http://ansinet.com/itj

ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 12 (11): 2261-2264, 2013
ISSN 1812-5638 / DOI: 10.3923/itj.2013.2261.2264

Interference Analysis of Multi-user DS-UWB Signals on Unified S-band TT and C Systems

Xiaohui Liu, Yunsheng Kuang, Zhendong Yin and Zhilu Wu
School of Electronics and Information Engineering, Harbin Institute of Technology, Harbin, Heilongjiang 150001, China

Abstract: In this study, we analyze the interference pattern of multi-user direct sequence ultra-wideband (DS-UWB) signals on unified S-band telemetry tracking and control (USB TT and C) systems. Due to the overlay nature of UWB signals, it's inevitable that UWB signals will cause interference to USB TT and C systems. Compared to the bandwidth of DS-UWB signals, USB TT and C can be regarded as a narrowband system and there are two main interference patterns: pulse interference and white noise interference, which is determined by some of the parameters of two systems. Hence, the relationship between these parameters and the interference pattern can be analyzed and use the results to design two systems to cause minimum interference and achieve spectrum coexistence.

Key words: DS-UWB, spectrum coexistence, USB TT and C

INTRODUCTION

Ultra wideband (UWB) is an attractive wireless communication technology for its characteristics of high data transmission rate, low power density, high interference resistance, strong multi-path resolution and so on (Win and Scholtz, 1998; Shen *et al*., 2006). In recent years, UWB technology has been broadened to Wireless Local Area Networks (WLAN), Wireless Sensor Networks (WSN), radar detection and high-speed communications of indoor and outdoor applications (Choliz *et al*., 2011; Zhangliang and Quanshi, 2004), especially in satellite communication, which can build the Inter Satellite Link (ISL) to achieve inter satellite communication and formation flying among multiple satellites (Sacchi *et al*., 2008). UWB system transmits a series of burst pulses (time duration is up to nanosecond) whose spectrum is very wide. Therefore, it is inevitable to overlap the spectra of some narrowband signals. In satellite communications, the primary communication system is the unified S-band (USB) telemetry tracking and control (TT and C) system (Krenq *et al*., 2007) and the UWB signals are bound to make some negative influence to the receiving of USB TT and C signals. Hence, it is necessary to take some measures to avoid interfere the USB TT and C systems when transmitting UWB signals (Wu *et al*., 2010).

FCC has stipulated that the power spectrum density of UWB signals is less than-41.3dBm/MHZ and constituted the corresponding standard. In addition, many studies have been done to see how UWB signals interfere to other communication systems, especially narrowband systems and get many significant conclusions (Foerster, 2002). First, by analyzing the power spectrum of UWB waveform, it shows that the power spectrum is composed of continuous and discrete spectrum and the discrete spectrum which is overlapped by that of narrowband signals has great impact on the interference (Wang *et al*., 2007). Second, there are many parameters that affect a UWB system's interference effects to a narrowband system. Such as the UWB modulation pattern, transmission waveform and repetition frequency, the center frequency of the narrowband system and the base-band rate of the narrowband system (Tang and Parhi, 2003).

In this study, it is regarded that multi-user direct sequence UWB (DS-UWB) signals as the interference resources to analyze the interference model to the USB TT and C narrowband systems. The multi-user situation is mainly focus on, which more than one UWB interference signals go into the USB TT and C receiver. In this case, some parameters will determine how strong the multi-user DS-UWB signals interfere with the USB TT and C systems, including the PRF of DS-UWB signals, the center frequency of USB TT and C system, the base-band bit rate and the number of UWB interference resources.

MULTI-USER DS-UWB SYSTEM

There are two main multiple access scenarios in UWB communication systems: time hopping (TH-UWB) and

Corresponding Author: Zhendong Yin, School of Electronics and Information Engineering, Harbin Institute of Technology, Harbin, Heilongjiang 150001, China

direct sequence (DS-UWB). DS-UWB can separate signals of different users by the orthogonality of the Pseudo Noise (PN) codes which are divided by different users. In this study, DS-UWB systems are developed which combine both direct sequence code division multiple access (DS-CDMA) and UWB techniques (Li and Rusch, 2002). In DS-UWB systems, each user is assigned an exclusive series of PN codes which own the good orthogonality in code space. All of the users transmit their own information in the same channel simultaneously and the transmission signal of multi-user DS-UWB communication system can be expressed as follows:

$$u(t)=\sum_{k=1}^{K}\sum_{j=-\infty}^{\infty}\sum_{i=0}^{N_c-1}\sqrt{P_{av}^{(k)}T_c}\,b_k(j)c_k(i)p(t-jN_cT_c-iT_c-\tau_k) \quad (1)$$

