

RECOMMENDATION ITU-R SM.1755

Characteristics of ultra-wideband technology

(Questions ITU-R 226/1 and ITU-R 227/1)

(2006)

Scope

Information on technical and operational characteristics of UWB devices is needed to study the impact of these devices on other radiocommunication services. This Recommendation is giving the list of terms and definitions as well as general characteristics of UWB technology.

The ITU Radiocommunication Assembly,

considering

- a) that intentional transmissions from devices using ultra-wideband (UWB) technology may extend over a very large frequency range;
- b) that devices using UWB technology are being developed with transmissions that span numerous radiocommunication service allocations;
- c) that devices using UWB technology may therefore impact, simultaneously, many systems operating within a number of radiocommunication services, including those which are used internationally;
- d) that UWB technology may be integrated into many applications such as short-range indoor and outdoor communications, radar imaging, medical imaging, asset tracking, surveillance, vehicular radar and intelligent transportation;
- e) that it may be difficult to distinguish UWB transmissions from emissions or unintentional radiations in equipment that also contains other technologies, where different limits may apply;
- f) that applications using UWB technology may benefit sectors such as public protection, construction, engineering, science, medical, consumer applications, information technology, multimedia entertainment and transportation;
- g) that devices using UWB technology for certain applications may result in their high density deployment in some environments where stations of radiocommunication services have already been or will be deployed;
- h) that the spectrum requirements and operational restrictions for devices using UWB technology may vary according to their application;
- j) that devices using UWB technology normally operate on a non-protected, non-interference basis;
- k) that information on the technical and operational characteristics of devices using UWB technology and applications is needed to study the impact of devices using UWB technology on radiocommunication services; and

l) that information on the terms and definitions associated with UWB technology, and devices using UWB technology, is needed,

recommends

1 that the terms, definitions and abbreviations contained in Annex 1 should be used in describing UWB technology and devices using UWB technology;

2 that the general characteristics contained in Annex 2 should be used to characterize UWB technology;

3 that the technical and operational characteristics contained in Annex 3 should be considered in studies relating to the impact of devices using UWB technology (those devices that are not presently recognized as operating under allocations to radiocommunication services) on radiocommunication systems;

4 that the following Notes will be considered as part of this Recommendation.

NOTE 1 – Administrations authorizing or licensing devices using UWB technology should ensure, pursuant to the provisions of the Radio Regulations, that these devices, will not cause interference to and will not claim protection from, or place constraints, on the radiocommunication services of other administrations as defined in the Radio Regulations and operating in accordance with those Regulations.

NOTE 2 – Upon receipt of a notice of interference to the radiocommunication services referred to in Note 1 above from devices using UWB technology, administrations should take immediate action(s) to eliminate such interference.

Annex 1

Ultra-wideband terms, definitions and abbreviations

1 Ultra-wideband terms and definitions

In describing ultra-wideband (UWB) technologies and devices, the following terms have the definitions indicated:

Ultra-wideband technology: technology for short-range radiocommunication, involving the intentional generation and transmission of radio-frequency energy that spreads over a very large frequency range, which may overlap several frequency bands allocated to radiocommunication

services. Devices using UWB technology typically have intentional radiation from the antenna with either a –10 dB bandwidth of at least 500 MHz or a –10 dB fractional bandwidth greater than 0.2.¹

UWB transmission: radiation generated using UWB technology.

Activity factor: the fraction of time during which a device using UWB technology is transmitting.²

Impulse: a surge of unidirectional polarity that is often used to excite a UWB band-limiting filter whose output, when radiated, is a UWB pulse.

Pulse: a radiated short transient UWB signal whose time duration is nominally the reciprocal of its –10 dB bandwidth.

Radar imaging device: a device used to obtain images of obstructed objects. This includes in-wall and through-wall detection, ground penetrating radar, medical imaging, construction and home repair imaging, mining, and surveillance devices.

Ground penetrating radar (GPR) device: a radar imaging device that operates typically when in contact with or within close proximity to the ground for the purpose of detecting or mapping subsurface structures. While primarily used for examining “underground”, the term “ground” can be expanded to mean any lossy dielectric material.

