[0001]

This invention generally relates to networks of communications devices, in particular ultra wideband (UWB) communications devices.

[0002]

Techniques for UWB communication developed from radar and other military applications, and pioneering work was carried out by Dr G. F. Ross, as described in US3728632U.S. Pat. No. 3,728,632. Ultra-wideband communications systems employ very short pulses of electromagnetic radiation (impulses) with short rise and fall times, resulting in a spectrum with a very wide bandwidth. Some systems employ direct excitation of an antenna with such a pulse which then radiates with its characteristic impulse or step response (depending upon the excitation). Such systems are referred to as "“carrier free"” since the resulting rf emission lacks any well-defined carrier frequency. However other UWB systems radiate one or a few cycles of a high frequency carrier and thus it is possible to define a meaningful centre frequency and/or phase despite the large signal bandwidth. The US Federal Communications Commission (FCC) defines UWB as a —10dB−10 dB bandwidth of at least 25% of a centre (or average) frequency or a bandwidth of at least 1.5GHz1.5 GHz; the US DARPA definition is similar but refers to a —20dB−20 dB bandwidth. Such formal definitions are useful and clearly differentiates UWB systems from conventional narrow and wideband systems but the techniques described in this specification are not limited to systems falling within this precise definition and may be employed with similar systems employing very short pulses of electromagnetic radiation.

[0003]

UWB communications systems have a number of advantages over conventional systems. Broadly speaking, the very large bandwidth facilitates very high data rate communications and since pulses of radiation are employed the average transmit power (and also power consumption) may be kept low even though the power in each pulse may be relatively large. Also, since the power in each pulse is spread over a large bandwidth the power per unit frequency may be very low indeed, allowing UWB systems to coexist with other spectrum users and, in military applications, providing a low probability of intercept. The short pulses also make UWB communications systems relatively unsusceptible to multipath effects since multiple reflections can in general be resolved. Finally UWB systems lend themselves to a substantially all-digital implementation, with consequent cost savings and other advantages.

~~Figure 1a~~[0004]

FIG. 1 a shows a typical UWB transceiver 100. This comprises an transmit/receive antenna 102 with a characteristic impulse response indicated by bandpass filter (BPF) 104 (although in some instances a bandpass filter may be explicitly included), couples to a transmit/receive switch 106.

[0005]

The transmit chain comprises an impulse generator 108 modulatable by a baseband transmit data input 110, and an antenna driver 112. The driver may be omitted since only a small output voltage swing is generally required. One of a number of modulation techniques may be employed, typically either OOK (on-off keying i.e. transmitting or not transmitting a pulse), M-ary amplitude shift keying (pulse amplitude modulation), or PPM (pulse position modulation i.e. dithering the pulse position). Typically the transmitted pulse has a duration of <~~lns~~1 ns and may have a bandwidth of the order of gigahertz.

[0006]

The receive chain typically comprises a low noise amplifier (LNA) and automatic gain control (AGC) stage 114 followed by a correlator or matched filter (MF) 116, matched to the received pulse shape so that it outputs an impulse when presented with rf energy having the correct (matching) pulse shape. The output of MF 116 is generally digitised by an analogue-to-digital convertor (ADC) 118 and then presented to a (digital or software-based) variable gain threshold circuit 120, the output of which comprises the received data. The skilled person will understand that forward error correction (FEC) such as block error coding and other baseband processing may also be employed, but such techniques are well-known and conventional and hence these is omitted for clarity.

~~Figure lb~~[0007]

FIG. 1 b shows one example of a carrier-based UWB transmitter 122, as described in more detail in ~~US~~U.S. Pat. No. 6,026,125 (hereby incorporated by reference). This form of~~-~~ transmitter allows the UWB transmission centre frequency and bandwidth to be controlled and, because it is carrier-based, allows the use of frequency and phase as well as amplitude and position modulation. Thus, for example, QAM (quadrature amplitude modulation) or M-ary PSK (phase shift keying) may be employed.