where, K denotes the number of DS-UWB users; N_c denotes the spread spectrum gain of the system; $P_{av}^{(k)}$ denotes the average power of user k (k = 1, 2, ..., K); T_c denotes the Pulse Repetition Period (PRP); $b_k \in \{-1, +1\}$ represents the transmission base-band bit of user k which can be seen as a two-valued random variable satisfying uniform distribution; $c_k \in \{-1, +1\}$ represents the PN code of user k and base-band bit $b_k(j)$ is spread with the specific PN codes c_k with the length of N_c; p(t) represent the normalized UWB chip pulse monocycle whose energy is normalized to one, that is:

$$\int_{-\infty}^{\infty}p^2(t)dt=1 \quad (2)$$

generally, p(t) adopts the second derivative Gaussian pulse with the duration of a nanosecond and the bandwidth of more than GHz and τ_k represents the random delay of user k which satisfies $0 = \tau_k < T_c$.

Let $a_k(i) = b_k(j)c_k(i)$, $a_k \in \{-1, +1\}$. Due to the run property of the PN code, the number of +1 always equals to the number of-1 plus one during one period. Hence, assume that $a_k(i)$ is also a two-valued random variable which satisfies uniform distribution. Equation 1 can be rewritten as follows:

$$u(t)=\sum_{k=1}^{K}\sum_{i=-\infty}^{\infty}\sqrt{P_{av}^{(k)}T_c}\,a_k(i)p(t-iT_c-\tau_k) \quad (3)$$

INTERFERENCE MODEL

Compared to the bandwidth of DS-UWB signals, USB TT and C can be seen as a narrowband system. Let f_0 be the carrier frequency of USB signal and B be the bandwidth of USB signal. In the transmission band from f_0-B/2 to f_0+B/2, the power spectrum density of DS-UWB system's monocycle waveform is a constant and equals to $|P(f_0)|^2$, where P(f) represents the Fourier transformation of the UWB chip pulse monocycle p(t). So passing through the radio filter of USB TT and C systems, the output expression of multi-user DS-UWB signals in frequency domain can be written as:

$$F(f)=\begin{cases}\sum_{k=1}^{K}\sum_{i=-\infty}^{\infty}\sqrt{P_{av}^{(k)}T_c}\,a_k(i)P(f_0)\exp[-j2\pi(iT_c+\tau_k)] & |f-f_0|\le\frac{B}{2}\\ 0 & |f-f_0|>\frac{B}{2}\end{cases} \quad (4)$$

And the time domain expression can be written as:

$$u(t)=P(f_0)\sum_{k=1}^{K}\sum_{i=-\infty}^{\infty}\sqrt{P_{av}^{(k)}T_c}\,a_k(i)\frac{\sin(\pi B(t-iT_c-\tau_k))}{\pi(t-iT_c-\tau_k)}\cos(2\pi f_0(t-iT_c-\tau_k)) \quad (5)$$

From Eq. 5, it can be seen that after passing through the narrowband filter, the waveform of the UWB pulse monocycle will be expanded as a 'sinc' function form in time domain and its pulse width equals to 2/B. Let N_p denote the ration of the UWB pulse repetition frequency f_c and the base-band symbol rate of the USB TT and C system R_b, where $f_c = 1/T_c$. Generally, the value of N_p equals to 2 f_c/B and determines the interference mode to the USB system:

- **$N_p \le 1$:** In this case, some of the narrowband USB base-band bit will have only one UWB pulse interference waveform and others will not be interfered with the UWB pulse waveform. The USB pulse will be separated each other in time domain. And the main interference mode will be pulse string interference
- **$N_p > 1$:** In this case, each narrowband USB base-band bit will have one or more UWB pulse interference waveform and each UWB 'sinc' form pulse will mix up each other in time domain. So, in this case, the interference energy distribution in time domain will become average. Extremely, when the value of N_p tends to infinity, the interference mode will be the additional White Gaussian Noise (AWGN)

The multi-user DS-UWB interference waveforms to USB TT and C systems under different N_p values are depicted in Fig. 1, which corresponds to the first and the second case.

