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Ultra-wideband signals of ETSI frequency band for radiocommunication systems

***Abstract**. This paper focuses on time and frequency analysis as well as modulation techniques of Ultra Wideband (UWB) wireless communication signals due to ETSI standard. Current status of existing regulations and industrial standardization is discussed. Mathematical models of used electromagnetic pulses in UWB radiocommunication systems are presented. The synthesis proceedings of signal parameters due to spectrum requirements are reported and discussed. Provided analysis consider EMD problems related to transmission of short duration pulses.*

***Streszczenie.** W artykule dokonano analizy w dziedzinie czasu i częstotliwości oraz omówiono techniki modulacji sygnałów UWB systemów komunikacyjnych zgodnie ze standardem ETSI. Zaprezentowano opis matematyczny oraz omówiono ich syntezę. Uwzględniono zagadnienia EMD dotyczące transmisji. (**Sygnały ultraszerokopasmowe zgodne z pasmem pracy ETSI przeznaczone dla systemów radiokomunikacyjnych**).*

Keywords: Ultra-wideband technology, ETSI UWB spectrum mask, ultra-short pulse, modulation, EMD analysis.
Słowa kluczowe: technologia ultraszerokopasmowa, analiza EMD, widmo UWB wg ETSI, ultrakrótkie impulsy, modulacja, analiza EMD.

Introduction

Ultra-wideband communication provides a different approach to wireless technologies compared to conventional narrow band systems. The main concept behind UWB radio systems is to transmit pulses of very short duration, as opposed to traditional communication schemes which send sinusoidal waves. The aim of this paper is to present analysis and synthesis of UWB signals due to ETSI standard to illustrate EMD problems of wireless communication.

Regulation and standardization

All commercial radio systems are subject of different laws and regulations regarding power and spectral requirements. According the First Report and Order, issued in February 2002 by FCC, UWB devices can occupy radio spectrum from 3.1 − 10.6 GHz with power spectral density of EIRP limited to –41,3dBm/MHz [1]. The European approach is different. The European Telecommunications Standards Institute (ETSI)developed UWB regulation and standards for the European Union in 2007 specifying emission limits in range 6,0- 8,5GHz with emission power level up to –41,3dBm/MHz [2].

Pulse shape of UWB Signals

The UWB pulse waveform can be any function which meets the spectral mask requirements.

Ultra-wideband Gaussian pulse is the second derivative of Gaussian function and called Gaussian doublet. The shape of signal is described by the form [4]:

$$G(t) = A_G\left[1-\left(\frac{t}{\alpha}-\beta\right)^2\right]\exp\left[-\frac{1}{2}\left(\frac{t}{\alpha}-\beta\right)^2\right] \quad (1)$$

where: parameter A_G characterizes amplitude of pulse andα and β describe the time of pulse and its shifting in time domain, respectively. The spectrum of single UWB Gaussian pulse is given by formula[4]:

$$W_G(\omega) = A_G\sqrt{2\pi\alpha^2}(\omega\alpha)^2\exp\left[\frac{(\omega\alpha)^2}{-2}\right]\exp(-j\omega\alpha\beta) \quad (2)$$

The example of UWB Gaussian doublet for different parameters and related spectrum are shown in Fig.1,a.

a) b) c)

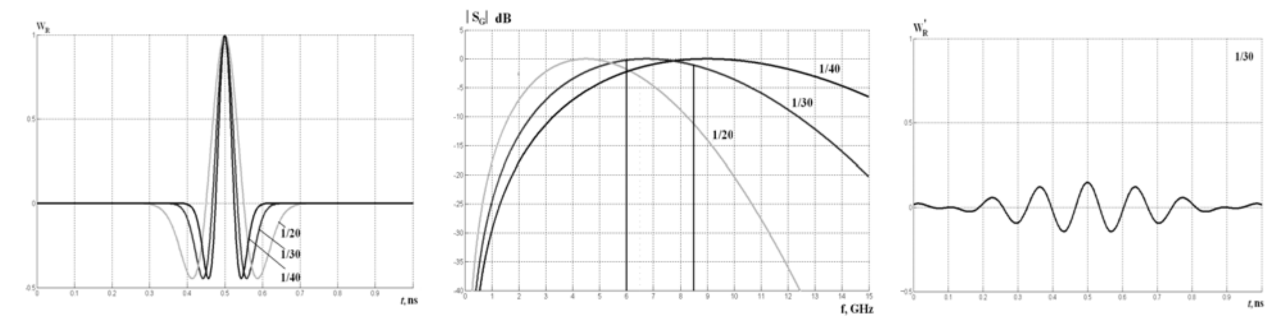

Fig.1. UWB Gaussian pulses for different parameters (α = 1/20, 1/30 and 1/40ns).

a) b) c)

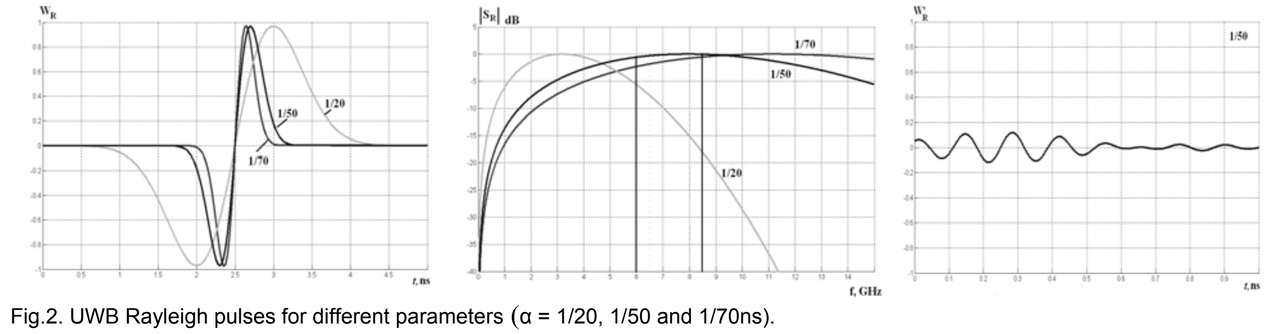

Fig.2. UWB Rayleigh pulses for different parameters (α = 1/20, 1/50 and 1/70ns).

