Secure and Unlistenable Signal Transmission in UWB System Using Spread Spectrum Techniques in Electronic Warfare Systems

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ABSTRACT:
The use of electronic equipment, such as radars and communication systems, as integral components of defensive military weapons including missiles and aircraft plays a pivotal role in electronic warfare. Regardless of their application method, their proper utilization enhances operational speed, timing, and military power, thereby increasing the success rate in modern warfare. Ultra-Wideband (UWB) systems are a robust broadband technique with high efficiency and low power consumption, widely employed in wireless communications for ultra-high data rates. This article investigates signal transmission in UWB systems, proposing an effective method with limited prior research. Spread spectrum techniques ensure resistance against interference and interception. The proposed signal transmission system maintains high signal quality in error-prone channels and remains undetectable due to its low amplitude and power.

KEYWORDS: Direct Sequence, UWB, Frequency Hopping, Interception.

1. INTRODUCTION

1.1. History of the use of "electronic warfare"

The first electronic warfare was carried out in the 1904 war between Japan and Russia. Electronic warfare against radar is carried out in such a way that the electronic warfare system receives the enemy's radar waves and analyzes them, trying to produce similar waves. Also, the enemy radar, which produces its own waves and sends them to the target, encounters a large volume of false waves when the waves it produces return, which it must process and separate false waves from non-false waves or even falsely declare a flying object to be another object.

Electronic warfare has shown its value in various wars; but the Vietnam War and the 1973 war between the Arabs and the Zionist regime were the first of them in a special way; while in 1965 and 1966, the American terrorist army encountered the air defense system in Vietnam for the first time and caused many high casualties, but quickly began equipping its fighters with electronic warfare. The next case was in the 1973 war; When, in the first two weeks of the war, the Zionist regime lost about 102 fighter jets to the Egyptian defense umbrella, most of which were defensive, it quickly deployed electronic warfare and was able to reduce losses to less than 20 aircraft in the second week.

1.2. The importance of electronic warfare measures

The use of electronic equipment is either done independently, such as radars and telecommunications, or as part of defensive military weapons, such as missiles and aircraft, which, in any case, if used correctly, will increase speed,

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time, and military power, and will increase the success rate in modern wars. The result is that in light of this use, the conditions of the battlefields have been determined in such a way that today, in addition to creating depth, vastness, and fate, these fields have also acquired a fourth dimension called the "domain and spectrum of electromagnetic waves." This dimension has penetrated so much into all corners and points of the battlefield that it can be said that progress in other dimensions of war would not be possible without it. Although this realm (electromagnetic wave spectrum) is not physically tangible and visible like time, it has effects and results that confirm the value of its presence. On the other hand, the introduction of a systemic approach to wars and human conflicts in the form of principles and theories of command and control has made military and conflicting forces so in need of strong and complex communications, rapid guidance and control, as well as decisive and timely decision-making that the role of electronic and telecommunication equipment in implementing these principles and methods is not only undeniable, but also makes any action impossible without them. Another important consideration is the necessity for a country to identify its competitors and adversaries in the global and regional arenas, as well as to understand the conditions that enable it to play an effective regional and global role and, at a minimum, ensure its continued existence [1]. Therefore, a country that does not have sufficient information in collective and tactical affairs will act like a blind and deaf element, weak and passive. Therefore, it is expected that the use of electromagnetic radiation from electronic devices and equipment of enemies and competitors can be considered as one of the most important and richest sources of information acquisition.

In today's world, the use of new information and communication technologies and countries to use them (E-readiness) is considered an important indicator of the progress of industries in different countries of the world. UWB (Ultra Wide Band) systems play a key role in the development of communications and information technology, and at the forefront of them are industries and telecommunications affairs, which increases the productivity and quality of telecommunications services and, as a result, the satisfaction of more and more subscribers using these services. The implementation and standardization of UWB and its connection with new concepts and applications of electronic commerce and electronic strategy in the country, as an engine of progress in the ICT sector, plays a fundamental role in accelerating the exchange of communications [2].

