Optoelectronic True Time Delay Beamsteering for RF Burst Spread-Spectrum Signal Transmission

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Abstract

Proven properties of spread-spectrum (SS) RF communications such as interference rejection and large information carrying capability have led to increased use of SS signaling schemes in RF wireless communications systems. Whether the system engineer seeks to increase information carrying capability or operate in a low signal-to-noise ratio environment, communications with a broadband RF signal can increase performance. One might envision an RF bandwidth that is greater than 50% of the RF center frequency. However, in practice, spreading bandwidths are often only a few percent of the center frequency or carrier frequency.

A larger spreading bandwidth brings with it the problem of designing directional antennas that will faithfully transmit and receive the SS signal. Conventional phase-steered antenna arrays do not solve the problem since they lead to frequency dependent steering (beam-squint) of the broadband signal. However, photonic beamsteering using true-time delay can be a viable solution to the beam-squint problem.

We are now in the process of developing a complete photonically controlled time hopped (TH) spread spectrum communications system. The system transmits and receives short precisely timed bursts of only a few RF cycles. The short bursts lead to SS processing gains [1] on the order of the reciprocal of the transmission duty cycle. The receiver architecture employs picosecond photoconductivity for signal correlation. The system details are discussed in our previous paper [2]. In this paper we focus on an interesting approach to generating, transmitting, and steering the broad-band burst mode signals.

In a conventional photonic true-time delay (TTD) phased-array architecture, we could generate our RF signal at a remote transmitter. The RF signal would amplitude modulate a

CW laser carrier. The modulated laser beam would be fed to each antenna of an array via fiber-optic links. The RF signal would then be recovered at each antenna via a photodetector. Frequency independent beam-steering would be accomplished by varying the effective optical path length between the RF modulated laser and each antenna in the array. However, such an architecture has significant dynamic range limitations arising from laser relative intensity noise (RIN) and modulation nonlinearity. Since our SS signal to be transmitted is a low duty cycle broadband burst, the transmitted signal will have a large peak-to-average power ratio. This implies that the components in the transmission path (including the photonic TTD) must exhibit a large dynamic range. Our target dynamic range of 60 dB/GHz cannot be handled by this conventional approach.

Instead, we have developed a unique approach. Rather than transmitting our RF signal through photonic or electronic beamsteering circuitry, we generate our RF burst *at* each antenna of our array (see Fig. 1). The burst is generated in jitter-free synchronization with a timing cue from a pulsed laser. By adjusting the relative arrival time of the laser pulse at each of the antennas in an array, the transmitted RF burst can be steered. Thus we have the benefit of TTD beam steering without the dynamic range constraint of the photonics. As far as the SS signal is concerned, the information to be transmitted is imbedded in the *timing* of the RF pulses; hence the information is sent by controlling the timing of the optical pulses.

Figure 2 shows the setup of a single array element. A bow-tie antenna is used with an Si photoconductive switch bridging the gap between the upper and lower halves of the antenna. The bow-tie antenna also functions as a capacitive storage pulsed power system. While the switch is open, the top and bottom halves charge to opposite polarity, with energy being stored in the static capacitance of the antenna. When the switch is illuminated by a laser pulse, the switch impedance drops on a sub-nanosecond time scale, launching a traveling wave that propagates outward from the switch. An RF burst is radiated as the travelling wave is launched and as it is reflected from the ends of the antenna.

We tested this architecture with a three element array and performed optical time delay in order to demonstrate TTD beamsteering of an RF burst. Results from these tests will be presented. We have found that for our SS system application, this simple approach allows us to circumvent the usual photonic system technological challenge of linearity while exploiting the jitter-free capability of photoconductive switching.

References

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

[2] Eric E. Funk, Stephen E. Saddow, Louis J. Jasper, Jr., and Chi H. Lee "Optically Controlled Spread-Spectrum RF Data Link," *1996 IEEE-MTT-S International Microwave Symposium*, June 17-21, 1996, Paper # TH3D-5.

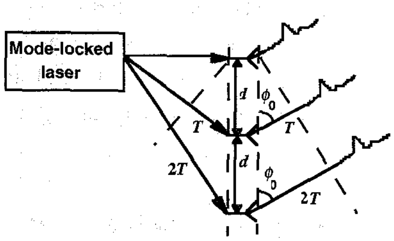

Figure 1. Array of three laser triggered antennas configured for true-time delay beamsteering. Each antenna is a bow-tie antenna as shown in Figure 2.

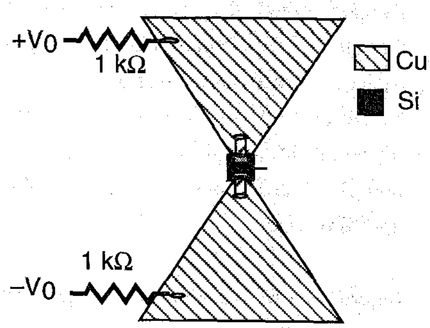

Figure 2. Single bow-tie element on printed circuit board.