# UWB COMMUNICATIONS

## 1. GENERAL

Ultra-wideband (UWB) is a radio transmission with a spectrum that occupies more than 20 percent of the center frequency, or a minimum of 500 MHz while adhering to certain output power limits. UWB technology offers flexibility, robustness, and good ranging capabilities, making it well suited for applications that need a high data rate over a short transmission range.

A 14 February 2002 Report and Order by the Federal Communications Commission (FCC) authorizes the unlicensed use of UWB in 3.1–10.6 GHz. This is intended to provide an efficient use of scarce radio bandwidth while enabling both high data rate personal area network (PAN) wireless connectivity and longer-range, low data rate applications as well as radar and imaging systems

Because the goal of UWB is to transmit higher bandwidth signals at low power output, the range is not meant to surpass what is called a Wireless Personal Area Network (WPAN), and general maximum distance for transmission is 30 feet or 10 meters.

## 2. HISTORICAL PERSPECTIVE

UWB communications is not a new technology. It was first employed by G. Marconi in 1901 to transmit Morse code sequences across the Atlantic Ocean using spark gap radio transmitters. However, the benefit of a large bandwidth and the capability of implementing multi-user systems provided by electromagnetic pulses were never considered at that time.

Approximately 50 years after G. Marconi, modern pulse-based transmission gained momentum in military applications in the form of impulse radars. The genesis of UWB technology is a result of the research works in time-domain electromagnetics that began in 1962. The concept was to characterize linear, time-invariant (LTI) systems by their output response to an impulse excitation, instead of the more conventional means of swept frequency response (i.e., amplitude and phase measurements versus frequency). This output response is known as impulse response h(t) of the LTI system. Output response y(t) of an LTI system to any input response x(t) is determined the convolution theorem:

$$y(t) = \int_{-\infty}^{\infty} b(\tau)\, x(t-\tau) d\tau$$

It was not possible to measure the impulse response directly until the development of impulse excitation and measurement techniques. Once these techniques were in place, it became obvious that these could be used for short pulse radar and communication systems.

Many of the communication technologies were first experimented and used in military applications for some decades, only to be used for commercial applications at a much later time. UWB is no exception to this trend. From the 1960s to the 1990s, this technology was restricted to military and Department of Defence (DoD) applications under classified programs such as highly secure communications. In 1978, G.F. Ross and C.L. Bennett applied these techniques for radar and communication applications. This technology was referred to as base band, carrier-free, or impulse until the late 1980s and was termed UWB by the U.S. DoD around 1989. By that time, UWB theory had experienced 30 years of development. Although UWB technology is old, its application for communication is relatively new. The recent advancements in microprocessor and fast switching in semiconductor technology has made UWB ready for commercial applications. Therefore, it is more appropriate to consider UWB as a new name for a long-existing technology.

## 3. HIGH DATA RATES, LOW POWER

Shannon's formula expresses the channel capacity of a band-limited information transmission channel with additive white, Gaussian noise as

$C = BW \log_2(1 + S/N)$ bits/second.

The essential elements of "Shannon's formula" are that

(1) the channel bandwidth sets a limit to how fast symbols can be transmitted over the channel. The signal-to-noise ratio; and

(2) S/N) determines how much information each symbol can represent.

The signal and noise power levels are measured at the receiver end of the channel. Thus, the power level is a function of both transmitted power and the attenuation of the signal over the transmission medium (channel).

Shannon's capacity limit equation shows capacity increasing as a function of BW faster than as a function of signal to noise ratio (SNR). Shannon's equation shows that increasing channel capacity requires linear increases in bandwidth while similar capacity increases would require exponential increases in power. Therefore, UWB technology is capable of transmitting high data rates using very low power.

## 4. UWB COMMUNICATIONS SYSTEMS

Fig. 1 shows a general model of a single-link communication system. It includes three major blocks of communication, viz., a transmitter, the channel, and a receiver. The input data to the transmitter is the message to be sent from the source to the destination. The main function of the transmitter is to send out the message to the channel, which is done with the help of an antenna. An antenna is a means for radiating (transmitting antenna) or receiving (receiving antenna) radio waves. Data modulation is the systematic variation of some properties of the carrier signal such as amplitude, phase, or frequency according to the message signal. There are several reasons for modulating a message using a carrier: a) ease of radiation, b) to reduce noise and interference, and c) for transmission of several messages over a single channel. Besides these, other functions of a transmitter are mixing, filtering and amplification.

