Review

AETHER WIRE UWB SYSTEM

- SYSTEM REVIEW

  Transmission uses **coded sequences of Gaussian impulses** and reception uses **correlation**. The code sequences are pseudo-random codes like those used for direct-sequence spread spectrum systems. Correlation is used to discriminate a particular code sequence from other signals. For communication, the simplest modulation of code sequences is "**antipodal**" modulation: either a given code sequence or its inverse is sent to represent one bit of information.

- ULTRA-WIDEBAND SIGNALS

  The development of the ultra-wideband **Large-Current Radiator** (LCR) http://umunhum.stanford.edu/~morf/ss/ss/UWB_CDROM_1/PAPERS/BB_RADAR.PDF antenna has made it possible to radiate nanosecond wide impulses with inexpensive CMOS chips. The LCR is a current-mode antenna which radiates outwards from the surface of a flat square conductor.

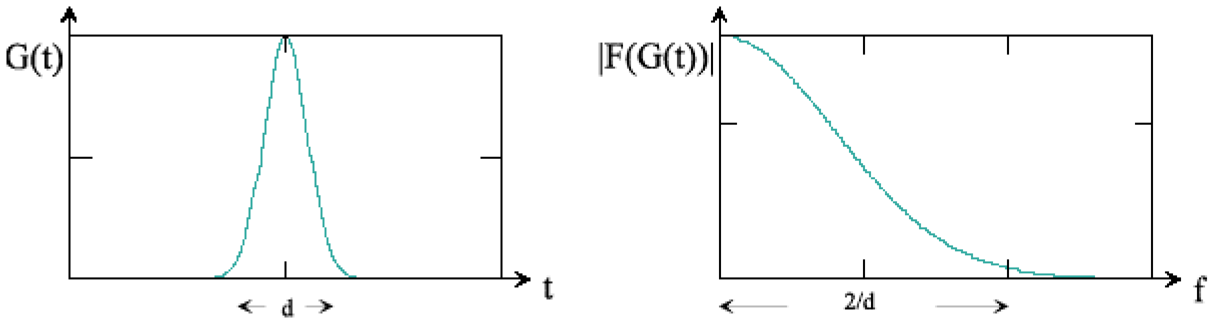

FIGURE 1 A Gaussian impulse of width **d** and its amplitude spectrum.

- CODING

  Ideally, codes should be chosen so that the correlation of a code sequence against itself will have a single peak, making it easy to determine when the proper sequence has arrived. **Maximal Sequence codes** and **Complementary codes** http://www.intersil.com/data/an/an9/an9850/an9850.pdf approach this ideal. The cross-correlation of one code sequence with a different sequence should not have correlation peaks.

- DOUBLETS

1. Due to the LCR, we have to use the “doublets”.

   The minimum total current occurs when, starting from zero current, a negative impulse immediately follows a positive impulse, and vice versa. We refer to such pairs of impulses as "**doublets**" (Fig. 2).

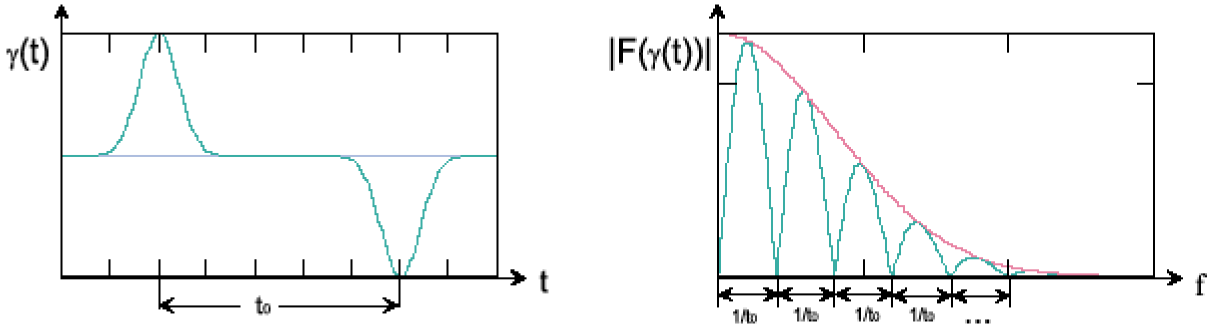

FIGURE 2 A "doublet" with impulse separation **t0** and its amplitude spectrum.

