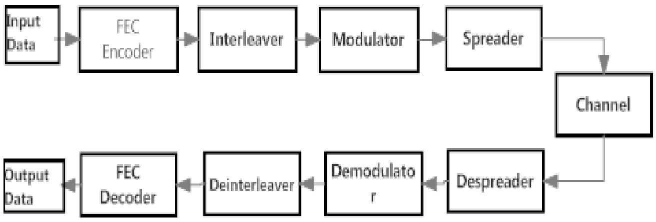

Fig. 1 CDMA Basic Block Diagram

orthogonal frequency division multiplexing (ofdm) is a multi-carrier modulation-transmission technique, which divides the available spectrum into many carriers, each one being modulated by a low rate data stream. ofdm can be similar to FDMA in that the multiple user access is achieved by subdividing the available bandwidth into multiple channels allocated to users. However, OFDM uses the spectrum much more efficiently by spacing the channels much closer together. This is achieved by making all the carriers orthogonal to one another, preventing ICI.

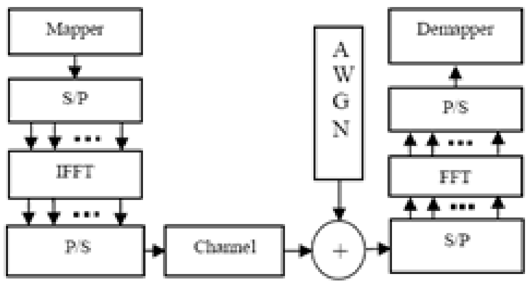

Fig. 2 OFDM Basic Block diagram.

It is found that OFDM performs extremely well compared with CDMA, providing a very high tolerance to multi-path delay spread, peak power clipping and channel noise. OFDM is found to have total immunity to multi-path delay spread provided the reflection time is less than the guard period used in the OFDM signal. In a typical system a delay spread of up to 100 msec could be tolerated, corresponding to multi-path reflections of 30 kms. Considering cellular base, CDMA.

capacity is limited by multiple access interference (MAI), which results from the imperfection of auto and cross-correlation characteristics of spreading codes. Although, zero cross correlated orthogonal codes could result in no MAI in flat fading channels, the orthogonality will not be guaranteed in frequency selective fading channels because of inter chip interference, which will cause MAI and degrade the system performance.

Though CDMA is very good as far as security aspects are concerned, it is found to perform poorly in a single cellular system. Typically, with each cell allowing only10-20 simultaneous users in a cell compared to 128 users for OFDM.

Some other performance comparison is shown below.

II. MULTIPATH DELAY SPREAD PERFORMANCE

To eliminate ISI the guard period insertion is done in OFDM. For a delay spread that is longer than the effective guard period, BER rises rapidly due to ISI. The maximum BER will occur when the delay spread is greater than the symbol time. See Fig. 3

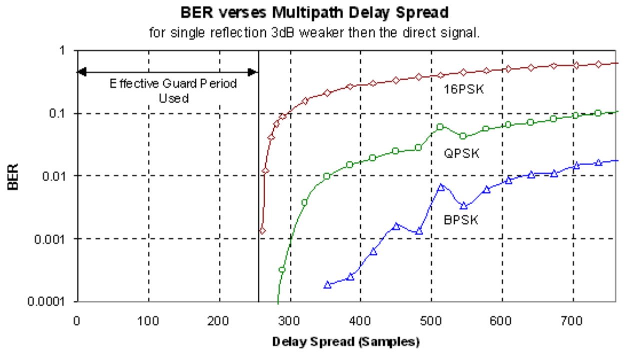

Fig. 3 Delay Spread tolerance of OFDM

As shown in Fig.4 CDMA is inherently tolerant to multi-path delay spread signals as any signal delayed by more than one chip time becomes uncorrelated to the PN code used to decode the signal. This results in the multi-path simply appearing as noise. This noise lead to an increase in the amount of interference seen by each user subjected to the multi-path and thus increases the received BER