The structure of this paper is as follows: in the second section, the proposed UWB system is introduced, and in the third section, the materials and methods of this proposed system are discussed. In the fourth section, the simulation of this system and its methods are shown, and finally, the conclusion is stated.

2. UWB (ULTRA WIDE BAND) SYSTEM

Ultra-wideband (UWB) technology is a suitable solution for short-range, high-speed wireless communications[3]. This technology was first used in military radars in 1960, but it became general in 1990 and was considered by the Federal Communications Commission (FCC) in 1998, and related standardizations in this field began. Since then, the growth and expansion of telecommunication networks and the need for their diverse services have led to the use of higher bandwidths. This issue is of great importance in wireless communications. In the meantime, indoor telecommunication systems require a wider bandwidth than the bandwidth of existing systems due to the large number of users with high transmission rates who are located in a small space. Recently, UWB systems have been considered by research centers and standardization organizations as a good candidate for multi-user wireless communications due to their ability to provide very high bit rates and very low power consumption [3]. These systems do not use sinusoidal carriers to transmit signals, but instead transmit very narrow pulses (which is why they are also called impulse radio), and thus occupy a very wide bandwidth. The bandwidth of these systems ranges from DC to several GHz.

The UWB signal is noise-like, making it difficult to detect and avoid. Due to their low power spectral density, UWB signals cause little interference with other narrowband radio systems. The time-modulated (TM) impulse radio signal appears to be a carrier-free baseband transmission. The absence of a carrier frequency is a fundamental feature that distinguishes impulse radio and radar impulse transmissions from narrowband applications and from direct sequence (DS) spread spectrum (SS) multi-user (MC) transmissions, which can also be characterized as a (ultra) wideband technique [4].

UWB signals are impulses with very short durations, sharp rise and fall times. Therefore, they have a wide bandwidth of about several gigahertzes. Information is transmitted by these pulses with very short durations (picoseconds) and very high bandwidth. As mentioned earlier, the signal energy is spread over a large bandwidth and the amount of energy per frequency becomes very small. Of course, it should be noted that the main goal of UWB design was also to have very low signal energy per frequency and to be able to work efficiently with other narrowband systems that share the UWB frequency range in the same environment (without any interference) [5].

Fig. 1 shows the five main spatial ranges of wireless systems and Fig. 2 shows the frequency ranges of various telecommunication systems in this area.

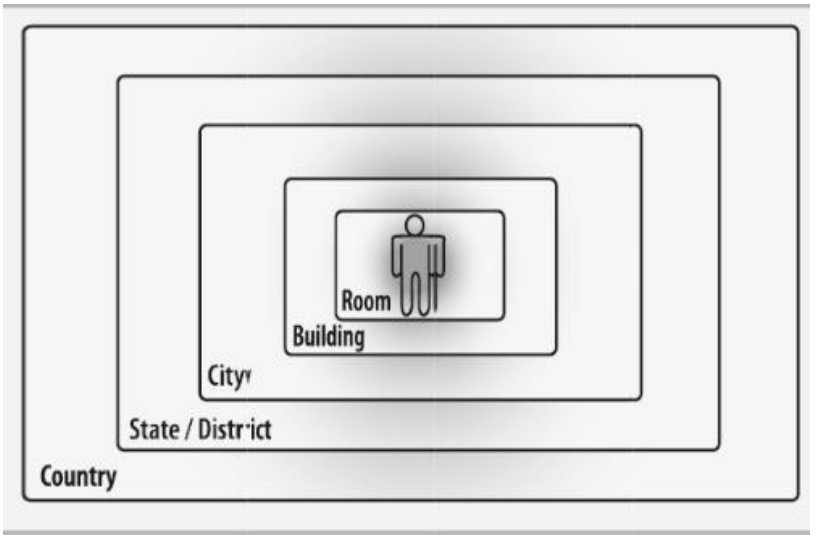


Fig. 1. Five main spatial ranges of different telecommunication systems.

