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

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Time Coherent Ultra-Wideband Pulse Generation Using Photoconductive Switching

Eric E. Funk, Stephen E. Saddow,* Louis J. Jasper, Jr.,* and Chi H. Lee

University of Maryland
Department of Electrical Engineering
College Park, MD 20742

*Army Research Laboratory
Weapons Technology Directorate
2800 Powder Mill Road
Adelphi, MD 20783

Abstract

Jitter-free photoconductive (PC) switching is employed to generate a jam-resistant, time-coherent ultra-wideband (UWB) pulse train. The power from multiple PC switch triggered antenna elements is combined in free space to produce a steerable UWB beam.

Summary

When immunity to noise is required, an ultra-wideband (UWB) communications link is a good solution because of the inherently large process gain that is available [1]. Perhaps the easiest method of generating UWB radiation is by using a fast switch to generate an impulse or step. However, the usefulness of such a technique for conveying information is limited by the jitter of the switch. The photoconductive (PC) switch has been previously employed for the generation of high-power pulses [2,3], but the switch has typically been operated near its breakdown limits, where current filamentation gives way to unreliable and high-jitter performance.

In this work we have demonstrated the benefits of operating the PC switch at lower powers where it operates without optical to electrical jitter. The PC switch is used as the central component in an integrated antenna element (Fig. 1), which combines the function of energy storage with UWB generation and radiation. When triggered by a mode-locked laser/regenerative amplifier, a train of temporally coherent (jitter-free) UWB pulses is radiated. We show how the temporal coherence of the pulses can be used to recover the signal in the presence of a strong jamming signal, and to trigger a small array of three elements (Fig. 1) to produce a steerable beam of UWB radiation.

The top and bottom halves of each of the three bow-tie elements were electrically isolated through a Si PC switch and charged to the voltage $\pm V_0$, as illustrated in Fig. 1. A ~5-μJ, 1.053-μm, 126-ps full-width at half maximum laser pulse train (not shown) is focused onto each of the three PC switches. The inter-element trigger pulse arrival times are controllable by optical delay lines employing prisms mounted on precision translation

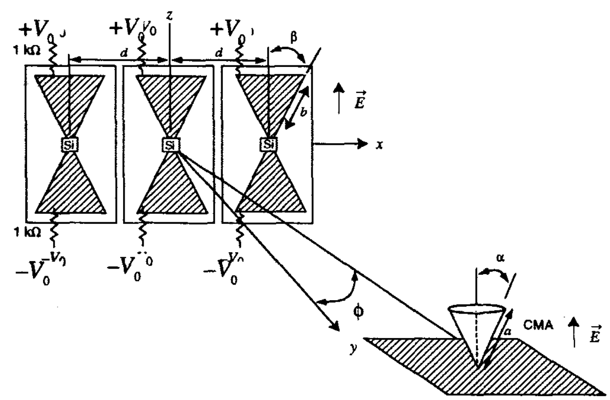

Figure 1. Schematic diagram of experimental setup showing spatial relationship between three bowtie antennas and field probe. Arrival time of optical pulses controlled by true optical time delay. b = 5.7 cm, β = 27 °, a = 1.3 cm (array experiment) a = 2.7 cm (jamming experiment), α = 47°, and d = 10 cm.

stages. A short z-polarized conical monopole field probe is placed 1 m from the array at an azimuth angle of ϕ and elevation angle of 0°.

Each antenna element stores energy as a consequence of its static capacitance. The fast-closing (ps), slow-opening (μs) PC switch provides a step-like electrical excitation to the antennas. The received pulse has the shape of a bipolar pulse corresponding to the second derivative of the step-function and the first derivative of the radiated field. The pulses radiated by each of the elements are coincident at only two azimuth angles, $\phi = \phi_1$ and $\phi = \phi_1 + 180°$, as determined by the inter-element optical trigger delay. At this angle, the individual fields add together coherently to give a total field that is three times larger (and a peak-power that is nine times larger) than that radiated by a single element; thus, in an N-element array, the peak power scales as N^2. For example, Fig. 2 shows the evolution of the received pulse shape as we scan the field probe from $\phi = 0°$ to $\phi = 90°$ when the inter-element optical trigger delay is adjusted to give a maximum amplitude at $\phi \approx 40°$.

In another experiment, the signal from a single element was received in the presence of a strong narrowband jamming (1-GHz) signal. The degraded UWB signal could be improved (as shown in Fig. 3) by triggering the receiver (sampling oscillo-scope) in synchronization with the oscillator used to mode-lock the laser. The signal could further be improved by averaging multiple traces together. In a practical system, synchronization would be achieved by locking the receiver to the jitter-free transmitted pulse train with a phased-locked loop. Another method of improving the signal-to-noise ratio is to perform a cross-correlation in the receiver. The correlation trace shown in Fig. 3 was obtained, using software, by a cross-correlation between the jammed UWB pulse and an unjammed UWB pulse (stored in memory). In a practical receiver, cross-correlation would take place in real-time with a dedicated piece of hardware. All of these techniques rely on the time-coherence of the UWB pulse train.

References

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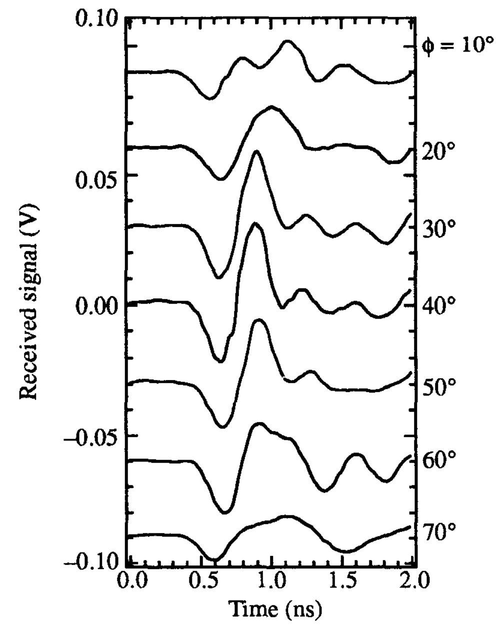

Figure. 2. Received signal at various azimuth angles, ϕ, with relative optical trigger delay of 160 ps between adjacent antenna elements.

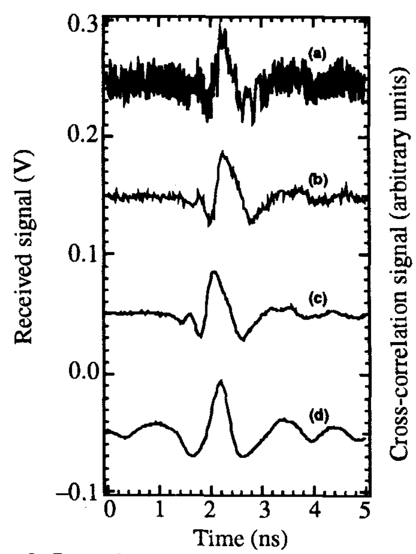

Figure 3. Jamming resistance demonstration: (a) externally triggered sampling oscilloscope receiving jammed signal; (b) signal-to-noise ratio improvement with 32 traces averaged in synchronization; (c) unjammed signal; and (d) signal-to-noise ratio improvement using software cross-correlation.