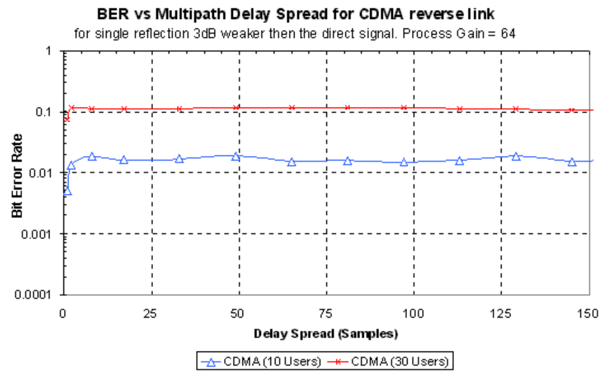

Fig.4 Effect of multi-path delay spread on the reverse link of a CDMA system

III. PEAK POWER CLIPPING PERFORMANCE

If a transmission technique is tolerant to peak power clipping (allows signal power to be clipped), reduces the peak to RMS signal power ratio thus allowing the signal power to be increased for the same sized transmitter. The transmitted OFDM signal could be heavily clipped with little effect on the received BER. Refer Fig.3. In fact, the signal could the clipped by up to 9 dB without a significant increase in the BER. This means that the signal is highly resistant to clipping distortions caused by the power amplifier used in transmitting the signal. It also means that the signal can be purposely clipped by up to 6 dB so that the peak to RMS ratio can be reduced allowing an increased transmitted power. In CDMA, according to Fig. 4, for the reverse link the BER starts high initially due to inter-user interference. The peak power clipping of the signal has little effect on the reverse link because the extra noise due to the distortion is not

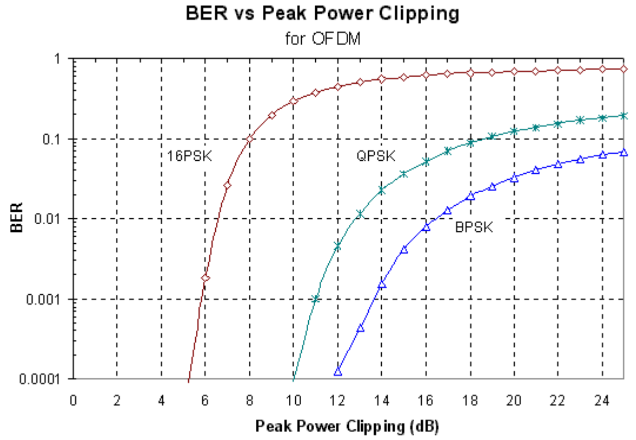

Fig.5 Effect of peak power clipping for OFDM

Very high compared with the inter-user interference, plus any added noise is reduced by the process gain of the system. Peak power clipping for the reverse link is also likely to be small, as clipping would only ever occur due to distortion in the base station receiver, as this is the only point where all the signals are combined. A well-designed receiver is unlikely to cause significant clipping of the signal. The forward link result is more important as significant clipping of the transmitted signal could occur at the base station transmitter. The result for the forward link is completely different to the reverse link. The peak power clipping tolerance of the forward link is very similar to OFDM. The BER is low for clipping of less than 10 dB.

IV. GUASSIAN NOISE TOLERANCE

SNR performance of OFDM is similar to a standard single carrier digital transmission. This is expected, as the transmitted signal is similar to a standard FDM, though it is with closely placed orthogonal multiple carriers. Using QPSK the transmission can tolerate SNR>10-12 dB.