2. For each bit in any code sequence, we generate a doublet which starts with either a positive impulse or a negative impulse. If the autocorrelation of a sequence of impulses has a single correlation peak, then the autocorrelation of the same sequence encoded using doublets has a **central peak bracketed by two negative peaks**. As discussed later, this complex pattern is much easier to recognize than a single peak, especially when the signal is contaminated with considerable noise.
3. An additional advantage of using doublet-encoded sequences is that the choices of the time separation between impulses in a doublet and the time separation between doublets allows the frequency spectrum to be manipulated (Fig. 2). For instance, **nulls can often be placed at frequencies which harbor high intensity narrowband interference.**

- TIME-INTEGRATING CORRELATOR

1. The usual method for implementing correlators "slides" the analog input signal past the reference code sequence. This Sliding Correlator requires some sort of memory for the input signal, such as charge coupled devices (CCD's), http://www.ecn.purdue.edu/WBG/Device_Research/CCDs/Index.html surface acoustic wave (SAW) devices, http://www3.sympatico.ca/colin.kydd.campbell/ all-pass filters, etc. All of these are unsuited for our purposes. ADC's and CCD's are too slow, and CCD's are also too power consumptive, SAW's have limited programmability.
2. We have chosen to use a **Time-Integrating Correlator** (TIC). The reference code sequence is shifted past the changing analog input signal and the product of the code and signal is summed in a set of analog integrators (Fig. 3).
3. The advantage of a TIC is that all of the difficulties of achieving precise and distortionless analog delay are replaced by the simple task of **delaying a digital code sequence**. The disadvantage of a TIC is that a **separate integrator is needed** for what represents one sample of the output of a Sliding Correlator.

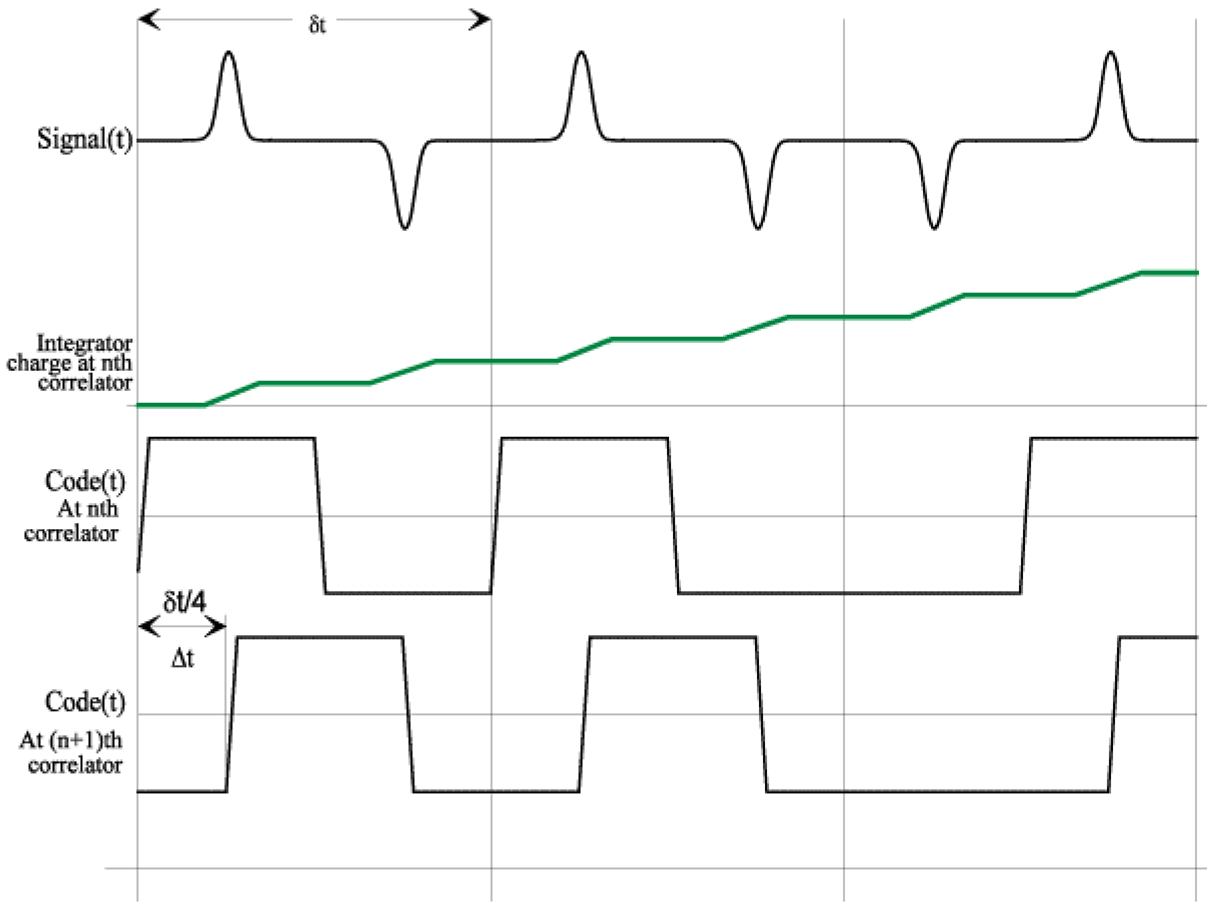

FIGURE 3 This diagram illustrates the operation of a Time-Integrating Correlator. The top row shows the received code sequence "110" encoded using impulse doublets. The second row shows the accumulation of charge in the nth integrator. The third row represents the +1/-1 values of the reference code sequence. The fourth row shows the overlap of the integration periods of the nth integrator with the (n+1)th integrator.