Wall radar imaging device: a sensor that is designed to examine and map the interior of walls. The wall is usually made of a concrete structure or similar dense impermeable material that absorbs much of the impinging radio-wave energy. Typical applications include reinforced concrete building walls, retaining walls, tunnel liners, the wall of a mine, the side of a bridge, or another physical structure that is dense enough and thick enough to dissipate and absorb most of the signal strength transmitted by the imaging device.

Through-wall radar imaging device: a sensor used to transmit energy through an opaque structure such as a wall or a ceiling to detect the movement or location of persons or objects that are located on the other side. These devices are deliberately designed to maximize energy transfer through an opaque structure. This category may include products such as stud locators that are designed to locate objects behind walls that are not sufficiently thick or dense enough to absorb the transmitted signal, such as gypsum, plaster or similar walls.

UWB communication device: a short-range communication device to transmit and/or receive information between devices.

UWB measurement device: a device used to measure distance or position.

¹ The –10 dB bandwidth B_{-10} and –10 dB fractional bandwidth μ_{-10} are calculated as follows:

$$B_{-10} = f_H - f_L$$

$$\mu_{-10} = B_{-10}/f_C$$

where:

f_H : highest frequency at which the power spectral density of the UWB transmission is –10 dB relative to f_M

where:

f_M : frequency of maximum UWB transmission

f_L : lowest frequency at which the power spectral density of the UWB transmission is –10 dB relative to f_M ,

$f_C = (f_H + f_L)/2$: centre frequency of the –10 dB bandwidth.

The fractional bandwidth may be expressed as a percentage.

² For multiple devices, see § 3 of Annex 3.

Medical imaging device: a sensor used to detect the location or movement of objects inside the body of a human or an animal.

Location sensing and tracking: a network of sensors installed at precisely surveyed locations to measure the location of a remote device using UWB technology.

Vehicular radar device: a radar device mounted on land transportation vehicles to detect the location and movement of persons or objects near a vehicle.

Multi-functional device: a device that enables multiple UWB applications, such as radar imaging, vehicular radar, location sensing and tracking, and communication functions, using a common platform.

NOTE 1 – The terms necessary bandwidth, occupied bandwidth, unwanted emissions, out-of-band domain and spurious domain, as defined in Article 1 of the Radio Regulations, are generally not relevant to ultra-wideband transmissions.

2 Abbreviations related to ultra-wideband

DS-CDMA	Direct sequence-code division multiple access
DSSS	Direct sequence spread spectrum
GPR	Ground penetrating radar
MB-OFDM	Multiband OFDM
OFDM	Orthogonal frequency division multiplexing
PPM	Pulse position modulation
PRF	Pulse repetition frequency
PSD	Power spectral density
RBW	Resolution bandwidth
SRR	Short-range radar
UWB	Ultra-wideband
WPAN	Wireless personal area network

Annex 2

General characteristics of UWB technology

1 Potential high-density use

UWB technology can potentially be integrated into many applications that could offer benefits to the public, consumers, businesses, and industries. For example, UWB could be integrated into applications for improved public safety through the use of vehicular radar devices for collision avoidance, airbag activation and road sensors, short-range high data rate communication devices, tagging devices, liquid level detectors and sensors, surveillance devices, location determination devices, and as a replacement for wired high data rate connections over short distances. Though most devices using UWB technology would operate at very low power, the many potential UWB applications could result in high density of devices using UWB technology in certain environments such as office and business cores.

2 High data rate

Devices using UWB technology may operate at very low power levels and can support applications involving multiple users at high data rates (e.g. short-range wireless personal area networks (WPANs) at data rates greater than 100 Mbit/s).

3 Secure communications

UWB signals are potentially more covert and potentially harder to detect than non-UWB radiocommunication signals. This is because UWB signals occupy a large bandwidth, can be made noise-like, and can communicate with a unique randomizing timing code at millions of bits per second. Each bit is typically represented by a large number of pulses of very low amplitude typically below the noise level. These features result in secure transmissions with low probability of detection (LPD) and low probability of interception (LPI).