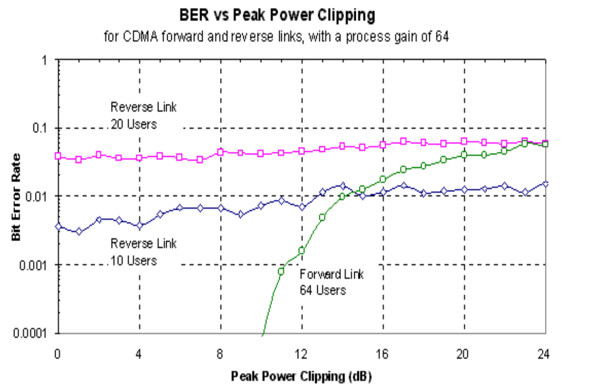

Fig.6 Effect of peak power clipping on the BER for the forward and reverse links of CDMA.

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BER gets rapidly poor as the SNR drops below 6 dB. However, BPSK allows BER to be improved in a noisy channel, at the expense of transmission data capacity. Using BPSK the OFDM transmission can tolerate SNR >6-8 dB. If a low noise link and SNR>25 dB, 16PSK mapped OFDM can increase the transmission data capacity.

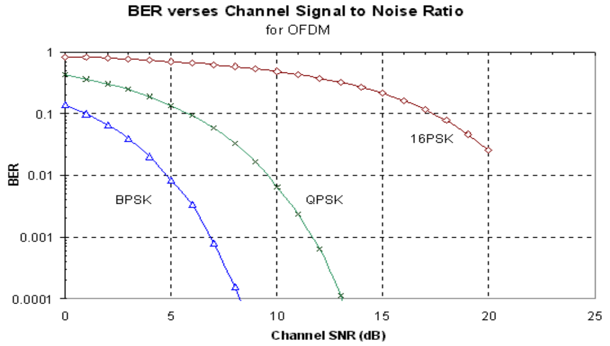

Fig. 7 BER vs SNR for OFDM using BSPK, QPSK and 16PSK

The noise performance of the CDMA reverse link shows that the BER rises as the SNR of the channel worsen. Due to the high level of inter-user interference. The BER of each of the lines (10, 20, 30 users) approaches approximately the same BER at a SNR of 0 dB. At 0 dB the effective noise of the channel is the same as adding 60 users to the cell, thus the difference between 10, 20 and 30 users becomes insignificant. The BER is very bad for more than 10 users regardless of the channel SNR. However, for 10 users the BER becomes greater than the 0.01 (SNR of ~14 dB), which is the maximum BER that can be normally tolerated for voice communications. Refer Fig. 8

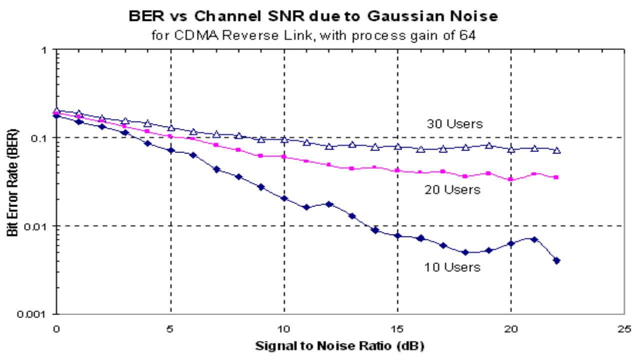

Fig. 8 BER verses the radio channel SNR for the reverse link of a CDMA system.

V. DRAWBACKS

The problems associated with OFDM is frequency selective fading, which results in carriers being heavily attenuated due to destructive interference at the receiver. This may result in the carriers being lost in the noise. Another weak point is it is very sensitive to frequency and phase errors between the transmitter and the receiver. The main sources of these errors are frequency stability problems, phase noise of the transmitter and any frequency offset errors between the transmitter and the receiver, due to moving-mobiles and Doppler Effect. This may lead to error in finding the start time of the FFT symbol. This problem can be overcome by synchronizing the clocks between the transmitter and the receiver, by designing the system appropriately or by reducing the number of carrier used. The noise performance of OFDM is found dependent on the modulation technique used for mapping each carrier of the signal. The performance of the OFDM signal is found to be the same as for a single carrier system, using the same modulation-mapping. The minimum SNR required for BPSK is ~8 dB, where for QPSK ~12 dB and for 16PSK ~25 dB is the SNR requirements for better performance same is for OFDM. OFDM signal is contaminated by non-linear distortion of transmitter power amplifier, because it is combined amplitude-frequency modulation and it is necessary to maintain the linearity.