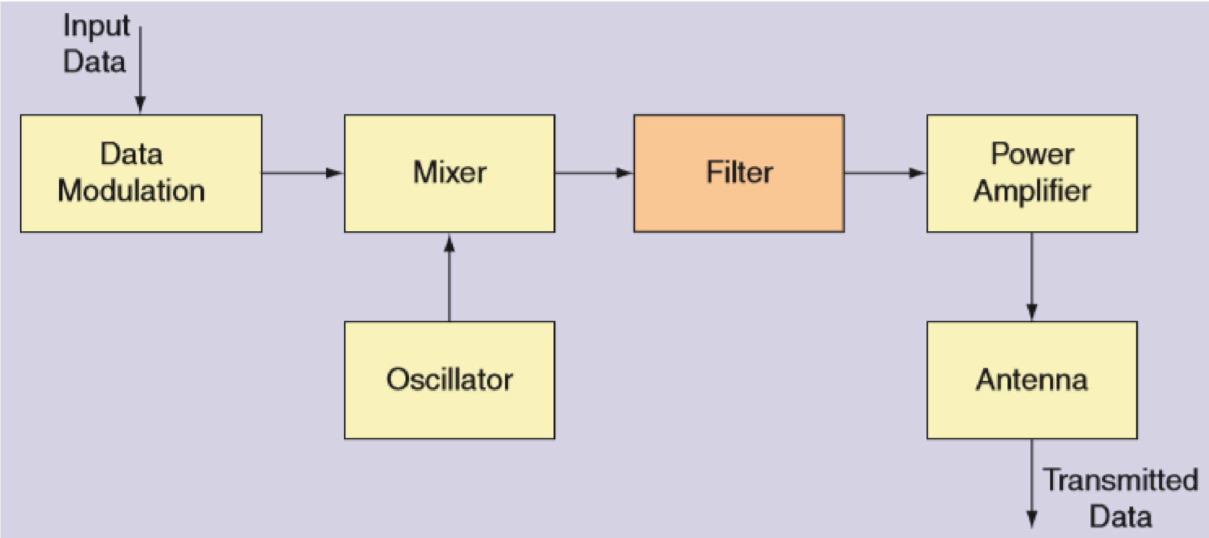


**Fig. 1** Block diagram of a typical a narrowband Transmitter

UWB communications are fundamentally different from all other communication techniques because it employs extremely narrow radio frequency (RF) pulses, which are generated from the UWB pulse generator, to communicate between transmitters and receivers. Utilizing short-duration pulses as the building blocks for communications directly generates a very wide bandwidth, as we know that a very short signal in time domain produces a very wide spectrum signal in frequency domain from Fourier analysis. A significant difference between traditional radio transmissions and UWB radio transmissions is that traditional transmissions transmit information by varying the power/frequency/ and/or phase of a sinusoidal wave also known as modulation while UWB transmissions transmit information by generating radio energy at specific time instants and occupying large bandwidth through pulse position or time division or code division multiplexing.

