NON COHERENT DETECTION IN THE CONTEXT OF CODED COMMUNICATION

R. Bera [1] , Sanjib Sil [2], D. Kandar [3]

[1]*Sikkim Manipal Institute of Technology, Sikkim Manipal University, Majitar, Rangpo, East Sikkim 737132, India, E-mail: r_bera@hotmail.com*

[2]*Department of Electronics and Telecommunication Engineering, Jadavpur University, Kolkata 700032, India.*

[3]*Institute of Radiophysics & Electronics, University of Calcutta 92 A.P. C. Road, Kolkata 700 009. India.*

ABSTRACT

In today's world of Spread Spectrum based coded mobile communication, security and anti jamming features are added in the physical layer which enhance the performance of mobile devices as compared to existing GSM based uncoded communication. The authors are encouraged to utilize this 3G mobile technology to their PCN (personnel communication networking) wireless system. A DSSS based wireless devices are implemented in their PCN system. A microcontroller based network layer is interfaced with the DSSS based physical layer to form the PCN and an additional level of security is added in the CODEC part of the network layer. It therefore, requires a second level of detection and decoding where non coherent mode of detection is utilized to ease the system operation.

INTRODUCTION

A spread-spectrum communication system is one in which the transmitted signal is spread over a wide frequency band, typically much wider than the minimum bandwidth required to transmit the data. The spreading uses a waveform that appears random to anyone except the intended receiver of the transmitted signal. The waveform is actually pseudo-random in the sense that it can be generated by precise rules yet has the statistical properties of a truly random sequence. Spreading consists of multiplying the input data by a pseudo-random or pseudo-noise (PN) sequence, the bit rate of which is much higher than the data rate. This increases the data rate while adding redundancy to the system. The ratio of the sequence bit rate to the data rate is known as the spreading factor. When the signal is received, the spreading is removed from the desired signal by multiplying it by the same PN sequence that is exactly synchronized to the transmitted PN signal. When such a despreading operation is applied to the interferer's signals, ideally there is no further contribution to the user of interest's signal level. This is achieved in CDMA systems by assigning each user/transmitter distinct codes that have low cross-correlation properties, such as the ideal orthogonal codes or any one of the PN, Gold or Kasami sequences [1],[2].

SIMULATION OF BIT ERROR PERFORMANCE OF DSSS BASED COMMUNICATION SYSTEM

The authors have developed matlab program to study the performance of such system under following four cases:

Case1: Orthogonal spreading - single-user vs. two-user comparison This Simulation model compares a single-user system vs. a two-user data transmission system with the two data streams being independently spread by different orthogonal codes. The model uses random binary data which is BPSK modulated (real), spread by orthogonal codes of length 64 and then transmitted over a AWGN channel. The receiver consists of a despreader followed by a BPSK demodulator. For the same data, the example model calculates the performance for a two-user transmission along with the single-user transmission for the same channel settings. Note that for the individual users, the error rates are exactly the same in both cases. This shows that perfect despreading is possible due to the ideal cross-correlation properties of the orthogonal codes selected.

Case 2: Orthogonal spreading - multipath propagation This Simulation models a single-user system in which the signal is transmitted over multiple paths. This is similar to a mobile channel environment where the signals are received over multiple paths, each of which have different amplitudes and delays. To take advantage of the multipath transmission, the receiver employs diversity reception which combines the independent paths coherently. Note, to keep the system simple, no fading effects are considered here and the receiver assumes knowledge of the number of paths and their respective delays. For the second user's data transmission with the same spreading code as in case 1, we now see deterioration in performance when compared with case 1 (compare the 180 errors with 81 in the previous case). This can be attributed to the non-ideal auto-correlation values of the orthogonal spreading codes chosen, which prevents perfect resolution of the individual paths. As a consequence, we don't see the merits of diversity combining either.

