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Regards,
Eric Funk, Ph. D.
Partner, Red Mountain Radio LLC
eric@redmountainradio.com
970-325-2158 ×12

A PHOTOCONDUCTIVE CORRELATION RECEIVER FOR WIRELESS DIGITAL COMMUNICATIONS

**Eric E. Funk, Scott Ramsey, Chi H. Lee,
and John Craven***

Joint Program for Advanced Electronic Materials,
Department of Electrical Engineering,
and
Laboratory for Atomic, Molecular, and Optical Science and Engineering,
University of Maryland,
College Park, MD 20742

*U.S. Department of Defense

ABSTRACT

We demonstrate an impulse radio architecture which employs a GaAs photoconductive switch in performing correlated reception. Results show a bit-error-rate of better than 10^{-8} at 38 Mb/s and excellent interference rejection.

I. INTRODUCTION

Wireless digital communications systems now commonly employ spread-spectrum (SS) modulation and correlated reception. Due to the demand for higher data rates and greater security, spread-spectrum bandwidths of approximately 1 GHz are now being considered. Signal processing at these bandwidths is difficult and costly with conventional electronics. Hence, some unique approaches are being considered.

Impulse radio [1] is one such technique that is now being investigated. Impulse radio is based on the transmission of precisely timed short RF pulses, typically one to three RF cycles long, near a 1 GHz center frequency. The presence or position of these pulses is used to transmit information; there is no carrier conversion involved.

Impulse radio offers a potentially less expensive/easier means of realizing large (> 100 MHz) spread-spectrum bandwidths and, in turn, higher processing gains when compared to digital signal processing (DSP) techniques presently in use in direct sequence (DS) and frequency hopped (FH) systems. A well designed impulse radio system can exploit the large available processing gain for the purposes of signal security. In addition, the large signal bandwidth has been shown to effectively mitigate frequency selective fading [2] which leads to an overall reduction in the fade margin of the link budget.

However, some of these advantages are traded against some difficult receiver design requirements. Most importantly, the impulse radio receiver must accept interference over the full signal bandwidth. Interference from the full VHF and UHF broadcast and two-way radio bands can easily mask the impulse radio signal in a receiver with poor dynamic range.

We believe that correlated reception [3] using photoconductive gating is an ideal approach to dealing with the impulse radio signal. Photoconductive switching technology [4], with its high speed, low jitter, and large dynamic range is ideally suited to both generating and gating these RF bursts. In this work, we demonstrate the performance of a photoconductive switch as the key component in a 38 Mb/s correlation receiver.

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II. DEMONSTRATION SYSTEM

The transmitter and correlation receiver are shown in Fig. 1. In the transmitter, a clock signal drives a step-recovery diode (SRD), generating a train of unipolar pulses at 38 MHz repetition rate. These unipolar pulses are then on/off keyed (OOK) by a synchronized 38 Mb/s binary message. A single pulse is used per bit *for this demonstration*, however multiple pulses per bit could also be used with a DS code. Finally, the OOK pulse train is amplified in a broadband amplifier and radiated by a broadband reciprocal bow-tie antenna. Alternatively, the transmitted signal could be generated by use of a photoconductively switched antenna [5].

In the receiver, a reciprocal bowtie antenna feeds a gating photoconductive switch. The fast gating function acts as a correlator on the received impulse train. The gated signal is amplified in a broadband low-noise amplifier and passed through a microwave crystal diode detector before threshold detection.

Our photoconductive switch consists of a small interdigitated capacitor on an undoped GaAs microstrip line with finger width and spacing of 30 μm. The capacitance is low enough to give more than 20 dB of off-state isolation. The switch is triggered by a 810 nm Ti:sapphire laser pulse train which is synchronized to the incoming RF pulses. A trigger energy of 900 pJ/pulse is used with the soft-focus of a 15 cm focal length lens.

The gating function is most easily characterized under DC bias, where the switch produces a 500 ps full width at half maximum pulse. Shorter gating could be obtained by use of other photoconducting materials, however, for this application, the 500 ps window is more than sufficient.

