ANALYSIS OF DATA RATE TRADE OFF OF UWB COMMUNICATION SYSTEMS

Rajesh Thakare [1] and Kishore Kulat [2]
[1]Assistant Professor Dept. of Electronics Engg. DBACER Nagpur, India
[2]Professor Dept. of Electronics & Computer Science Engg. VNIT, Nagpur, India

ABSTRACT

As UWB system transmit low power stream of short pulses in large spectrum ,their energy is spread over a large amount of spectrum .This signal can penetrate in noisy radio environment and provide high quality service for various application. In this paper the probability of symbol error for M-ary PAM and M-ary PPM is evaluated. For a given probability of symbol error data range performance of a reliable communication link is analyze using M-ary PAM and M-ary PPM modulation. The results are simulated using MATLAB

KEYWORDS: *Communication Systems, UWB, PAM, PPM.*

I. INTRODUCTION

Radio technology that modulates impulse based waveforms instead of continuous carrier waves provides a UWB signal. As the carrier frequency is absent it is also called baseband technology. UWB is traditionally recognized as impulse radio, which transmit information with short pulses [1]. This offers solutions for bandwidth, cost, power consumptions, and physical size requirements of next generation consumer electronic devices. More data in a given period of time is able to transmit with UWB as compared to other traditional technology [2]. The potential data rate is proportional to bandwidth of the channel and logarithm of signal-to-noise ratio (Shannon's Law). Huge bandwidth of UWB can guarantee a large channel capacity without invoking a high transmits power. Therefore the spectrum occupied by existing technologies can be used by UWB without causing harmful interference [6,3].

UWB is a fast emerging technology used for future short range indoor radio communication. This system provides very high bit rates services, low power consumption and accuracy position capability [4]. As system occupies very large bandwidth the same bandwidth is also used by other existing communication systems. To have guarantee, existing communication system from UWB emission, the federal communication commission (FCC) restricted the UWB operating band in the 3.1-10.6GHz frequency range and regulated UWB power emission with frequency-power mask issued for each specific UWB application.[5].

Worldwide UWB regulatory bodies can be categorized as international, regional, or national. At the international level the International Telecommunication Union Radio Sector (ITU-R) plays a major role for providing recommendations. In July 2002, ITU-R Study Group 1 established Task Group 1/8 (TG1/8) to study the compatibility between UWB devices and radio communication services, comprising four working groups (WGs) (ITU-R TG1/8)[2].

- WG1 UWB characteristics
- WG2 UWB compatibility with other radio services
- WG3 UWB spectrum management framework

- WG4 UWB measurement techniques

The important advantages that have made UWB technology very favorable when compared to other technologies are its improved channel capacity and its very low level of interference.

This paper is organized as follows: Section II provide definition and identification of UWB signal. Section III provides emission limit for various applications, Section IV provide System Block Diagram of UWB Section Performance analysis of different levels of the *M*-ary PAM. *M*-ary PPM modulations in the AWGN channel is provided in section V, Section VI holds the simulation results. The paper will be concluded in section VII and future scope is given VIII.

II. DEFINITION AND IDENTIFICATION OF UWB SIGNAL

The identification of UWB signals are depends on center frequency. UWB system is classified using one of two different measures of bandwidth as per the FCC. A system can either have an instantaneous bandwidth in excess of 500MHz or have a fractional bandwidth that exceeds 0.20 (by comparison a narrowband signal typically has a fractional bandwidth which is less than 0.01). Both cutoff frequencies are defined according to the -10 dB points of the signal's spectrum. UWB radio can use frequencies from 3.1GHz to 10.6GHz[3].Fractional bandwidth is defined as the signal's bandwidth divided by its center frequency or more precisely as

$$B_{\mathrm{Wf}} = 2 \times \frac{f_h - f_l}{f_h + f_l} \tag{1}$$

Where, fh- highest frequency

fl - lowest frequency of the signal at the -10 dB points [FCC].

A method to identify UWB signal is depends upon following parameters.

- Center frequency(f_c)
- Lower cut off frequency (f_l)
- higher cut off frequency(f_h)

From the above parameter, calculate Band Width of signal as

$$Bw = f_h - f_l \tag{2}$$

and center frequency of signal

$$f_c = (f_h + f_l)/2 \tag{3}$$

As defined by the FCC's, UWB signals must have bandwidth greater than 500 MHz or fractional bandwidth greater than 0.20. Both cutoff frequencies are defined according to the -10 dB emission points of the signal's spectrum.

$$Bwf = BW/\, f_c \tag{4}$$

Where,Bwf is fractional bandwidth of a signal.