Case 3: Pseudo-random spreading - multipath propagation. This example model considers pseudo-random spreading for a single-user system in the above multipath transmission environment. It is to be noted that the spreading factor (63) is almost the same as that used for orthogonal spreading for comparison purposes. In this case, for a 3-path channel note the gains due to diversity combining (compare 41 errors to 83 in case 1 and 180 in case 2). This is made possible by the ideal auto-correlation properties of the PN sequences used.

Case 4: Pseudo-random spreading - two-user multipath propagation. Finally, this model considers pseudo-random spreading for a combined two-user transmission in the same previously chosen multipath environment. For the two distinct PN sequences used for spreading, it is to be noted that the individual user performance has now worsened for the same channel conditions (compare 93 errors to 41 from Section 3). This is primarily due to the higher cross-correlation values between the two sequences which prevent ideal separation. Note, there are still advantages to combining as the error rate for a multipath plus AWGN channel with RAKE combining is nearly as good as the AWGN-only case of section 1. Now consider the case where spreading is done by using different Kasami sequences for the two users. Here it can be seen that almost perfect user separation (compare 39 errors with 41 from Section 3), over multiple paths with the gains of combining can be achieved. This can be attributed to the "good" correlation properties of Kasami sequences, which provide a balance between the ideal cross-correlation properties of Orthogonal codes and the ideal auto-correlation properties of PN sequences.

HARDWARE IMPLEMENTATION

The authors are encouraged by the above simulation experiments and have designed a DSSS based wireless system at 900 MHZ ISM Band. This is further extended by adding a network layer using a 8051 microcontroller and its software to have a DS-CDMA system of 20 users with a single base station covering a distance of 500 meter. The wireless remote control units from 20 predetermined users as shown in fig 1. can activate only a remote switch at the base station unit where control action takes place. The reverse path is activated automatically between base station and mobile unit only after reception at the base unit. This ensures the activation status at the base station by observing the glow of a LED at the mobile unit. The PCN[5] system can also be used as full duplex voice communication between mobile units or between mobile and base station unit. In the transmit section of the mobile unit a coder is used followed by a modulator. In the coder, a 14 bit code is generated using a 8051 microcontroller and used to transmit on UHF carrier frequency of 900 MHz with DSSS modulation. The Code starts with a control bit called ‘ Start’ bit followed by 13 ‘ data’ bits and is repeated 10 times to establish reliability of detection at the receiving end. The multiple access scheme is based on sending different codes from 20 different wireless mobile field units.

In the receive section a Comparator based threshold detection is used prior to microcontroller based decoding and is also used as A/D converter like the satellite receiver. By this process , the pulse is regenerated at the receive end. The lot of efforts are given for this regeneration and it results in a regenerated coded pulse in such a fashion that it is very difficult to believe that the clean received pulse has been obtained after passing through the noisy wireless channel. The decoding scheme is based on pulse width measurement of the received codes using software and a look up table has been formed in the software program to convert the measured pulse width to bits. The 14 bits code thus recovered are then compared with the transmitted sequence of bits obtained from a reference table of the software. The decision will be taken only for the matching code sequence. The microcontroller will do some predefined controlled actions after the match. Two level of matching using the control bit for the first level and software base correlation for the second level plays the major role in decoding scheme.

The wireless discrete channel at 900 MHz includes modulator, wireless media and detector. Before starting actual design, the two basic channel characteristics[4], bandwidth and power are estimated which constitute communication resources available to us. A fast pulse generator having a rise time of some nanosecond is fed to the modulation input of the transmitter and a digital storage oscilloscope is used to monitor and measure the transmitted and received pulses and other waveforms very precisely. The pulse response of the wireless channel is very poor and it results in a sine wave reception at the output of the detector. The flat amplitude response is obtained over a pulse repetition time of 600 μsec to 750 μsec only yielding better S/N ratio. The delay of 750 μsec is measured for a transmitter and receiver separation of 5 meter. The received power is estimated in terms of detected voltage as square law detector is in use. The received sinusoidal voltage is estimated to 1volt peak to peak in reference to TTL level voltage fed to the transmitter. The other two channel characteristics like linearity and Interference are also tested and a jamming margin of 20 dB is obtained with an acceptable jamming performance. Fig. 2 shows base band received signal amplitude vs. frequency curve It helps in taking decision about the choice of two FSK frequency of the baseband modem . Fig.3 illustrates the interference suppression capability of DSSS radio unit and is the right justification for the choice of DSSS in the physical layer.

