International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 2 Issue 10, October-2013, pp: (85-89), Available online at: www.erpublications.com

High Speed Transmission by QAM-WCDMA Modulation

Amit K Dutta
JIS College of Engineering, Kalyani, WB, India

Abstract: A very high speed wireless data communication in the range of 1 Gb/s is required for next generation (4G) mobile communication systems. This paper addresses the problems and solutions associated with that need. A scheme called Decision Feedback Cancellation along with optimum adaptive process is discussed which offers an increase in capacity by ten folds over existing system without increase in noise. This is done by QAM-WCDMA modulation method.

Keywords- Gigabit, QAM, WCDMA, DFC, Wireless Communication and BCH Code.

I. Introduction

Wireless communication is evolving according to advancement in wireless technology. Recent demand in research is for high speed data transmission nearing 1Gb/s rate in the wireless indoor and outdoor local area networks [1][2]. Designing very high speed wireless links that offers good quality of services in absence of line of sight communication offers a significant research and engineering challenge. 1 Gb/s transmission means the bandwidth (measured in Hz) and spectral efficiency (measured in bits/sec/Hz) product reaches a billion. In this article we find Wideband Code Division Multiple Access (WCDMA) as the solution to the problem along with a QAM modulation scheme. In absence of fading this is sufficient to meet the goal of a billion bits/second, though the A/D design in baseband will be complicated which is not discussed here.

Direct Sequence Code Division Multiple Access (DS-CDMA), which is the main point of focus, is one of the most promising technology of twentieth century for cellular telecommunications services. The advantages of DS-CDMA include improved cellular capacity and superior performance in Multi-path environments. The capacity increase for voice transmission is roughly ten folds than frequency division multiple access and time division multiple access. Normally speech is not continuous [3] and we talk roughly 3/8 of the time. So for CDMA we get a capacity increase by 8/3. Moreover if we use Decision Feedback Cancellation scheme along with adaptive detector we get a capacity increase by ten. In case of data communication we get a theoretical equation of Shannon's Capacity theorem $C=B \log_2(1+P/BN)$, where C is the capacity, B is bandwidth, P is average power and N is noise. Now if we increase B to 10 by QAM-WCDMA, the noise variance increases by 16 (equivalent) and there is a noise reduction to 0.0625 (considering shifted m-sequence). Also we may take P=2 because there is a compression. If we consider QAM-WCDMA, the capacity will be more than ten times. Moreover CDMA technology is most suited because it has "bandwidth on demand" multimedia application and soft handoff.

Recently it has been found that Multicarrier Code Division Multiple Access is expected to be the best among all other code division multiple access schemes [1]. However, MC-CDMA requires IFFT in modulation and FFT in demodulation scheme which are computationally complicated. So we choose a Synchronous CDMA for Downlink and TDM-Synchronous CDMA for Uplink. Moreover, we like to compress data and transmit QAM signal. So the overall transmission will be QAM-synchronous WCDMA [4].

The organization of the paper is as follows. Section II introduces the transmitter [5] and in the Section III the channel model is described. In Section IV we discuss about the demodulation structure – De-correlating Detector. In the Section V we describe about the Decision Feedback Cancellation (DFC) scheme and DFC based adaptive scheme. Section VI is about Trellis Coded Modulation [6][7] to improve the performance of QAM Modulation and Section VII about the system of TCM Coded QAM-WCDMA scheme and we conclude the paper in the next Section.

II. Modulation

Figure 1 illustrates the QAM-WCDMA transmitter [4]. At the transmitter, after the binary data is BCH channel encoded and interleaved, the encoded data sequence is transformed into serial to N parallel bits. In each parallel bit, 5 bits are converted into a Pulse Amplitude Modulated symbol. So it will be a PAM signal modulated by a spreading sequence which will be a shifted m-sequence. Here we choose a pseudorandom sequence of length 31. This allows parallel 31 bits to be transmitted at the same time. We choose 32 levels PAM modulation in in-phase and quadrature-phase streams. So the transmitted bits are 2 * 31 *5*5 *0.645*10^6 for a bandwidth of 20 MHz i.e. 31*0.645 MHz. We can put 5N parallel paths with a delay of 0,T_c/4,T_c/2 and 3T_c/4. We can scale down the data rate.