4 Robust communications

Devices using UWB technology are generally designed to have large processing gain, a measure of a device's robustness against interference.

5 Communication system capacity

The theoretical system capacity of any communication system, including a UWB system, may be calculated from the Shannon relation:

$$C = B \log_2 \left(1 + \frac{\int P_d(f) df}{\int_B N_0 df} \right) \quad (1)$$

where:

- C : channel capacity (bit/s)
- B : channel bandwidth (Hz)
- $P_d(f)$: signal power spectral density (W/Hz (or dBm/Hz))
- N_0 : noise power spectral density (W/Hz (or dBm/Hz)).

The Shannon relation shows that the theoretical channel capacity of a UWB communication system is very large because of its bandwidth, even though its power spectral density is very low and restricted in amplitude.

6 UWB power spectra

UWB signals generated by basic pulse position modulation have numerous spectral peaks. Randomization is used to make the signal more noise-like. The shape of the power spectral density of an emitted UWB signal is usually controlled by an appropriate choice of the pulse shape, modulation technique, timing jitter, and pseudo-noise code sequences used for randomization of the UWB pulses. The spectral shape of a UWB transmission is additionally defined by components such as antennas.

6.1 Requirement for a large bandwidth

UWB transmissions spread over a very large frequency bandwidth in comparison with non-UWB transmissions. Among the challenges is finding a suitable spectrum and a way to introduce UWB applications without causing interference into radiocommunication services.

6.2 Pulse shaping

Pulse shaping enables control of the frequency content of the UWB transmission, which can reduce interference into radiocommunication systems. It is fundamental that pulse shapes for UWB communications must have a zero-mean because an antenna cannot radiate signals at zero frequency. Creative designs of pulse shapes and a variety of modulation options can be incorporated in UWB communication system designs.

6.3 UWB modulations

For UWB pulses, information can be coded using pulse position modulation (i.e. binary or M -ary PPM), pulse amplitude modulation (i.e. binary or M -ary PAM), bi-phase modulation of pulse polarity (i.e. BPM), modulation by a doublet of a positive pulse followed by a negative pulse or vice versa, and pulse on-off keying (OOK). Furthermore, combinations of these modulations can be used. As an example, a hybrid bi-phase and PPM modulation scheme has been shown to eliminate discrete components of the UWB PSD.

UWB signal transmission involves pulse shaping, spreading, modulation, and randomization. Appropriate hybrid modulation and randomization of a UWB signal makes its spectrum appear like additive white Gaussian noise. The choice of the UWB modulation scheme impacts the power spectral density of the radiated signal and consequently its impact on radiocommunication services. In particular, the impact of the discrete components of the PSD can be mitigated or they can be eliminated.

6.3.1 Pulse position modulation (PPM)

PPM is a UWB modulation technique by which data are represented by time shifts from a reference time. Binary PPM has been a popular early choice and appears relatively early in the literature on UWB communications. PPM modulated UWB signals may have discrete spectra that carry no information, and may cause interference. This can be greatly mitigated by randomizing the positions of the pulses using pseudo-noise sequences, which whitens the spectrum significantly. This randomization for PPM has often been called time hopping (TH). Another way to reduce the interference from PPM UWB signals is to increase the period of the pulse train. This decreases the frequency of occurrence of discrete components of the PSD.

One form of a pulse position modulation is multiband impulse (MB-I) UWB which comprises a method whereby the spectrum is divided into sub-bands. Impulses of very short duration are sent in frequency and time-hopped sequences over several sub-bands. Polarity or bi-phase modulation of data is used with the time-frequency hopped impulses. A multidimensional modulation space may be employed by filling out a matrix of time and frequency with impulses. Complex and efficient (with respect to E_b/N_0) coherently detected modulations are also possible. The noise-like quality of the signal results from the time-frequency hopping.

6.3.2 Bi-phase modulation

For a binary phase modulation, a specific pulse shape and its negative are used to represent a zero and a one. Bi-phase modulation yields an advantage of 3 to 6 dB over PPM in multipath-free environments. It also has a peak power to average power ratio of less than 3 (compared to a sine wave with a ratio of 2).