Hand Shaking and Initial Call Setup

In order to establish connection between two of the desired mobile units ,

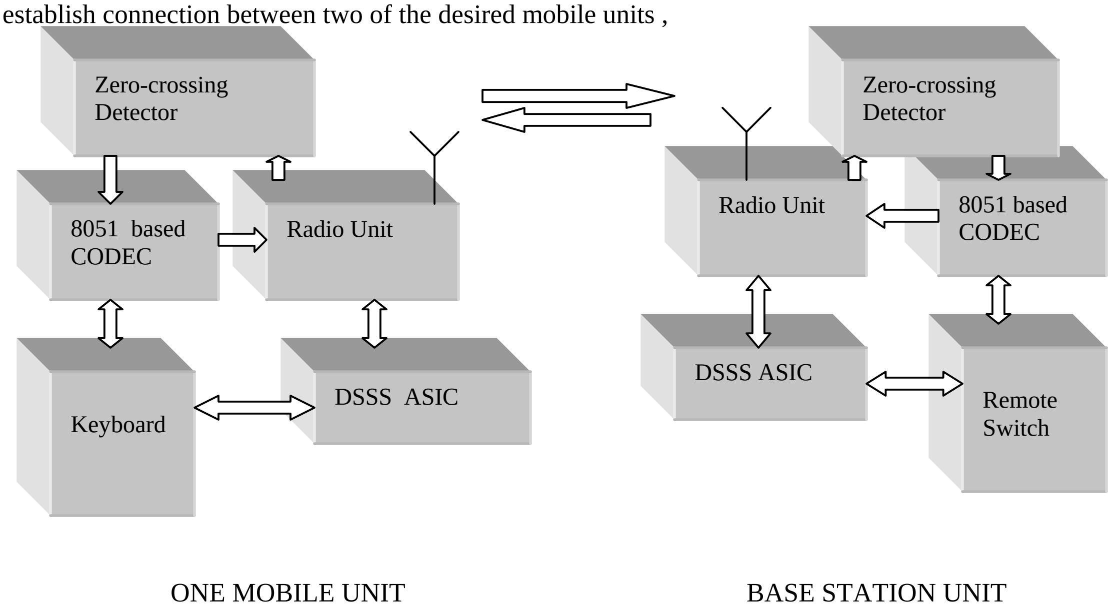


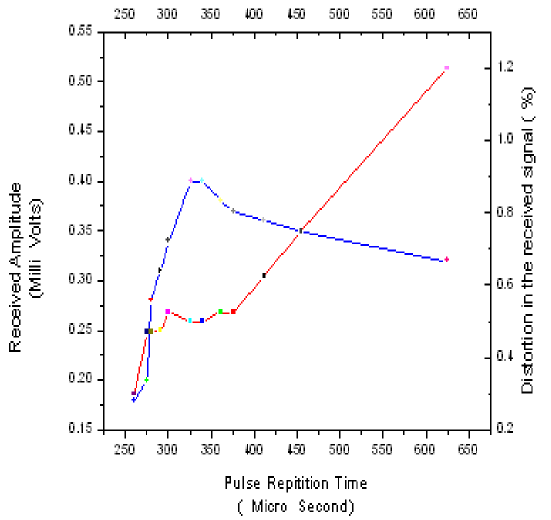
Fig.1: Block diagram of a DSSS wireless system in a DS-CDMA network.

the microcontroller based codec is utilized to generates a code, which is nothing but a pulse train is fed to the transmit enable of the radio unit through of the digital spread spectrum telephone set. Then this will be transmitted. The receive enable of the radio unit is always enabled. The radio unit of the other computer will receive this code. The output of the radio unit is a sine wave. To convert this sine wave into square wave we need a sine to square wave converter. Here we are using a zero-crossing detector as sine to square wave converter. Then the received signal is fed to codec of the receiver and is decoded. Then it is compared with the address of this computer. If it matches then the connection is established. If it does not match then it is ignored. This is how the connection is established between two mobile sets.