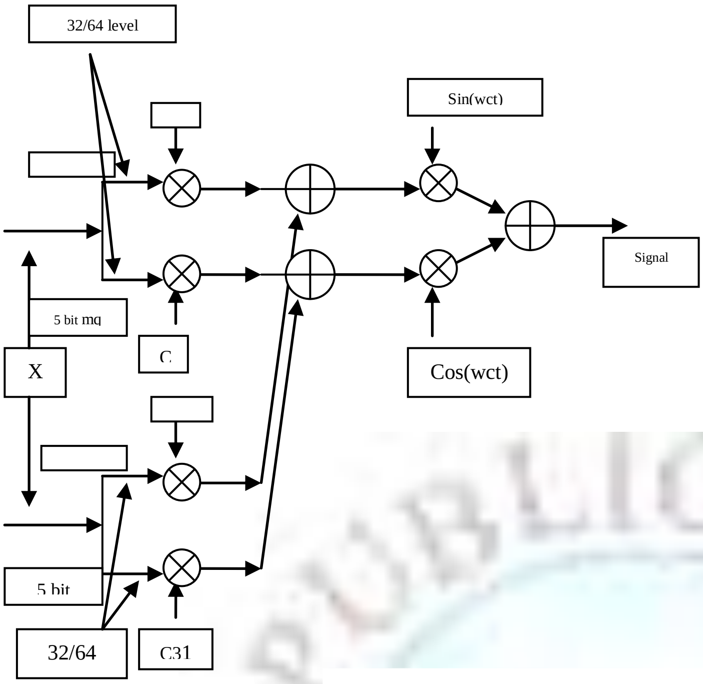

Figure.1 Modulator for QAM-WCDMA which has 31X2 data input for I and Q branches.

Mathematically, the synchronous WCDMA transmitted signal in baseband is given by:

$$r = \sum_{k=1}^{N} b_k C_k$$

Where b_k is the bit in kth parallel path and C_k is the spreading shifted m-sequence in kth parallel path. N is the total number of parallel paths.

For QAM-WCDMA the transmitted signal will be

$$S(t) = \left(\sum_{k=1}^{N} A_k C_k\right)\cos w_c t + \left(\sum_{k=1}^{N} B_k C_k\right)\sin w_c t$$

Where A_k and B_k are the PAM signal for 5 bits in parallel paths.

III. CHANNEL MODELLING

Here we assume that if the bandwidth-delay spread product of the channel satisfies B*□$_{max}$ >=0.1 the channel is generally said to be frequency selective [2]. Now for our case the channel is 20/40 MHz of bandwidth and the maximum rms delay spread is 1 microsecond at the frequency of 4.6 to 5 GHz[1]. So the channel is frequency selective. We consider the channel has impulse response as given by

$$h[n] = h_1\delta(n) + h_2\delta(n-\tau) + h_3\delta(n-2\tau) + \ldots\ldots\ldots$$

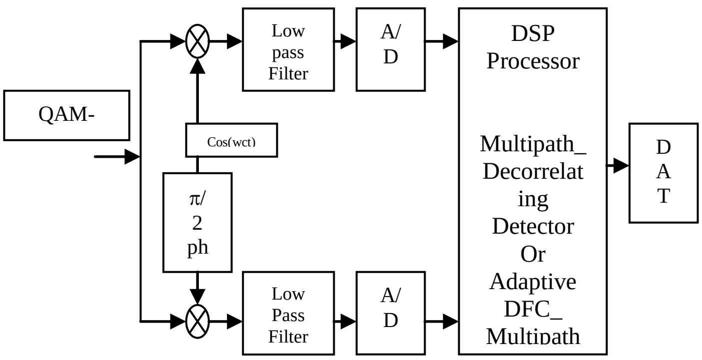

Figure 2: Demodulator for QAM-CDMA modulated signal.