For example let the band width of signal is 2MHz and the center frequency of signal 9,10 and 11 MHz. From this, calculate the fractional bandwidth of signal and identify whether it is a UWB signal or not is shown in Table 1.

Table 1. Identification of UWB Signals

Center Frequency(MHz)	Fractional bandwidth	Identification
9	0.22	UWB signal
10	0.2	UWB signal
11	0.18	Not UWB signal

As per FCC, a signal is assumed to be a UWB if its band width at -10dB points exceeds 500MHz, regardless of fractional band width.

For example let the band width of signal is 500MHz and the center frequency of signal 2.3,2.5 and 2.7 GHz. From this, calculate the fractional bandwidth of signal and identify whether it is a UWB signal or not is shown in Table 2.

Table 2 Identification of UWB Signals

Center Frequency(GHz)	Fractional bandwidth	Identification
2.3	0.217	UWB signal
2.5	0.2	UWB signal
2.7	0.18	Not UWB signal

This specify that systems with a center frequency greater than 2.5 GHz must have a bandwidth greater than 500 MHz and a system with a center frequency less than 2.5 GHz must have a fractional bandwidth greater than 0.20.

III. REGULATION

In February 2002, the Federal Communication Commission (FCC) approved a First Report and order allowing the production and operation of unlicensed UWB devices. UWB devices use a low transmission power spectral density in order to not interfere with existing narrowband communications systems. In general, the FCC ruling per application with Part 15 classification of -41.3 dBm for both outdoor and indoor operations can be summarized as shown in Table 1.Based on the FCC regulations, UWB devices are classified into three major categories: communications, imaging, and vehicular radar.

A. Communications Devices

For communications devices, the FCC has assigned different emission limits for indoor and outdoor UWB devices. The spectral mask for outdoor devices is 10 dB lower than that for indoor devices, between 1.61 GHz and 3.1 GHz, as shown in Figure 1and Figure 2 respectively. According to FCC regulations, indoor UWB devices must consist of handheld equipment, and their activities should be restricted to peer-to-peer operations inside buildings.

The FCC's rule dictates that no fixed infrastructure can be used for UWB communications in outdoor environments. Therefore, outdoor UWB communications are restricted to handheld devices that can send information only to their associated receivers.

In general, the FCC ruling per application with Part 15 classification of 41.3 dBm for both outdoor and indoor operations can be summarized as shown in Table 3.

Table 3 Emission limits for various UWB applications in each operational band

ERIP (dBm)			Operation Band (GHz)					
	Application		**0.96 to 1.61**	**61 to 1.99**	**1.99 to 3.1**	**3.1 to 10.6**	**10.6 to 22.0**	**22.0 to 29.0**
	ERIP (dBm)	Indoor	**75.3**	**53.3**	**51.3**	**41.3**	**51.3**	**51.3**
		Outdoor	**75.3**	**63.3**	**61.3**	**41.3**	**61.3**	**61.3**
	Imaging		**53.3**	**51.3**	**41.3**	**41.3**	**41.3**	**51.3**
	Vehicular Radar		**75.3**	**63.3**	**63.3**	**63.3**	**41.3**	**41.3**

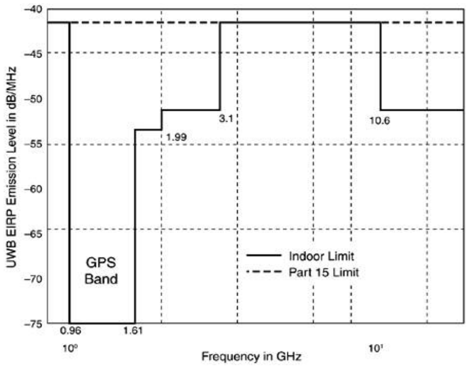

Figure 1 For indoor communications systems

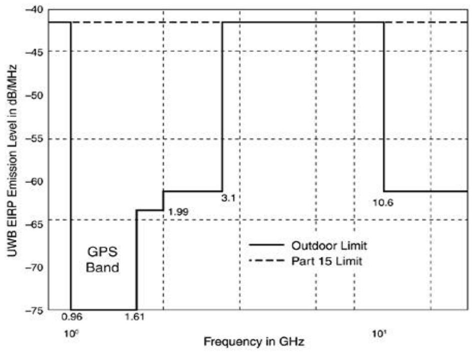

Figure 2 For outdoor handheld devices

B. Imaging Devices

Figure 3 shows the FCC emission limit for UWB-based through-wall imaging devices. The operation of these devices is constrained to law enforcement and rescue teams.