[0008]

Referring to ~~Figure lb~~FIG. 1 b, an oscillator 124 generates a high frequency carrier which is gated by a mixer 126 which, in effect, acts as a high speed switch. A second input to the mixer is provided by an impulse generator 128, filtered by an (optional) bandpass filter 130. The amplitude of the filtered impulse determines the time for which the mixer diodes are forward biased and hence the effective pulse width and bandwidth of the UWB signal at the output of the mixer. The bandwidth of the UWB signal is similarly also determined by the bandwidth of filter 130. The centre frequency and instantaneous phase of the UWB signal is determined by oscillator 124, and may be modulated by a data input 132. An example of a transmitter with a centre frequency of ~~1.5GHz~~1.5 GHz and a bandwidth of ~~400MHz~~400 MHz is described in ~~US~~U.S. Pat. No. 6,026,125. Pulse to pulse coherency can be achieved by phase locking the impulse generator to the oscillator.

[0009]

The output of mixer 126 is processed by a bandpass filter 134 to reject out-of-band frequencies and undesirable mixer products, optionally attenuated by a digitally controlled rf attenuator 136 to allow additional amplitude modulation, and then passed to a wideband power amplifier 138 such as a MMIC (monolithic microwave integrated circuit), and transmit antenna 140. The power amplifier may be gated on and off in synchrony with the impulses from generator 128, as described in US'125U.S.'125, to reduce power consumption.

Figure lc[0010]

FIG. 1 c shows a similar transmitter to that of Figure ibFIG. 1 b, in which like elements have like reference numerals. The transmitter of Figure lcFIG. 1 c is, broadly speaking, a special case of the transmitter of Figure lbFIG. 1 b in which the oscillator frequency has been set to zero. The output of oscillator 124 of Figure lbFIG. 1 b is effectively a dc level which serves to keep mixer 126 always on, so these elements are omitted (and the impulse generator or its output is modulated).

Figure ld[0011]

FIG. 1 d shows an alternative carrier-based UWB transmitter 142, also described in US6U.S. Pat. No. 6,026,125. Again like elements to those of Figure lbFIG. 1 b are shown by like reference numerals.

[0012]

In the arrangement of Figure ldFIG. 1 d a time gating circuit 144 gates the output of oscillator 124 under control of a timing signal 146. The pulse width of this timing signal determines the instantaneous UWB signal bandwidth. Thus the transmitted signal UWB bandwidth may be adjusted by adjusting the width of this pulse.

[0013]

Ultra-wideband receivers suitable for use with the UWB transmitters of Figures lbFIGS. 1 b to ld1 d are described in USU.S. Pat. No. 5,901,172. These receivers use tunnel diode-based detectors to enable single pulse detection at high speeds (several megabits per second) with reduced vulnerability to in-band interference. Broadly speaking a tunnel diode is switched between active and inactive modes, charge stored in the diode being discharged during its inactive mode. The tunnel diode acts, in effect, as a time-gated matched filter, and the correlation operation is synchronised to the incoming pulses.

~~Figure le~~[0014]

FIG. 1 e shows another example of a known UWB transmitter 148, as described for example in ~~US~~U.S. Pat. No. 6,304,623 (hereby incorporated by reference). In ~~Figure le~~FIG. 1 e a pulser 150 generates an rf pulse for transmission by antenna 152 under control of a timing signal 154 provided by a precision timing generator 156, itself controlled by a stable timebase 158. A code generator 160 receives a reference clock from the timing generator and provides pseudo-random time offset commands to the timing generator for dithering the transmitter pulse positions. This has the effect of spreading and flattening the comb-like spectrum which would otherwise be produced by regular, narrow pulses (in some systems amplitude modulation may be employed for a similar effect).

~~Figure if~~[0015]

FIG. 1 f shows a corresponding receiver 162, also described in ~~US'623~~U.S.'623. This uses a similar timing generator 164, timebase 166 and code generator 168 (generating the same pseudo-random sequence), but the timebase 166 is locked to the received signal by a tracking loop filter 170. The timing signal output of timing generator 164 drives a template generator 172 which outputs a template signal matching the transmitted UWB signal received by a receive antenna 174. A correlator/sampler 176 and accumulator 178 samples and correlates the received signal with the template, integrating over an aperture time of the correlator to produce an output which at the end of an integration cycle is compared with a reference by a detector 180 to determine whether a one or a zero has been received.

~~Figure 1g~~[0016]

FIG. 1 g shows another UWB transceiver 182 employing spread spectrum-type coding techniques. A similar transceiver is described in more detail in ~~US~~U.S. Pat. No. 6,400,754 the contents of which are hereby explicitly incorporated by reference.

[0017]

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