International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 2 Issue 10, October-2013, pp: (78-84), Available online at: www.erpublications.com

Where h_1, h_2 , h_3 has an exponential profile and the τ is the delay between two adjacent paths. h_1, h_2, h_3…. varies with a given statistics but remain constant for small variation in time.

IV. DEMODULATION – DECORRELATING DETECTOR

Figure 2 shows the demodulator structure for QAM-WCDMA modulated signal. The DSP processor implements the multiuser detector in in-phase and quadrature phase. In this section we consider de-correlating detector [9] for multipath spread. The multipath delays coefficients, that is, h_1, h_2, h_3 are known by transmitting a m-sequence for a bit period and receiving it over two/three bit periods [10]. We assume two multipath, so the in-phase baseband signal will be given by

$$r_I(n) = h_1 \sum_{k=1}^{N} A_k C_k(n) + h_2 \sum_{k=1}^{N} A_k C_k(n-\tau)$$

For two parallel paths and two multipath spread, the de-correlating detector will be

$$\begin{bmatrix} r_I C_1^t \\ r_I C_2^t \end{bmatrix} = \begin{bmatrix} h_1 + h_2 C_1(n-\tau) C_1^t & h_1 C_2 C_1^t + h_2 C_2(n-\tau) C_1^t \\ h_1 C_1 C_2^t + h_2 C_1(n-\tau) C_2^t & h_1 + h_2 C_2(n-\tau) C_2^t \end{bmatrix} \begin{bmatrix} A_1 \\ A_2 \end{bmatrix}$$

So we can find A_1 and A_2 the PAM signals.

V. DECISION FEEDBACK CANCELLATION AND ADAPTIVE DFC

Figure 3 shows the single stage of Decision Feed Back Cancellation scheme [11][12]. It has been reported [8] that interference cancellation has been used for QAM-WCDMA. Here we estimate the signal strength for each parallel path, re-spread it and subtract from incoming signal to form residue. Estimation is done by correlating the signal with the C_k. The estimation of the signal strength is done by adding signal of all DFC stages for each parallel path.

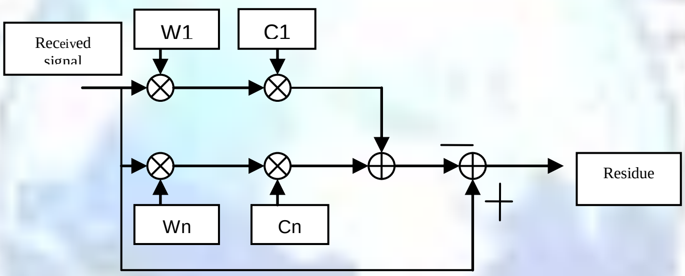

Figure 3: Single Stage of Decision Feedback Cancellation Scheme

.

The advantage is it is accurate as we increase the number of DFC stages.
Assume, there are two users without multipath spread, the received signal is given by

$$r = a_1 C_1 + a_2 C_2 + \eta$$

Where, a_1 and a_2 are the signal strength of path 1 and path 2 with their spreading sequences C_1 and C_2. Noise is given by η.
The estimation of the signal of path 1 with three stages of DFC

$$\hat{a}_1 = a_1 - a_1 C_1 C_2^t C_2 C_1^t C_1 C_2^t C_2 C_1^t / N_1^2 N_2^2$$

With a noise term,

$$\sigma = \frac{\eta}{N_1}\left\{ C_1^t - \frac{C_2^t C_2 C_1^t}{N_2} + \frac{C_1^t C_1 C_2^t C_2 C_1^1}{N_1 N_2} - \frac{C_2^t C_2 C_1^t C_1 C_2^t C_2 C_1^1}{N_1 N_2^2} \right\}$$

So, we find that the noise variance reduces.