As shown in the fig2a & 2b there is a switch which enables the 8051 based CODEC which in turn generates the desired code and also the transmit enable signal. The receive enable pin of the radio unit is always high. The transmit enable signal from the codec enables the transmission of the radio unit. Then the code is transmitted. The code frame contains a start bit, followed by 6 bit source address, then 6 bit destination address and finally an acknowledgement bit. Initially the acknowledgement bit is made '0'.

Requested code from a mobile unit is broadcasted by the base station and will be received by all users. All users in turn will decode the requested code and after decoding, they will co-relate the code. Now only that user, whose correlation coefficient is greater than 90% will retransmit the same code by exchanging source and destination address with acknowledgement bit high. For other users the correlation coefficient is in the order of 0% and hence they will discard that code.

Base station will forward the code to the sender through broadcasting and the connection will be established in this fashion between source and destination. Now “ TALK” mode will be written on the LCD display of the sender.
As this radio unit uses frequency shift keying (FSK) modulation, thus this code will be FSK modulated in the radio unit at 900MHz and then transmitted. Sinusoidal analog signal will be received by the radio unit. To decode the received signal, it should be converted into square wave using a zero-crossing detector. In this way, pulse is regenerated at the receiver. It is then followed by software based code recovery within the microcontroller and is done by actual measurement of pulse repetition time (PRT). And a software based decision will be taken by the microcontroller. A threshold value of 700µs is set here for the code recovery. If the PRT is less than 700µs then it is zero and otherwise it is 1. Thus, the code is recovered.



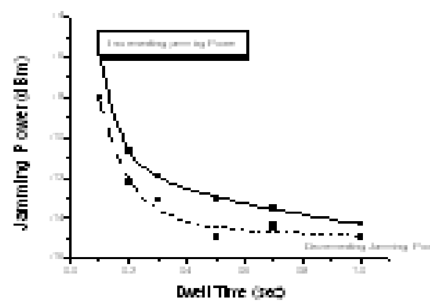


Fig. 2: Base band received signal amplitude Vs. Frequency curve.

Fig.3:Interference suppression capability of DSSS radio

CONCLUSION

The PCN system is thus ready for its two modes of operation supporting 20 mobile users over a distance of 500 meter. Either it can be used as a wireless remote control unit to control a central unit from distance. In this case of remote switch operation, security is incorporated at every layer viz. network, MAC and physical layer so that the operation can not be disturbed or jammed, thus enhancing the reliability. Or it can be used as voice communication unit exploring the DS-CDMA mode.

REFERENCE

[1] “On the System Design Aspects of Code Division Multiple Access (CDMA) Applied to Digital Cellular and Personal Communications Networks,” A. Salmasi and K. Gilhousen, *Proc. 41st IEEE VTC’91, 1991.*

[2] **“**Code Division Multiple Access -A Modern Trends in Multimedia Mobile Communication**”,** D. Kandar, **R. Bera** ,A. R. Sardar, S. Kandar, S. S. Singh and S. K. Sarkar, International Conference on Services Management ICSM2005 *held at IIMT, Gurgaon, Delhi during March 11-12,2005.*

[3] “Wireless communication and networks”, W. Stallings, *Pearson Education Asia publication, pp 320-333,2002*

[4] “Digital communication systems”, Simon Haykin, *John Wiley & Sons, 2004.*

[5] “ Computer networking –a top down approach featuring the internet”,J.A.Kurose and K.W.Ross, *Pearson Education Asia publication, pp 480-487,2003*