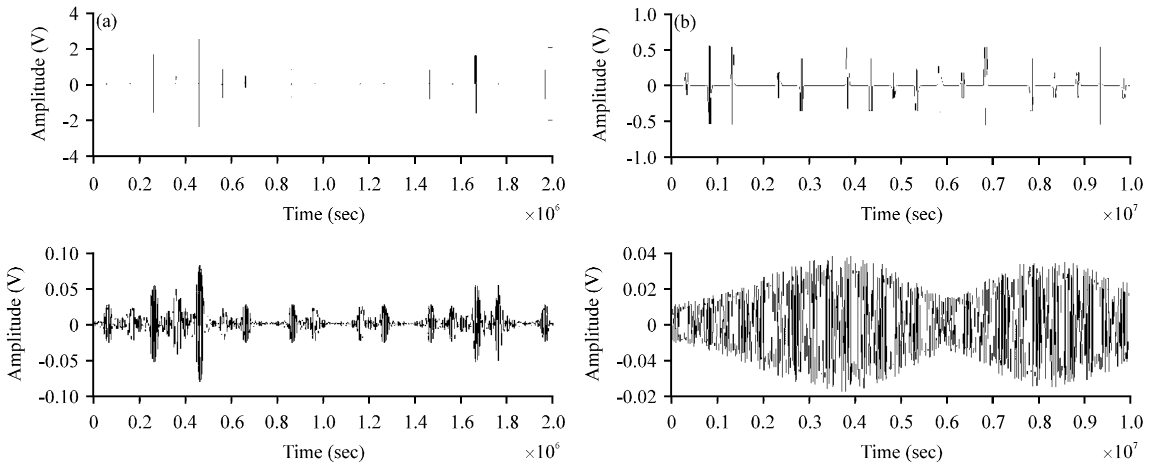

Fig. 1(a-b): Interference waveforms to USB TT and C systems under different N_p values, (a) N_p = 0.5 and (b) N_p = 10

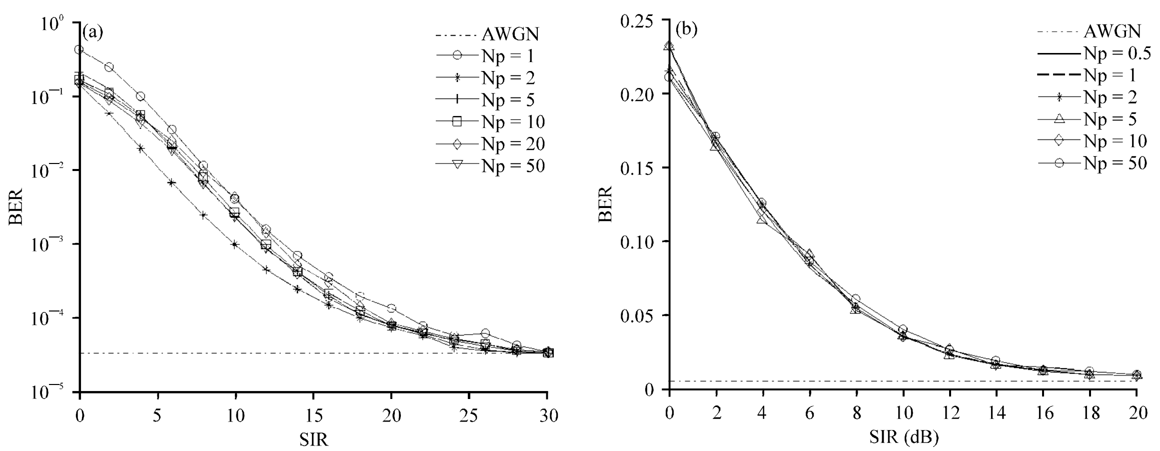

Fig. 2(a-b): BER performance versus SIR with different N_p values, (a) Synchronous and (b) Asynchronous

SIMULATION RESULTS AND DISCUSSION

First, the Bit-error Rate (BER) of the USB signals under different Signal to Interference Ratio (SIR) conditions are discussed, where SIR is defined as the ratio of the input power between USB and multi-user DS-UWB signals. There are two situations to be discussed: synchronous and asynchronous and the BER curves with different N_p values, different SIR conditions and SNR = 8 dB are depicted in Fig. 2. As shown in Fig. 2a, in synchronous case, the BER becomes greater with the increase of N_p value in the same SIR condition, which means that the pulse interference will have more impact on BER performance of USB systems than that of AWGN mode. However, in Fig. 2b, the BER variation trend is nearly the same no matter what the value of N_p is. So, the conclusion can be getting that the main interference mode is AWGN in asynchronous case whatever N_p is.

Second, we discuss the BER performance under different number of DS-UWB users and also take it into consideration in two cases: synchronous and asynchronous. The BER curves with different number of users are depicted in Fig. 3. From Fig. 3a, it can be seen that the increase trend of BER accelerates with the increase of N_p value, which means the AWGN mode will have more negative influence on USB system than that of pulse interference when there are a number of DS-UWB users transmitting interference signals to USB system. And in Fig. 3b, the increase trend is nearly the same because the main interference mode is AWGN in asynchronous situation.