In adaptive DFC scheme, we solve the Wiener-Hopf equation to get the tap coefficients w_k and use the coefficients to correlate and estimate strength in each path. The optimum coefficients are found by using reference [13], where it was found for asynchronous CDMA. For synchronous QAM-WCDMA with two multipath spread, let there be two parallel paths and two multipath h_1 and h_2 with a time delay of τ, the received signal in baseband is

$$r = h_1 A_1 C_1 + h_2 A_1 C_1(n-\tau) + h_1 A_2 C_2 + h_2 A_2 C_2(n-\tau)$$

But to find the tap coefficients we consider a single bit instead of PAM signal. Then the received signal is

$$r = h_1 b_1 C_1 + h_2 b_1 C_1 (n-\tau) + h_1 b_2 C_2 + h_2 b_2 C_2 (n-\tau)$$

So the Weiner-Hopf equation is $\mathbf{w}^* = R^{-1} p$

Where $R = E\{r^t r\}$.
So,

$$R = h_1^2 C_1^t C_1 + h_2^2 C_1^t(\tau) C_1(\tau) + h_1 h_2 C_1^t(\tau) C_1 + h_1 h_2 C_1^t C_1(\tau)$$

$$+ h_1^2 C_2^t C_2 + h_2^2 C_2^t(\tau) C_2(\tau) + h_1 h_2 C_2^t(\tau) C_2 + h_1 h_2 C_2^t C_2(\tau)$$

And $p = h_1 C_1 + h_2 C_1(\tau)$

We know that for synchronous CDMA the dimension is N and it is N even when the multipath is present. But convergence in adaptive DFC scheme is possible for less than 2N users. So we get a capacity increased to twice (that is 2N). We can use QAM and increase the capacity five times. So, overall capacity is increase more than 5 folds. In I and Q phase we get the increase to ten folds. We find the adaptive coefficients by using DFC block which is much faster.

VI. TRELLIS CODED MODULATION FOR PAM SIGNAL

Traditionally, coding and modulation are considered as two separate parts of a digital communication systems [6][7]. The input message bits are first channel encoded (extra 1 bit is added) and then these encoded bits are converted into an analog waveform by modulator. Both these blocks are optimized separately. A higher performance is obtained in trellis coded Modulation (TCM) for PAM where it is possible to get coding gain without bandwidth expansion by integrating the encoder with modulator [7].

Here we use Ungerboek TCM modulator for PAM signal [6]. Here the modulator is five bits for 4 bits PAM signal. We also propose a method of protecting the bits as given in reference [14] so that the signal is protected against phase reversal. It is like a scheme used for Differential Phase Shift Keying. We take X-NOR on the incoming data with the previous data bits in parallel. We expect to get a gain associated with X-NOR operation.

Like convolutional code, TCM schemes are described by using trellis diagram. Any input sequence to a TCM encoder gets encoded based on trellis diagram. The task of the TCM decoder is to find the path which is closest or most likely depending on maximum likelihood criteria. This is done by Viterbi Decoder.

VII. SYSTEM MODEL

Figure 4 is a block diagram of the end-to-end system under investigation [6]. Input bits representing data are passed through an encoder (BCH code) and then block interleaved (here it is 31 X 31). Then in parallel 31 bits are sent and serially they are grouped by 4 bits to get the trellis encoder. The output of trellis encoder is 5 bits and in each bit we put an

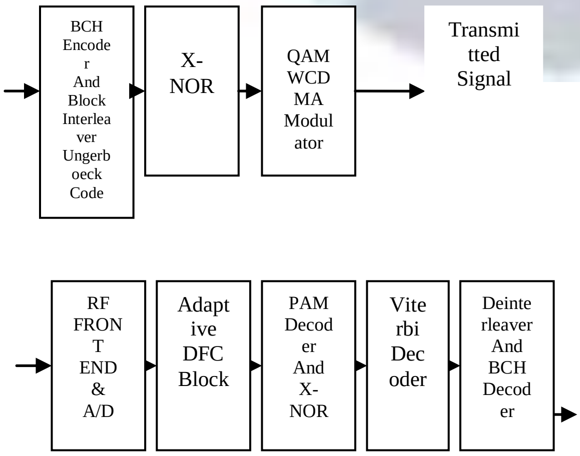

Figure 4: System overview of transmitter and receiver

X-nor logic to get rid of the phase reversal. Then we put it through the signal set (0-31) to get the PAM signal. Then it is spread by code and added to get the signal which is modulated. Signal in PAM modulator is shown in Figure 5.