C. Vehicular Radar Systems

Vehicular radar systems are allowed to emit, - 41.3 dBm/MHz only in the 22 GHz to 29 GHz frequency range. The center frequency of their signal should be higher than 24.075 GHz. These radar devices are allowed to be mounted on terrestrial transportation vehicles and can be activated either while the vehicles are moving or while they are stationary. Figure 4 shows the FCC emission limit for UWB-based vehicular radar systems.

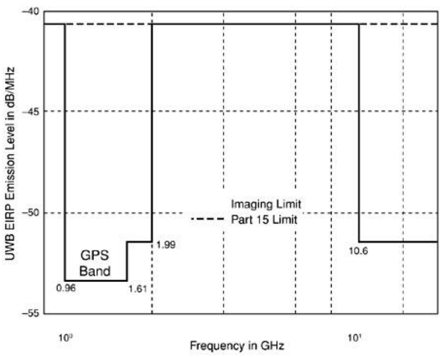

Figure 3 Through-wall imaging systems

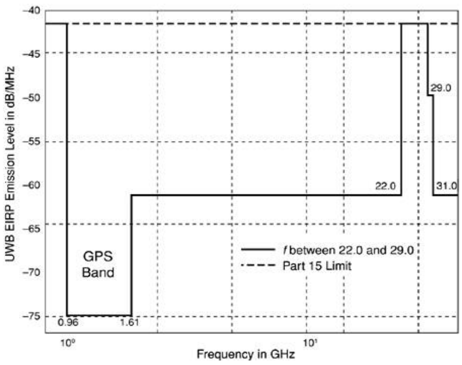

Figure. 4 For vehicular radar systems

IV. SYSTEM BLOCK DIAGRAM OF UWB

A basic UWB system will have a signal pulse generator that generates a Gaussian pulse. The encoded signal is transmitted using the Gaussian pulses. The pulses are amplified and transmitted via antenna to the receiver. Once the receiving antenna receives the signal the low noise amplifier will amplify the signal before it continues on into the receiver. Figure 5 shows the system block diagram. The LNA is shown in the overview right next to the pre-select filter. The antenna receives the signal from the outside source.

The LNA will amplify this signal. The input to LNA will be a signal received from a UWB transmitter. The output of the amplifier will be an amplified signal with low noise added.

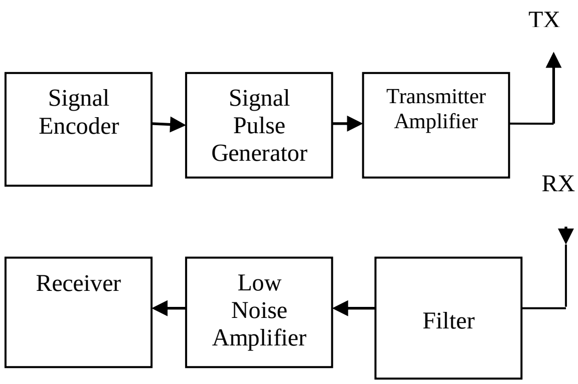

Figure 5: System Block Diagram of UWB

V. Performance Analysis in AWGN Channel

System specification is defined in terms of probability of symbol error Pre than SNR. The relation between SNR and Pre depends on modulation scheme. The major used UWB pulse modulations are Pulse Amplitude Modulation (PAM) and Pulse Position Modulation (PPM). In this section we evaluate and compare the performance of both modulations in the Additive White Gaussian Noise (AWGN) channel.

Considering the *M*-ary PAM modulation , the bit error probability (*Pre*) is given by

$$Pr_e = \left(1 - \frac{1}{M}\right) erfc \sqrt{\left(\frac{E_b}{N_o} \frac{3 \log_2 M}{M^2 - 1}\right)} \quad (5)$$

E_b is the average energy per bit, N_0 is the power spectral density in the AWGN channel and $M=2^k$, where k is the number of information bits that each symbol carries. Where erfc is the complementary error function

$$erfc(y) = \frac{2}{\sqrt{\pi}} \int_y^\infty e^{-\xi^2} \, d\xi \quad (6)$$

Considering the *M*-ary PPM modulation, the bit error probability can be estimated by an upper bound [8]. For *Eb/N0*>ln2

$$Pr_e = e^{-\log_2 M (E_b/N_o - 2 \log_e 2)/2} \quad (7)$$

Different pulses can be used for UWB communication [6]. In this paper we consider the fifth order derivative of the Gaussian pulse with σ equal to 51 psec. This pulse shape complies with the FCC indoor emission limits. The general relationship between the peak frequency f_{peak}, order of differentiation k ,and the shape factor α by observing that the Fourier transform of k-th derivative has the property