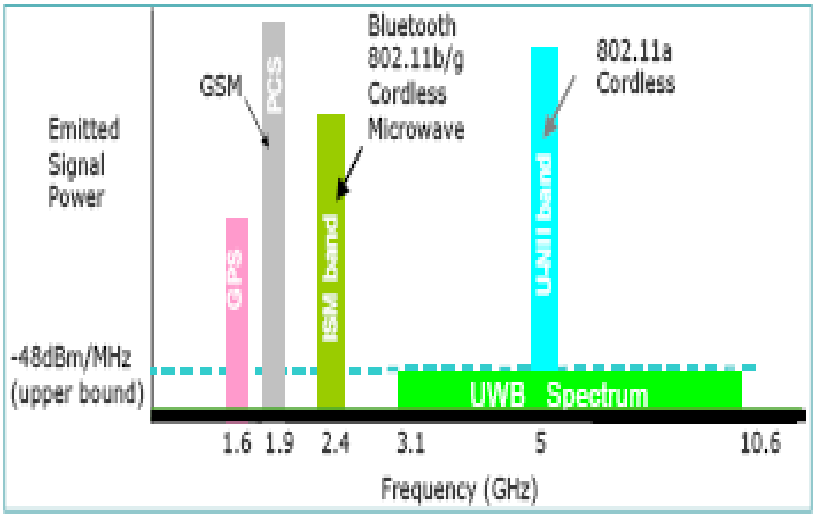


Fig. 2. Frequency range of various telecommunication systems.

2.1. Main classification of UWB from the application perspective

This classification is as follows: High-data-rate (HDR) communications, Low-data-rate (LDR) communications, Imaging, Automotive radar.

High-data-rate (HDR) communications

High-bit-rate communications is the first and most important group of UWB applications. IEEE 802.15.3a defines a bit rate higher than 110 Mbps for it, which can be expanded to 1 Gbps, and its applications cover the range of 3.1 GHz to 10.6 GHz.

Low-data-rate (LDR) communications

Another important category of low-rate communications is in the synchronous applications of general-purpose sensor networks, which are widely used in industry (Field bus), agriculture, and home use.

Imaging

This class is frequently used in ground penetrating radar (GPR), airport security walls, and metal detectors.

Automotive radar

As the name suggests, it is used as an obstacle detection sensor, for example in cars, at a frequency of 24 GHz, as shown in Fig. 3:

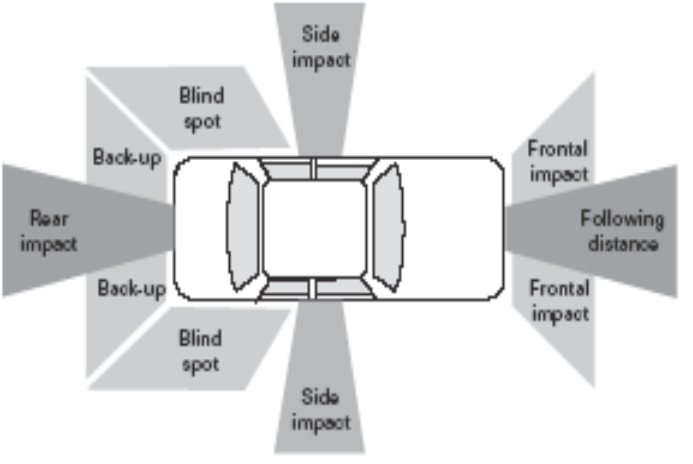


Fig. 3. Autonomous Motion Radars.

Among the characteristics and advantages mentioned in all 4 main classifications, we can mention their high speed, location adaptability, and low power consumption, which leads us to use more and more broadband systems in everyday life as PAN [6].

3. MATERIALS AND METHODS

3.1. Transmitted Signal in DS-UWB System

We have a direct sequence spread spectrum UWB system with N_u multiple access users. Fig. 4 shows the block diagram of the DS-PAM UWB system for a single user [7].