position

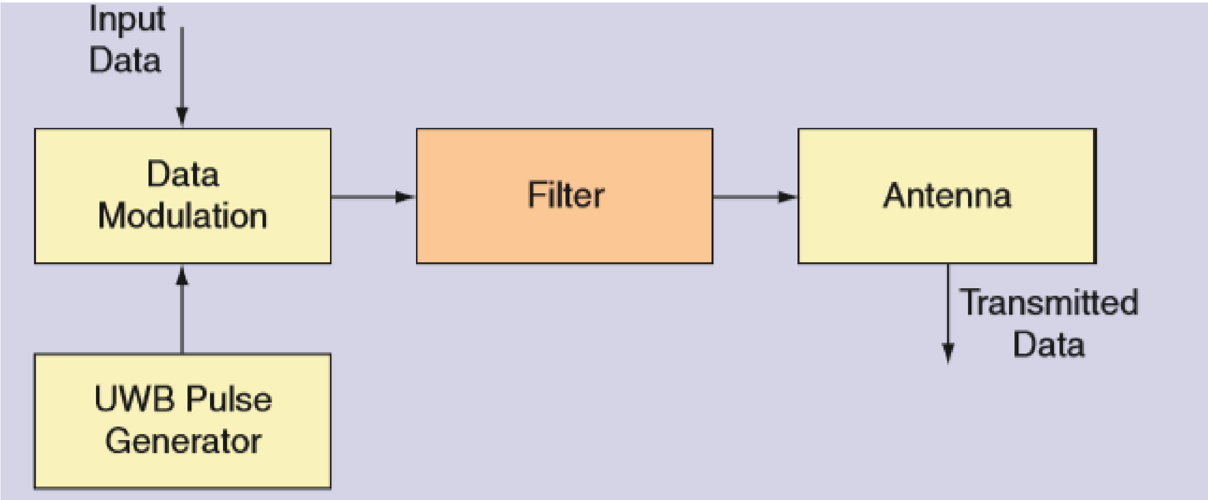


**Fig. 2** Block diagram of a typical UWB Transmitter

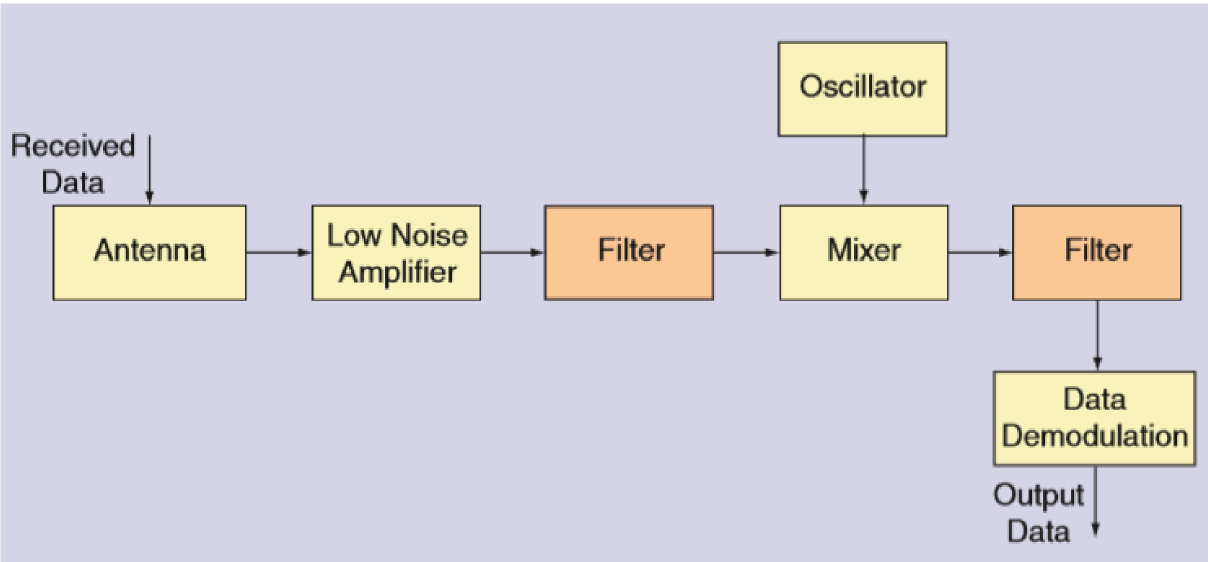


**Fig. 3** Block diagram of a typical a narrowband Receiver

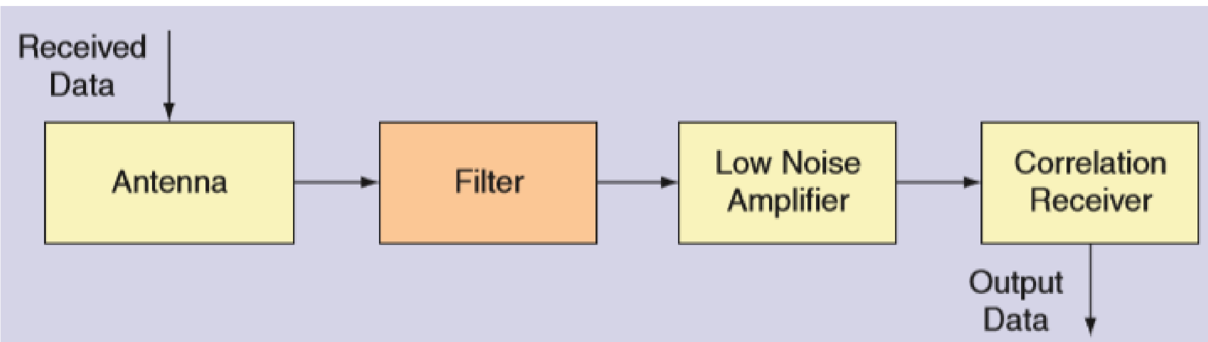

**Fig. 4** Block diagram of a typical UWB Receiver

## 5. ADVANTAGES OF UWB SYSTEMS

UWB has a number of features which make it attractive for consumer communications applications. In particular, UWB systems