$$X_k\,(f) \propto f^k e^{-\frac{\pi f^2 \alpha^2}{2}} \quad (8)$$

Where shape factor

$$\alpha^2 = 4\pi\sigma^2 \quad (9)$$

σ^2 is variance

VI. Simulation Result

In this work we consider a UWB power limited system that complies with the FCC emission limits. We evaluate the achievable range-data rate performance of a reliable communication link is analyze using M-ary PAM and M-ary PPM modulation. In Figure 6, the probabilities of symbol error are shown for different levels of *M*-ary PAM and *M*-ary PPM modulations.

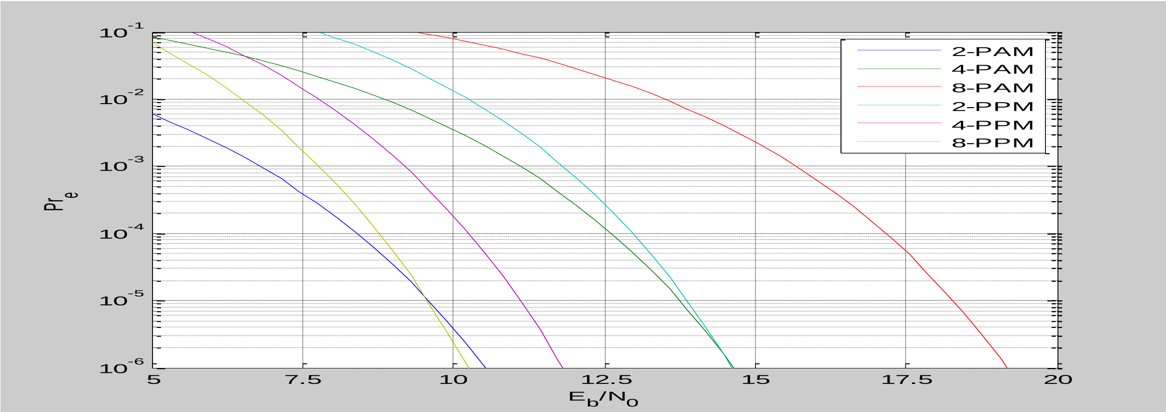

Figure 6 Probability of symbol error for M-ary PAM & PPM

Maximum value of distance between transmitter and receiver as function of data rate for [1-100kbits/s], [1-20Mbits/s] and [20-200Mbits/s] for M-PAM and M-PPM is shown in Figure 7,8 and 9 for fifth order derivative

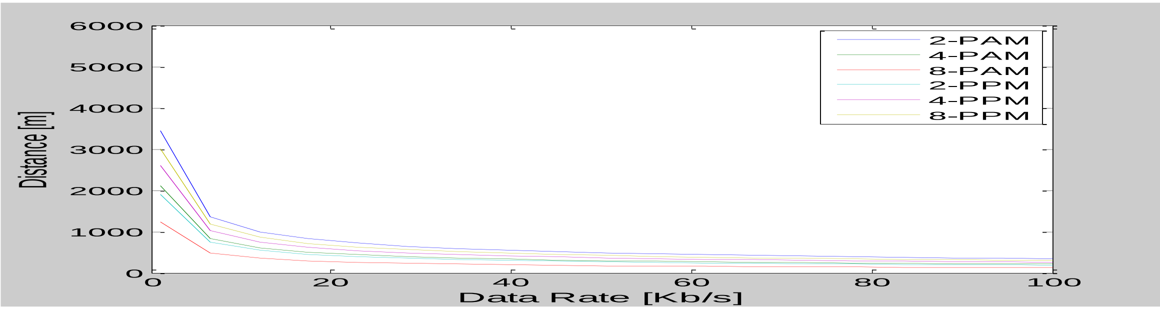

Figure 7 Distance as a function of data rate for [1-100kbits/s]