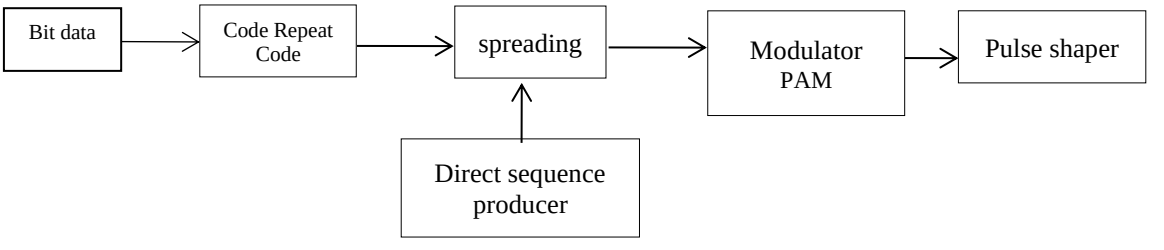


Fig. 4. Transmission diagram of DS-PAM-UWB system.

Each user has a pseudo-noise sequence that has N_c chip per data symbol (with T_f period) such $N_c T_c = T_f$ that N_c is the spread spectrum processing gain isAn example of a signal transmitted by the kth transmitter can be expressed as follows [7].

$$s_{tr}^{(k)}(t) = \sum_{j=-\infty}^{+\infty} \sum_{n=0}^{N_c-1} d_j^{(k)} C_n^{(k)} w_{tr}\left(t - jT_f - nT_c\right) \qquad (1)$$

Where index j is the frame number, t is the independent parameter of time, T_f is message symbol period, $\{D_j^{(k)}\}$ is binary information bit, $\{d_j^{(k)}\}$ is modulated data symbols of the kth user in frame j with $d_j^{(k)} = 2D_{\lfloor j/N_s \rfloor}^{(k)}$, N_s is pulse repetition time, T_c is chip time and $C_n^{(k)}$ is spreader chips and $w_{tr}(t)$ is transmitted pulse waveform.

3.2. Received signal in DS-UWB system

The signal received from the kth user at the receiver is equal to [7-8].

$$r(t) = \sum^{N_u} A_k s_{rec}^{(k)}(t - \tau_k) + n(t) \qquad (2)$$

A_k represents the attenuation of the received signal $s_{rec}^{(k)}(t - \tau_k)$ from the kth transmitter. τ_k Indicates the propagation delay time from the sender to the receiver. $n(t)$ and AWGN is noise that is modeled by $N(0, \sigma_n^2)$. The number of transmitters and the amplitude of the signals (A_k)are assumed to be constant. And we use the assumption of ideality of the channel. That is, each signal suffers only a fixed attenuation and a fixed delay. A system with an ideal channel changes the w_{tr} waveform of the transmitted pulse to the waveform of the w_{rec} received pulse at the receiver, which is due to the effect of the transmitter and receiver antennas. In references [9] and [10] the following mathematical model 3 is proposed for the received narrow pulse waveform.

$$w_{rec}(t + T_w/2) = \left[1 - 4\pi(t/\tau_m)^2\right]\exp(-2\pi(t/\tau_m)^2) \qquad (3)$$

Where T_w is the pulse period and τ_m is the pulse width parameter. This model is based on experimental measurements.

4. SIMULATION

Fig. 5 is an example of radio pulses used to transmit data in UWB systems.

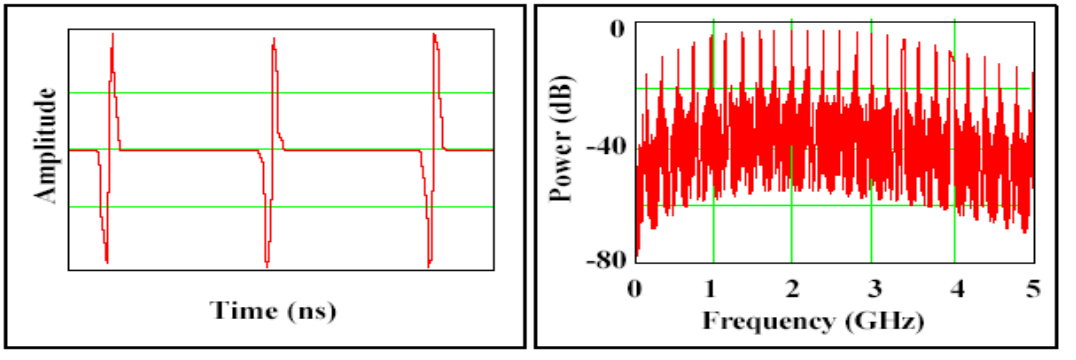


Fig. 5. A monocycle pulse train in the time and frequency domains.