The main problem associated with CDMA is near-far problem, limited users in a cell and complex rake receiver design.

VI. SOLUTIONS

After studying the various advantages and disadvantages of both CDMA and OFDM systems, the good issues of both the systems can be combined as the OFDM-CDM transmission technique, where the information is to be transmitted is spread over several OFDM sub-carriers. Arbitrary orthogonal codes can be used for spreading. The effect of this additional measure is that narrow-band fading is avoided. This can be seen as frequency diversity effect. Thus, at high code rates, an OFDM-CDM system performs better than a pure OFDM system.

The combined CDMA systems with OFDM can be mainly categorized into three types.

1) *MC/DS-CDMA (Multi-carrier Direct Sequence CDMA)*:

In this scheme the serial-to-parallel converted data symbols are DSSS modulated using a specific spreading code and these signals are transmitted in parallel on different sub-carriers or in other words spreading in the time domain leads to narrow-band sub-channels in frequency domain . It is guaranteed that there is no MAI in the synchronized down link in a cell in slow frequency selective fading channels.

2) *MC-CDMA (Multi-carrier CDMA):*

In this scheme multiple copies of the same data symbol each multiplied by one chip of a user specific spreading code are transmitted on different sub-carriers in parallel maintaining the orthogonality in frequency domain. Since the replicas of the same data symbol are transmitted on different sub-carriers, frequency diversity can be achieved to eliminate frequency selective fading but MAI may occur especially in the downlink.

3) *OFCDM (Orthogonal Frequency Code Division Multiplexing):*

It is originally based on MC-CDMA scheme. It comprises many multi-path interference occurring in such broadband channel by employing many low symbol rate sub-carriers and by making full use of the frequency diversity effect using the spread and coded signals over parallel sub-carriers. Although OFCDM achieves better throughput performance in a broadband channel, it suffers from the degradation caused by inter-code interference due to loss of orthogonality among code multiplexed channels. So dispreading the signal in

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frequency domain is a key technique in order to compensate for the destruction of orthogonality

However, if multi-path is not eliminated properly, equalization and dispreading in the receiver lead to noise amplification. For this reason the puer OFDM system performs better at low code rates were sufficient frequency diversity is provided by the code. However, the performance of OFDM-CDM systems can be improved with more sophisticated detection methods like iterative dispreading and decoding. A major disadvantage of OFDM-CDM systems is the fact that coherent detection is required, so channel estimation and equalization cannot be avoided.

If a Fourier matrix is used for spreading in an OFDM-CDM system then spreading and the IFFT at the transmitter cancel each other, resulting the single-carrier transmission system with a guard interval results. At the receiver, the signal processing can be interpreted as frequency domain equalization, with the additional advantage that the transmitted signal does not have the typical amplitude peaks of an OFDM signal. Thus, it seems to be reasonable to use the Fourier matrix for spreading if spreading is to be applied at all.

VII. CONCLUSION

OFDM is found to perform very well compared with CDMA, with its out-performing CDMA in many areas for a single and multi-cell environment. OFDM is found to allow up to 2 - 10 times more users than CDMA in a single cell environment and from 0.7 - 4 times more users in a multi-cellular environment. The difference in user capacity between OFDM and CDMA is dependent on whether cell sectorization and voice activity detection is used. It was found that CDMA only performs well in a multi-cellular environment where a single frequency is used in all cells. This increases the comparative performance against other systems that require a cellular pattern of frequencies to reduce inter-cellular interference.

One important major area, which hasn't been investigated here, is the problems that may be encountered when OFDM is used in a multi-user environment. One possible problem is that the receiver may require a very large dynamic range in order to handle the large signal strength variation between users. However, COFDM with forward error correction may solve many problems improving the BER.

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