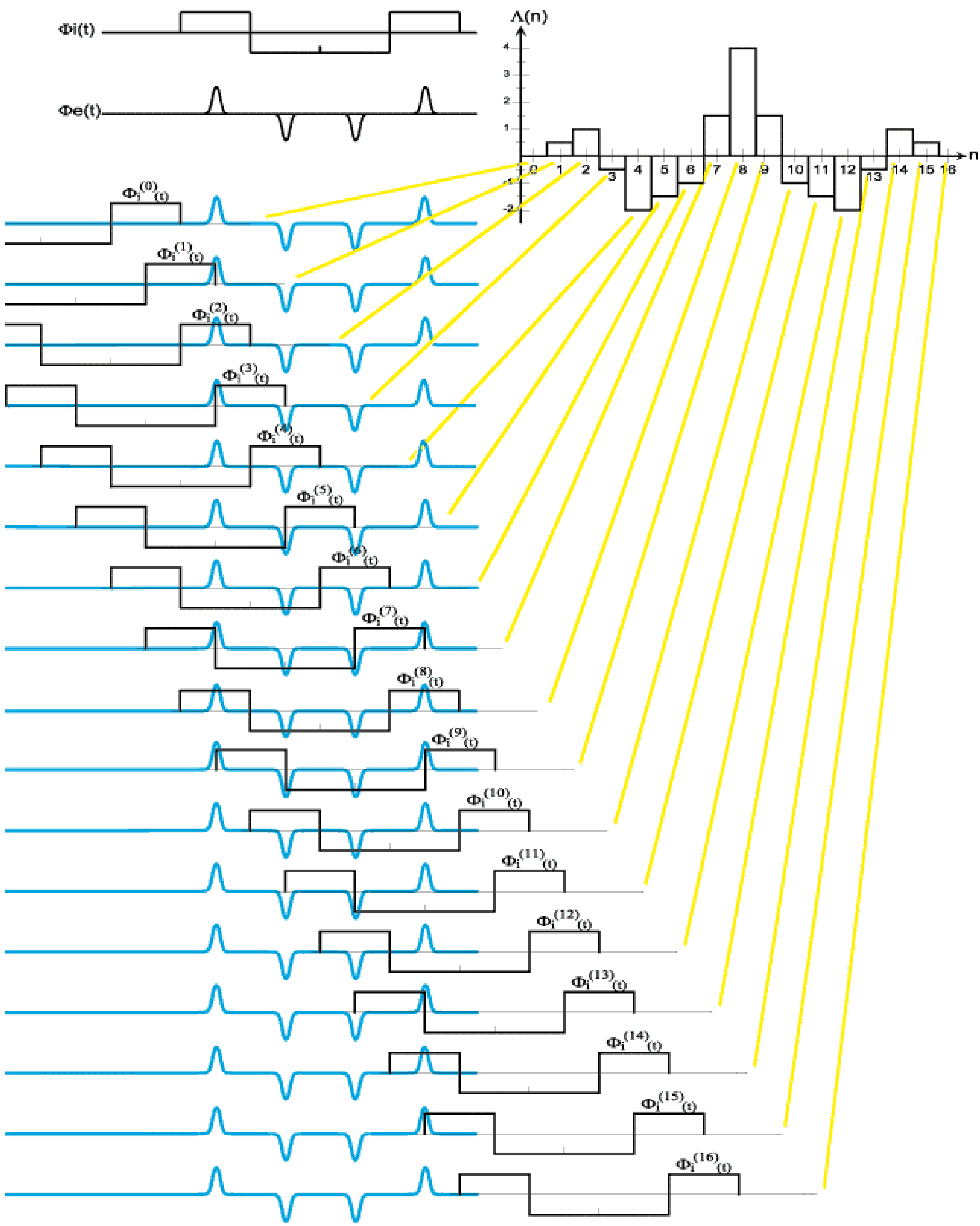

FIGURE 4. This diagram illustrates how the outputs of 17 integrator phases are generated by different alignments of the reference code i(t) with the received signal e(t). In this example, the integration period equals the impulse period, and adjacent integrator phases are overlapped by half of the impulse period.

- DETECTION

  A key feature of a Time-Integrating Correlator is that **the process of detecting a correlation peak does not have to be done in real time**. The correlation results are saved in the outputs of the integrator phases, which we then digitize. The complex TIC patterns that result can subsequently be analyzed with a microprocessor over a substantial period of time.