At the receiver, the faded signal is converted to baseband signal and sent through a 9/10 bits 80 Msps A/D in I and Q phase. Then at Adaptive DFC stage we estimate the signal in each 5x31 parallel paths, convert them to digital signal from PAM signal, x-nor the output and feed them to Viterbi Decoder. Then 5x31 parallel signals are de-interleaved and fed to the channel decoder.

VIII. CONCLUSION

In this article we discussed a broadband wireless scheme which allows a Giga bit/s transmission. The downlink is Synchronous QAM-WCDMA and uplink is TDM-QAM-WCDMA. The uplink shares the time like in GSM avoiding asynchronous QAM-WCDMA. We showed that a subtractive interference cancellation scheme named DFC scheme is better as number of user can be accommodated is twice with accurate estimate of the signal strength if there exists a convergence in adaptive scheme. This allows a higher bit rate that is more parallel paths in transmitter. Also a method is discussed to reduce bit error for phase reversal due to fading (a minimum gain of 2.75 in TCM coding).

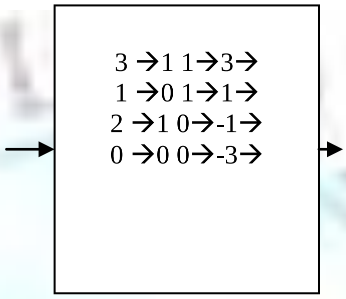

Figure 5: Mapping of PAM signal so that X-NOR can be done

IX. REFERENCES

[1]. F. Adachi, D. Garg, S. Takaoka and K. Takeda, " Broadband CDMA technique," IEEE Trans. on Wireless Communications, April 2005
[2]. A. J. Paulraj, D. A. Gore, R. U. Nabar and H. Bolcskei, "An Overview of MIMO Communications-A key to Gigabit Wireless," Proceedings of IEEE, February 2004
[3]. K. S. Gilhousen, I. M. Jacobs, R. Padovani, A J. Viterbi, L.A. Weaver Jr. and C. E. Wheatley, "On the capacity of a cellular CDMA Systems," IEEE Trans. on Vehicular Technology, Vol. 40, No 2 , May 1991
[4]. J. Vankka, M Kosunen, I Sanchis and K. Halonen, "A multicarrier QAM Modulator," IEEE Trans. on Circuits and Systems II: Analog and Digital Signal Processing, Vol. 47, January 2000, Pages 1-10
[5]. S. Moshavi, "Multi-user detection for DS-CDMA Communications," IEEE Communications Magazine, October 1996
[6]. E. Biglieri, D. Divsalar, P. J. Mclane and M. K. Simon, "Introduction to Trellis-Coded Modulation with Applications," Mcmillan, 1991
[7]. R. Bose, "Information Theory, Coding and Cryptography," Second Edition, Tata McGraw Hill, 2008
[8]. B. Xia and J. Wang, "QAM with interference Cancellation for high speed multicode CDMA," IEEE Seventh International Symposium on Spread Spectrum Techniques and Applications, 2002, Vol. 2
[9]. R. Lupas and S. Verdu, "Linear Multiuser Detectors for Synchronous Code Division Multiple-Access Channels," IEEE Trans. on Information Theory, IT-35, January 1989
[10]. R. Steele, "Mobile Radio Communication."
[11]. A. Dutta and S. Kiaei, "Adaptive Multiuser Detector for Asynchronous DS-CDMA in Rayleigh Fading," IEEE Trans. on Circuits and Systems-II: Analog and Digital Signal Processing, Vol 44, June 1997
[12]. A Dutta, Ph.D. Thesis, Oergon State University, 1997
[13]. S. L. Miller, "An Adaptive direct-sequence code-division multiple-access receiver for multiuser interference rejection," IEEE Trans. on Communications, Vol. 43 No. 2/3/4 February/March/April 1995
[14]. S. Haykin, "Communication Systems," 4th Edition John Wiley & Sons, Inc.2001

,