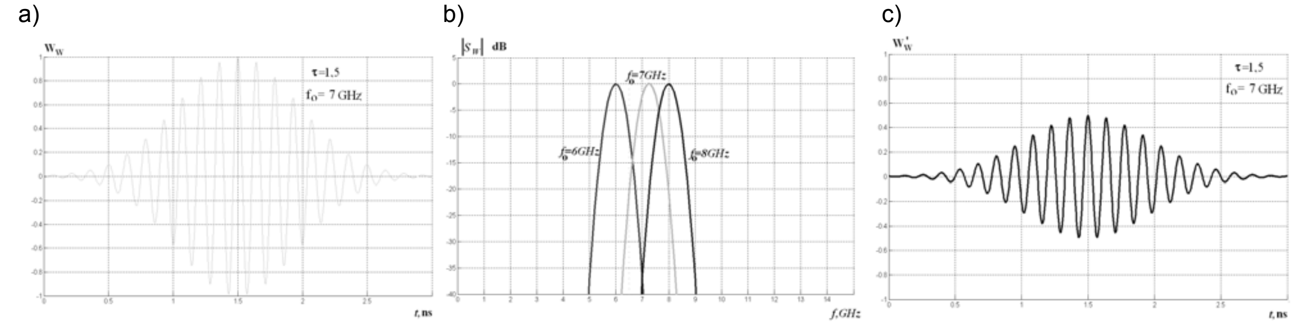

Fig.3. Wavelets with Gaussian envelope for different parameters f_o (constant $\tau = 1{,}5\text{ns}$).

The UWB Rayleigh pulse (the first derivative of Gaussian function) and can be expressed as [4]:

$$W_R(t) = A_R\left(\frac{t-\beta\alpha}{\alpha^2}\right)\exp\left[-\frac{1}{2}\left(\frac{t}{\alpha}-\beta\right)^2\right], \qquad (3)$$

$$S_R(\omega) = A_R\sqrt{2\pi}\left(\omega\alpha\right)\exp\left[\frac{(\omega\alpha)^2}{-2}\right]\exp\left[-j\left(\omega\alpha\beta+\frac{\pi}{2}\right)\right]. \qquad (4)$$

where: A_R describe amplitude of pulse andα and β like in previous formula define the duration and shifting in time domain of signal.

There are calculated analyzed pulses as the result of reconstruction from part of the spectrum in range from 6,0 to 8,5GHz. The pulse waveforms have got different shape than theoretical so it will be very difficult to distinguish them and detect transmitted information.

In practice the promising UWB signal due to requirements of ETSI power spectral density mask is wavelet. Wavelet is a sinusoidal wave limited by a specific envelope. Examined wavelets in the paper are limited by Gaussian envelope and can be given by formula [4]:

$$W_w(t) = \exp\left[-A\left(\frac{t-t_0}{\tau}\right)^2\right]\cos\left[2\pi\, f_0\left(t-t_0\right)\right] \qquad (5)$$

where: A describes amplitude of the wavelet, τ determines duration of the pulse and f_0 its frequency. Parameter t_0 defines position of the pulse on time axis.

Example of wavelet is presented in Fig.3,a and calculated spectra for different parameters shown in Fig. 3,b. It should be underline that despite of UWB Gaussian and Rayleigh pulses, wavelets' spectrum can be easily formed in whole frequency band 6.0-8,5GHz.

Modulation techniques for UWB

One pulse by itself does not transmit a lot of information. Information or data needs to be modulated onto a sequence of pulses. Data modulation in impulse radio is mainly based on simple modulation schemes like: pulse position modulation (PPM) and pulse amplitude modulation (PAM) or pulse shape modulation (PSM) [3]. Each pulse has a very wide spectrum, which meets power levels due to ETSI permission for UWB transmission.

The most common method of modulation presented in literature is pulse amplitude modulation. This technique is based on continuous transmission of very short-time signals where amplitude of the pulse varies contained digital information. As an example it can be treated pulse representing the information "1" has got amplitude 1 and the pulse representing the information "0" is described by amplitude in level of 0,5.

In practise there are some problems amplitude-modulated signal is more susceptible to noise interference than its larger amplitude counterpart. On the other hand more power is required to transmit the higher amplitude signal.

Other well-known technique for modulation is pulse position modulation. In this approach each pulse is delayed or sent in advance of a regular time scale. The information of the data bit is encoded by the position of the transmitted impulse with respect to a nominal position

There also other modulation schemes in this family. For example, on off keying (OOK) is a modulation technique where the absence or presence of a pulse means the digital information of "0" or "1", respectively. The difficulty of OOK is related to multipath. Echoes of the original pulses make it difficult to determine the absence of signal. An alternative to PAM and PPM modulations is Pulse Shape Modulation (PSM). In this technique different pulse shapes are used to represent information bits.

Conclusions

In a wireless network it is important to signals radiated by the various transmitters, which have influence on the performance of the radiocommunication system. Any practical UWB system designer should take into account spectral density mask requirements established by regulatory bodies as well as aspects of EMD problems related to transmission.

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