The corresponding waveform is plotted in Fig. 6 for the received signal of the UWB system.

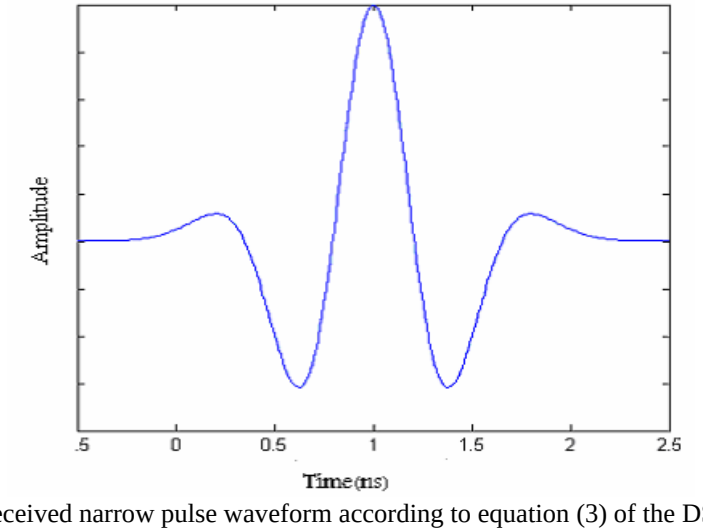


Fig. 6. The received narrow pulse waveform according to equation (3) of the DS-UWB system model.

4.1. Spreading models of UWB system

Two methods for randomizing pulses are direct sequence (DS) and time hopping (TH) techniques [11].

4.2. TH-UWB model in sending bit '0'

$$S_{tr}(t)=\sum_{i}\sum_{j=0}^{Ns-1} w_{tr}\left(t-iT_s-jT_f-c_{iN_s+j}T_c-d_i\,\delta\right) \quad (4)$$

$d_i=0$

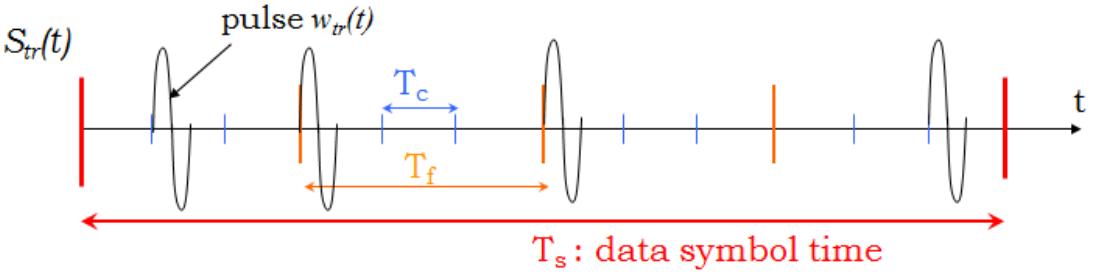


Fig. 7. TH-UWB model shape in sending bit '0'.

codeword $C=[1\,0\,0\,2]$, $N_h=2$

code period $N_p=4$

$T_s=N_s\cdot T_f$ *i.e.* $T_s=4\cdot T_f$ (5)

N_s : number of pulses per data symbol

$T_f\geq N_h\cdot T_c$ *i.e.* $T_f=3\cdot T_c$

4.3. TH-UWB model in sending bit '1'

$$S_{tr}(t)=\sum_{i}\sum_{j=0}^{Ns-1} w_{tr}\left(t-iT_s-jT_f-c_{iN_s+j}T_c-d_i\,\delta\right) \quad (6)$$