There are three primary features of our switch. First, the switch mitigates interference by providing isolation between the antenna and detector during the large interval when there is no impulse radio signal present. Second, during the brief intervals when a signal is present, it provides a gated signal to the threshold detector. Third, it ensures a large dynamic range, by providing a 1 dB input compression point of greater than 24 dBm (measured at 1 GHz). While certain high dynamic range mixers can match this compression point, the required LO drive signal is large enough to cause significant coupling of the LO into the IF port, rendering their performance unacceptable in a carrier-free baseband system.

The experimental setup described above was tested in our laboratory by performing an uncoded bit-error-rate test (BERT) with a 38 Mb/s pseudo-random bit sequence (PRBS). In order to assess resistance to narrowband interference, a strong 1 GHz CW signal was added to the environment from a nearby transmitter.

With a received power of -35 dBm at the antenna terminals (measured by integration of the received waveform) and no added interference from the CW transmitter, a bit-error-rate (BER) of better than 10^{-8} was measured. A typical return-to-zero (RZ) "eye diagram" measured at the output of the gate is also shown as an inset in Figure 2.

A 1 GHz CW signal was then added to the environment from a nearby transmitter. Figure 2 shows the measured BER vs. the signal-to-interference ratio (SIR) at the receiving antenna. Note that excellent BER performance is achievable even with an SIR of less than 0 dB. For example, an SIR of only –6 dB is required to achieve a BER of 10^{-6}. At this BER, the interference power is 1.2 μW. This shows how the processing gain that results from the large bandwidth of our signal can be used to provide interference resistance.

The results and evaluation discussed above show the capability of the photoconductive receiver to mitigate narrowband interference in an impulse radio system. This feature is essential since spectrum is shared with many other comparatively narrowband signals. We emphasize that this measurement was specifically designed to assess resistance to a very strong interferer and, by no means, represents the sensitivity limit.

III. CONCLUSION

Unlike most conventional spread-spectrum receivers, our receiver performs correlated reception of the signal at the receiver front-end on a broadband (700 MHz RF bandwidth) signal. This is accomplished without high-speed A/D converters which would otherwise limit the dynamic range of the system. We can also achieve one-to-one improvement in interference resistance by lowering our data rate. For example, we could operate at 12 kb/s with a SIR of -41 dB.

Although a laboratory laser was used for this initial demonstration, the switch geometry is being re-designed to operate with compact lasers such as Q-switched laser diodes[6]. This would make such a system realizable in a very compact package.

We also note that in this work, we have attempted to focus on interference-limited reception in the case of ideal synchronization. As such, we have run the transmitter and receiver from the same clock. Ultimately, the photoconductive switch would serve as a drop-in technology in a system where a tracking loop is employed to maintain wireless synchronization of clocks.

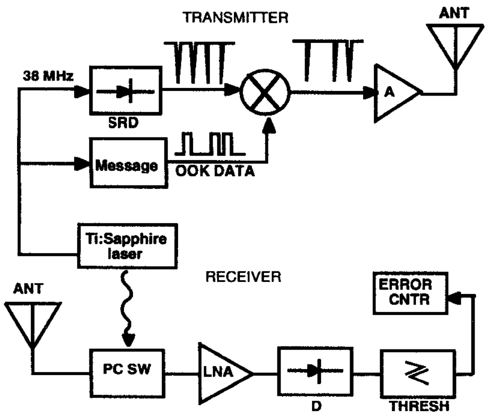

Figure 1. System architecture. SRD: step-recovery diode circuit, A: power amplifier, ANT: broadband antenna, PC SW: photoconductive switch, LNA: low noise amplifier, D: diode detector, THRESH: threshold detector.

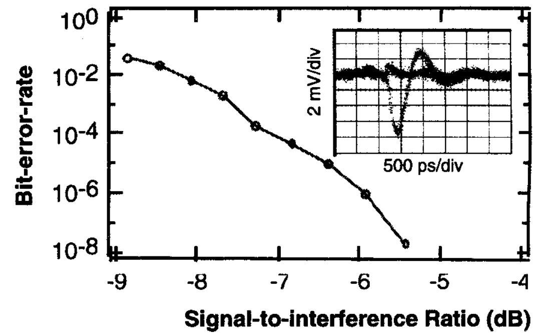

Figure 2. 38 Mb/s system performance. Measured BER vs. SIR signal-to-interference ratio (SIR). Inset: Eye-diagram measured at output of the photoconductive switch.

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