(I) UWB have potentially low complexity and low cost as compared with other wideband technologies. Unlike conventional systems, the UWB transmitter produces a very short time-domain pulse which is able to propagate without the need for an additional RF (radio frequency) mixing stage. The RF mixing stage takes a baseband signal and "injects" a carrier frequency or translates the signal to a frequency which has desirable propagation characteristics. The very wideband nature of the UWB signal means that it spans frequencies commonly used as carrier frequencies. The signal will propagate well without the need for additional up-conversion. The reverse process of down-conversion is also not required in the UWB receiver. Again, this means the omission of a local oscillator in the receiver, and the removal of associated complex delay and phase tracking loops. The very wideband nature of the UWB signal means that it spans frequencies commonly used as carrier frequencies. The signal will propagate well without the need for additional up-conversion. The reverse process of down-conversion is also not required in the UWB receiver. Again, this means the omission of a local oscillator in the receiver, and the removal of associated complex delay and phase tracking loops.

(II) UWB have a noise-like signal spectrum. Due to the low energy density and the pseudo-random (PR) characteristics of the transmitted signal, the UWB signal is noise-like which makes unintended detection difficult. Whilst there is some debate, it appears that the low-power, noise-like UWB transmissions do not cause significant interference to existing radio systems.

(III) UWB are resistant to severe multipath and jamming. Because of the large bandwidth of the transmitted signal, very high multipath resolution is achieved. The large bandwidth offers (and also requires) huge frequency diversity, which together with the discontinuous transmission makes the UWB signal resistant to severe multipath propagation and jamming/interference.

(IV) UWB have very good time-domain resolution allowing for location and tracking applications. The very narrow time-domain pulses mean that UWB radios are potentially able to offer timing precision much better than GPS and other radio systems. Together with good material penetration properties, UWB signals offer opportunities for short-range radar applications such as rescue and anti-crime operations, as well as in surveying, and in the mining industry.

## DISADVANTAGES OF UWB SYSTEMS

UWB systems have some inherent problems due to the huge spectrum (7.5 GHz bandwidth from 3.1–10.6 GHz) allocation. Some of the disadvantages of this promising technology includes: Interference:

• Interference is one of the major challenges in the design of UWB communication systems. Since UWB communication devices occupy a large frequency spectrum, interference mitigation or avoidance with coexisting users is one of the key issues of UWB technology. Existing electronic devices include current IEEE 802.11a WLAN devices (working at 5.150–5.825 GHz) and 2.4 GHz industrial, scientific, and medical (ISM) band devices, that are used by wireless personal area networks like Bluetooth. Complex signal processing:

• For narrowband systems that use carrier frequency, frequency-division multiplexing is very straightforward and the development of a narrowband device needs to consider the frequency bands directly affecting it and minimizing interference to out-of-band systems by emission control techniques like filtering and wave shaping. For carrier-less transmission and reception, every narrowband signal in the vicinity is a potential interferer and also every other carrier-less system. So any carrier-less system has to rely on relatively complex and sophisticated signal processing techniques to recover data from the noisy environment. Bit synchronization time:

• Since pulses with picoseconds precision are used in UWB, the time for a transmitter and receiver to achieve bit synchronization can be as high as a few milliseconds. So, the channel acquisition time is very high, which can significantly affect performance, especially for intermittent communications.

## APPLICATIONS OF UWB

There are myriad of applications for UWB technology. Some, like UWB radars, have been in use for many years while others are new potential applications viz., UWB sensor networks, UWB RFID, and UWB positioning systems. Some of these applications involve:

1. transferring large amounts of data in short-range for home or office networking
2. short range voice, data, and video applications television set and computer
3. helicopters and aircrafts that would otherwise have too many interfering multipath components
4. anticollision vehicular radar
5. through wall imaging used for rescue, security, and medical applications