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An Optoelectronic RF Wireless Communications System

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Summary

Spread-spectrum (SS) wireless links offer many distinct advantages including the ability to share the RF spectrum among many users, interference rejection, signal hiding, and low probability of intercept. On the transmit side, an information signal with bandwidth, B_I, is spread into a larger RF bandwidth, B_{RF}. On the receive side, the signal is typically correlated with a matched signal, collapsing it back to its initial bandwidth, B_I. Hence, the receiver's output signal to noise ratio (SNR) can be increased over the input SNR by up to G_p (dB). G_p is the processing gain [1] given by, G_p (dB) $\approx 10 \log (B_{RF}/ B_I)$.

In applications such as ultra-secure or high speed wireless LAN it may be difficult to achieve the high processing gains that are necessary with conventional electronics.

However, RF bursts with bandwidths from gigahertz to terahertz can now be generated and sampled opto-electronically with sub-picosecond optical-to-electrical jitter. These generation and gating capabilities form the basis of our impulse-modulated (IM), time-hopped (TH) SS communications system. The large available bandwidth will allow significant SS processing gain to be realized, even in high data rate communications systems. Furthermore, by the use of pulsed Q-switched diode lasers, we expect to eventually realize the system in a compact package.

Figure 1 shows our initial IM architecture. A sequence of impulses is generated first in the optical domain by a mode-locked laser/regenerative amplifier. The regenerative amplifier is synchronized to a pseudorandom bit sequence (PRBS) generator. The PRBS generator is configured to produce a time-hopped (TH) sequence of optical pulses. The TH optical pulse train is converted to an electrical pulse train in a photodiode, as shown in figure 1(a).

The resulting TH electrical pulse sequence is then amplified and amplitude shift keyed by the binary message. Each electrical pulse from the photodiode represents a single bit of the message. Finally, the keyed RF pulse sequence is shaped in a filter, amplified, and radiated by a wideband antenna.

The receiver architecture is shown in figure 1(b). A synchronized TH optical sequence identical to that of the transmitter is used to perform correlation. The TH optical train is converted to a reference TH electrical pulse train in a photodiode. An RF mixer performs correlation via multiplication of the filtered RF signal by the reference TH signal. The correlated signal is then sent through a low-pass filter and threshold detector which converts it back to a digital signal.

The principle of this system was proven at a 1200 b/s data rate in an across-the-laboratory wireless packet system. With an RF bandwidth of 0.35 GHz, we expected processing gains of up to 55 dB. Hence, with a transmit power of less than 1 μW, a 10 mW CW jamming signal produced no noticeable degradation in packet error rate.

While this system produced the necessary processing gain, some improvements were necessary. The primary drawbacks were the dynamic range limit imposed by the microwave mixer in the receiver and the use of an inefficient RF amplifier in the transmitter to amplify a TH signal with a low duty factor. Thus, we redesigned the system to take advantage of the large dynamic range and efficiency offered by photoconductive switching. We will describe the progress on the development and present initial results from the improved system shown in Fig. 2.

The improved transmitter uses a photoconductive switch bowtie antenna [2] to directly generate a high peak power wideband RF pulse. Narrowband digital to wideband

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RF conversion is accomplished simply by switching the antenna bias voltage polarity in response to the input digital information. The photoconductive switch bowtie structure performs the following three tasks: capacitive energy storage, RF pulse-forming, and RF radiation [2].

The improved receiver is shown in Fig. 2(b). The RF signal received by the bow-tie antenna is sent to a matched filter. The matched filter is being realized in a microwave transmission line structure.

The matched filter maximizes the peak signal to noise ratio of the incoming signal. Hence, correlated reception is completed by sampling the output of the matched filter with a GaAs photoconductive switch at the peak of each pulse which emerges from the filter. The sampled signal is sent to a threshold detector which converts the signal back to a digital signal.

Conventional broadband receivers are often subject to front-end saturation caused by strong narrowband signals within the RF bandpass and a limited dynamic range; our receiver is designed to mitigate this problem by performing correlation near the receiver antenna terminals with a photoconductive switch. Since a photoconductive switch has a dynamic range limited only by the breakdown voltage of the switching gap, the benefits of processing gain will not be compromised by dynamic range limitations

In these first demonstrations synchronization was maintained by operating both the transmitter and receiver with pulses from the same master laser. However, independent synchronization can be realized by the use of a pair of receivers operating in a sliding correlator configuration. With the help of timing reference signals received from the global positioning system, it is estimated that initial synchronization can be acquired in a fraction of a second.

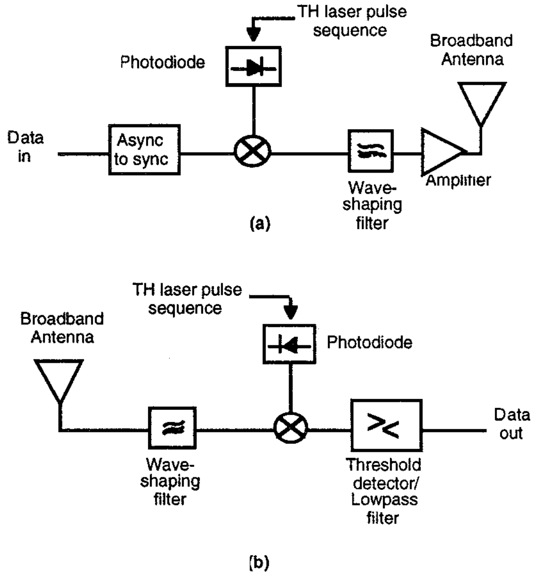

Figure 1. Block diagram of (a) opto-electronic time-hopped spread-spectrum transmitter and (b) opto-electronic correlation receiver.

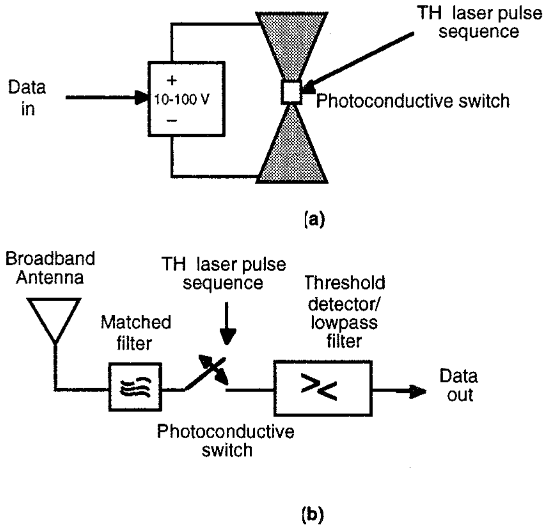

Figure 2. Block diagram of (a) photo-conductive transmitter and (b) photoconductive correlation receiver.

References

[1] Robert C. Dixon, *Spread Spectrum Systems with Commercial Applications*, New York: John Wiley & Sons Inc., 1994.

[2] Eric. E. Funk, and Chi H. Lee, "Free-space Power Combining and Beam Steering of Ultra-Wideband Radiation Using an Array of Laser Triggered Antennas," *IEEE Transactions on Microwave Theory and Techniques*, vol. 44, pp. 2039-2044, 1996.