$d_i=1$

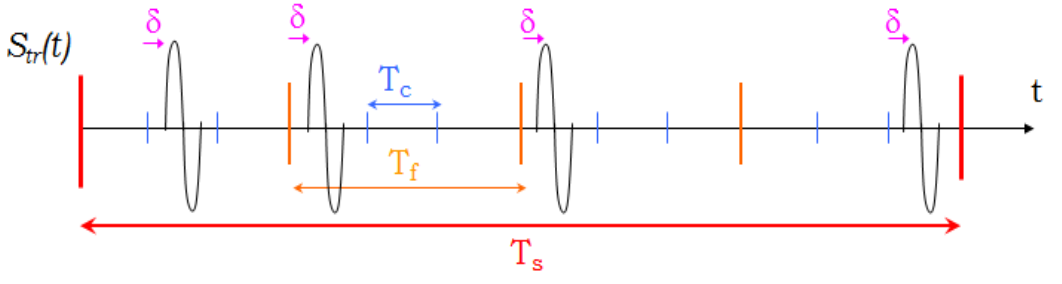


Fig. 8. TH-UWB model shape in sending bit '1'.

codeword $C=[1\,0\,0\,2]$, $N_h=2$

code period $N_p=4$

$T_s=N_s\cdot T_f$ *i.e.* $T_s=4\cdot T_f$ (7)

N_s : number of pulses per data symbol

$T_f\geq N_h\cdot T_c$ *i.e.* $T_f=3\cdot T_c$

4.4. DS-UWB model

$$s_{tr}(t) = \sum_{i} \sum_{n=0}^{N_c-1} d_i a_n w(t - iT_b - nT_c) \quad (8)$$

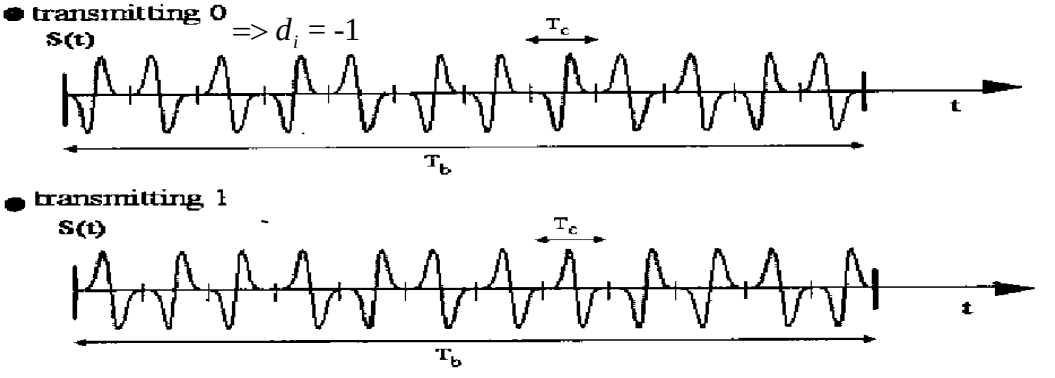


Fig. 9. How to create the spread waveform in the DS-UWB system?

So far, few researches have been conducted on image and signal transmission in the UWB system with two methods: the direct sequence technique of ultra-wideband with antipodal modulation (DS-UWB) and the time-hopping method of ultra-wideband with PPM modulation (TH-UWB) [12-13]. Other researches have been conducted on the AWGN channel and the performance of the UWB system with different modulations and access methods has been compared. The results show that the DS-UWB system using antipodal modulation has better performance with less complexity than the TH-UWB system with PPM modulation [14-15].

5. CONCLUSION

In this article, we examined the signals and methods used in military systems which is a secure and unlistenable method that is suitable for electronic warfare systems to communicate through these methods. In this article, the UWB system was described with two methods, direct sequence and frequency hopping techniques, with the form and method of the work. Also, the transmitted and received signal in the DS-UWB system was explained with a diagram. This research shows that the ultra-wideband system is a powerful wideband technique with high efficiency and low power consumption and is used in wireless communications for very high data rates. This article examines the signal transmission in the ultra-wideband system. This method is an effective idea. Wideband methods guarantee that they are resistant to interference and eavesdropping. The proposed signal transmission system maintains good signal quality under channel errors and exhibits low probability of interception (LPI) characteristics due to its low amplitude and transmission power, making it effectively unlistenable and difficult to detect.

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