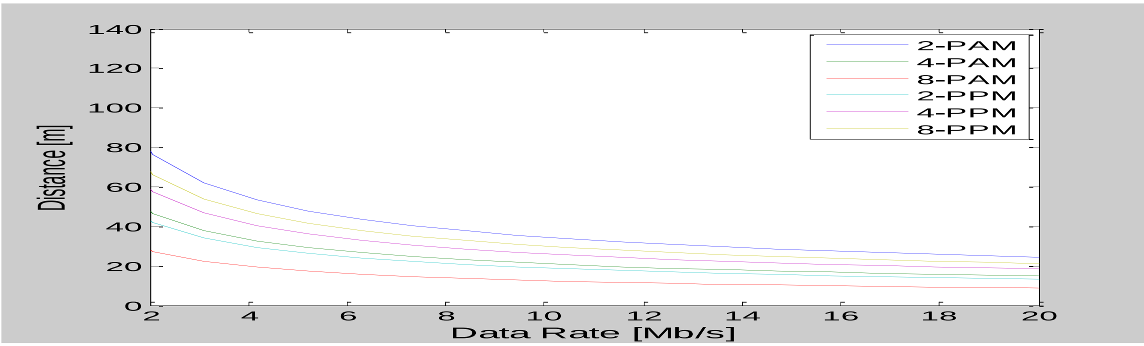

Figure 8 Distance as a function of data rate for [1-20Mbits/s]

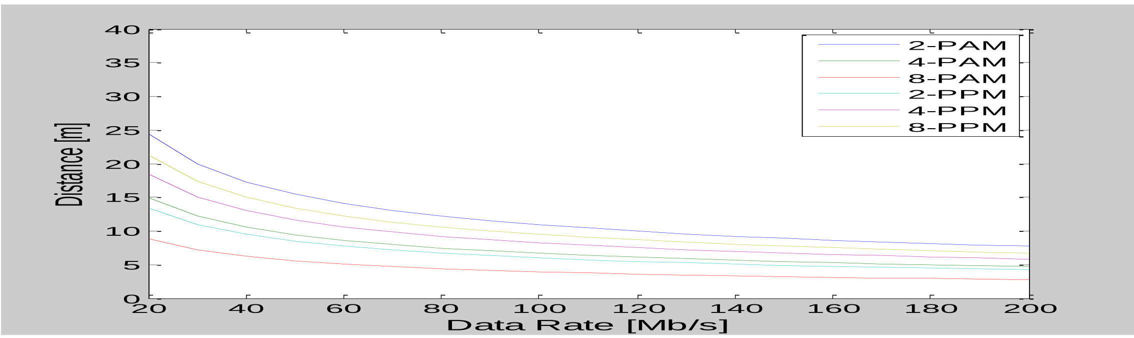

Figure 9 Distance as a function of data rate for [20-200Mbits/s]

VII. CONCLUSION

PPM signals are more immune to false detection due to channel noise. This is because the pulses that represent the data bits in PPM have the same amplitude, so the probability of detecting a false data bit is reduced. For M-PPM signal, performance improves as M increases but for M-PAM performance improves as M decreases.

The effect of distance between transmitter and receiver increase as the value of M increase in PPM but as data rate increases the distance decreases. The distance between transmitter and receiver decrease as the value of M increase in PAM, but as data rate increases the distance decreases.

VIII. FUTURE SCOPE

Due to large bandwidth, UWB-based radio multiple access communication system can accommodate many users. There are two common multiple access techniques for impulse radio UWB systems. Time hopping is one such technique. Direct Sequence (DS) is another multiple access technique that is popular in the UWB community to increase the data rate.

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AUTHORS BIOGRAPHY

Rajesh D. Thakare– was born in 1968. He received B.E. degree in Electronics and M.E. degree in Electronics Engineering from Sant Gadge Baba Amravati University, Amravati, Maharashtra, India in 1990 and 2001 respectively. He is currently pursuing PhD degree in Electronics Engineering from Rastrasant Tukodoji Maharaj, Nagpur University, India. He has authored /co-authored over 20 papers in International/National journals and conferences His current research interests include wireless communication especially co-existence issues of UWB with existing wireless system. He is life member of Indian Society for technical Education ISTE, Member of Institute of Engineers (IE) , Institute of Electronics and Telecommunication Engineers (IETE)

Kishore D. Kulat – was born in 1958. He received B.E. degree in Electrical Engineering from Visvesvaraya Regional College of Engineering (VRCE) Nagpur and M. Tech. degree in Electronics Engineering from VJTI, Mumbai, India in 1980 and 1984 respectively. He received PhD degree from VNIT, Nagpur in 2003.Currently he is professor and Head of the Department of Electronics and Computer science Engineering, VNIT, Nagpur. He has guided 10 PhD students. He has authored /coauthored over 85 papers in International/National journals and conferences. His current research interests include wireless (wi-fi, wi max) communication systems, networking and real time embedded system design. He is life member of Indian Society for technical Education ISTE, Fellow member of Institute of Electronics and Telecommunication Engineers (IETE) and member of Institution of Engineers (IE).