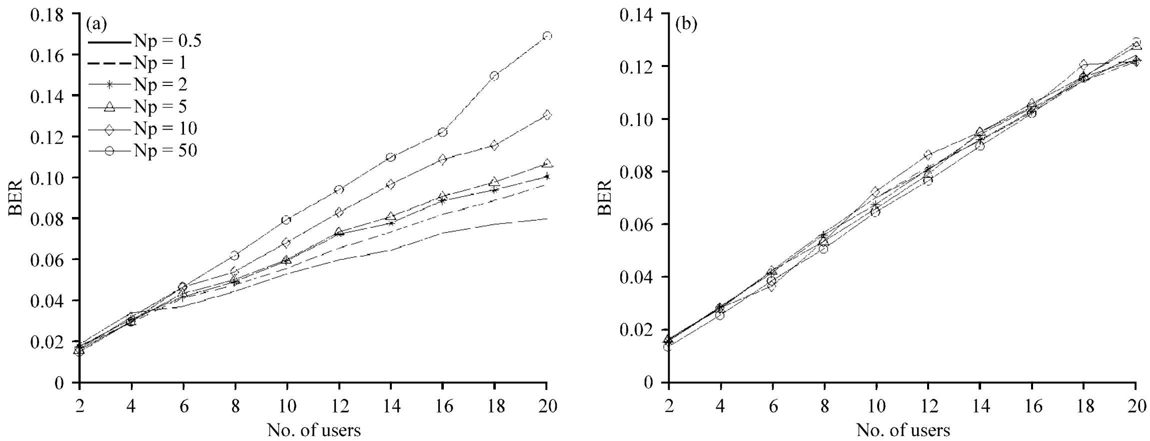

Fig. 3(a-b): BER performance versus number of users with different N_p values, (a) Synchronous and (b) Asynchronous

CONCLUSION

In this study, the interference mode of multi-user DS-UWB signals on Unified S-band TT and C systems are analyzed. Compared to the bandwidth of DS-UWB signals, the USB TT and C system can be seen as a narrowband system and there are two main interference patterns on narrowband systems: pulse interference and AWGN interference, which is determined by the ration between the pulse repetition rate of DS-UWB signals and the USB base-band bit rate. In synchronous case, when the ratio is less than 1, the main interference mode is pulse interference and the ration is greater than 1, especially trends to infinity, the interference mode turns out to be AWGN. In asynchronous case, AWGN is the main interference mode no matter what the ratio is. What's more, we analyze the relationship between the interference effectiveness and the number of DS-UWB users, which finds that the AWGN interference will have more negative influence on USB system than that of pulse interference when there are a number of DS-UWB users transmitting interference signals to USB system.

REFERENCES

Choliz, J., A. Hernandez and A. Valdovinos, 2011. communication and location tracking systems for wireless sensor networks. Sensors, 11: 9045-9068.

Foerster, J., 2002. Interference modeling of pulse-based UWB waveforms on narrowband systems. Proceedings of the 55th Vehicular Technology Conference, Volume 4, May 6-9, 2002, Birmingham, Alabama, pp: 1931-1935.

Krenq, J., M. Sue, S. Do and Y. Krikorian, 2007. Telemetry, tracking and command link performance using USB/STDN waveforms. Proceedings of the Aerospace Conference, March 3-10, 2007, Big Sky, MT., pp: 1-15.

Li, Q.H. and L.A. Rusch, 2002. Multiuser detection for DS-CDMA UWB in the home environment. IEEE J. Selected Areas Commun., 20: 1701-1711.

Sacchi, C., T. Rossi, M. Menapace and F. Granelli, 2008. Utilization of UWB transmission techiniques broadband satellite connections operating in W-band. Proceedings of the GLOBECOM Workshops, November 30-December 4, 2008, New Orleans, LO., pp: 1-6.

Shen, X., M. Guizani, H.H. Chen, R.C. Qiu and A.F. Molisch, 2006. Guest enditorial ultra-wideband wireless communications-theory and applications. IEEE J. Select. Areas Communi., 24: 713-716.

Tang, J. and K.K. Parhi, 2003. On the power spectrum density and parameter choice of multicarrier UWB communications. Proceedings of the 37th Asilomar Conference on Signals, Systems and Computers, Volume 2, November 9-12, 2003, Pacific Grove, California, pp: 1230-1234.

Wang, Y., X. Dong and I.J. Fair, 2007. Spectrum shaping and NBI suppression in UWB communications. IEEE Trans. Wireless Communi., 6: 1944-1952.

Win, M.Z. and R.A. Scholtz, 1998. Impulse radio: How it works. IEEE Commun. Lett., 2: 36-38.

Wu, Z., N. Zhao, G. Ren and T. Quan, 2010. Anti-interference strategies review of unified spread spectrum telemetry tracking and control system. Inform. Technol. J., 9: 979-983.

Zhangliang, X. and X. Quanshi, 2004. A novel multi-user detector in UWB communication systems. Proceedings of the Sensor Array and Multichannel Signal Processing Workshop, July 18-21, 2004, Barcelona, Spain, pp: 129-132.