- TIME DOMAIN FILTERING

  When the integration period is reduced, the signal-to-noise ratio is improved, because less noise is integrated where there is no signal (Fig. 5). Thus, this time domain filtering can be used, when the position of the received impulses is known quite accurately, to "mask out" noise where no signal is present.

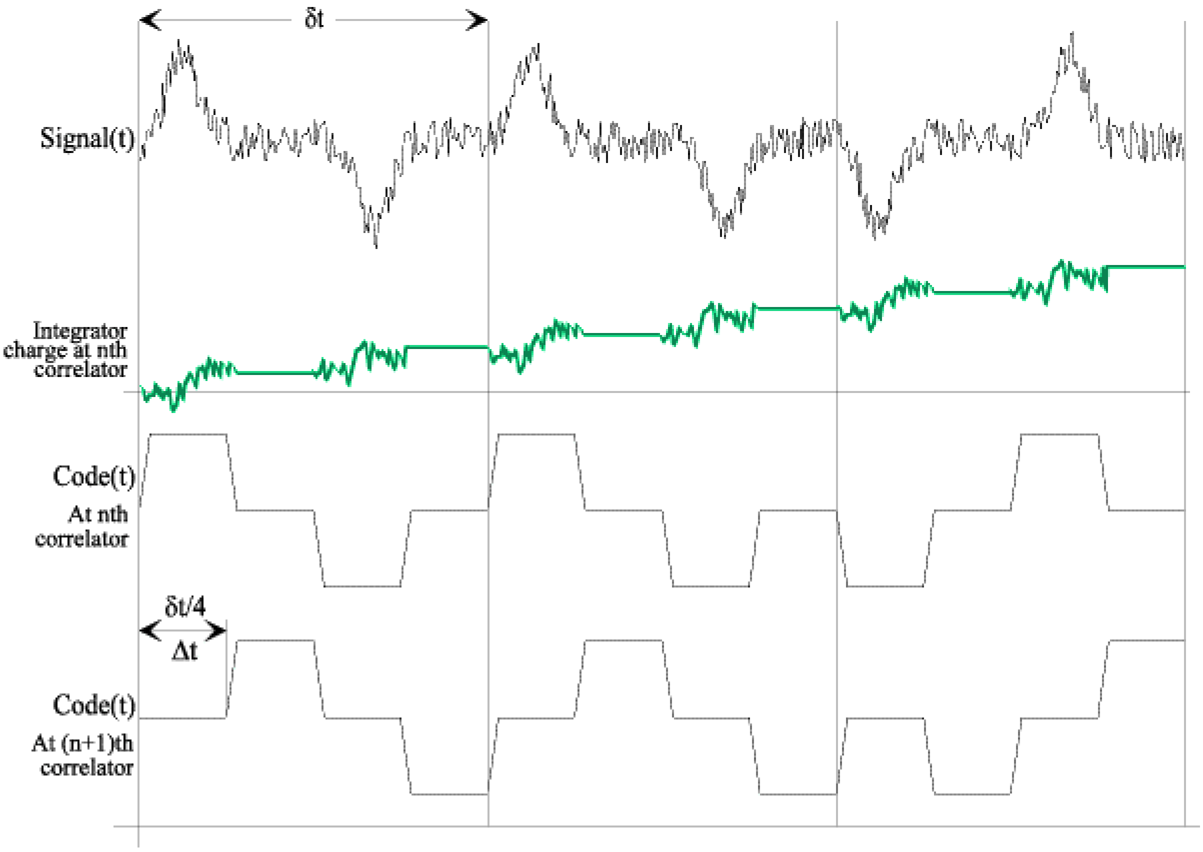

FIGURE 5. This diagram illustrates the operation of a Time-Integrating Correlator (TIC) where the integration period is half of the impulse period. The top row shows the received signal with noise. The second row shows the accumulation of charge in the nth integrator. The third row represents the +1/0/-1 values of the reference code sequence. The fourth row shows the reference code sequence for the (n+1)th integrator. Note how the input signal is effectively masked out when the reference is zero, with no loss in the signal contribution.

- COMPLEX TIC PATTERNS FOR HIGH-SENSITIVITY TIME MEASUREMENTS

  The Time-Integrating Correlator can be made very sensitive to slight shifts in the alignment of the received signal versus the reference code. This is achieved when the integration period for the TIC is as wide as the impulse period and the adjacent phases overlap by one half of the impulse period, as shown in Figure 3. This figure also illustrates the fact that the TIC performs the cross-correlation of two related but different signals the received signal, consisting of Gaussian impulses, and the reference code which has a rectangular pulse for each impulse in the received signal. The continuous time cross-correlation of these two signals is shown in the left-hand column of Figure 6.

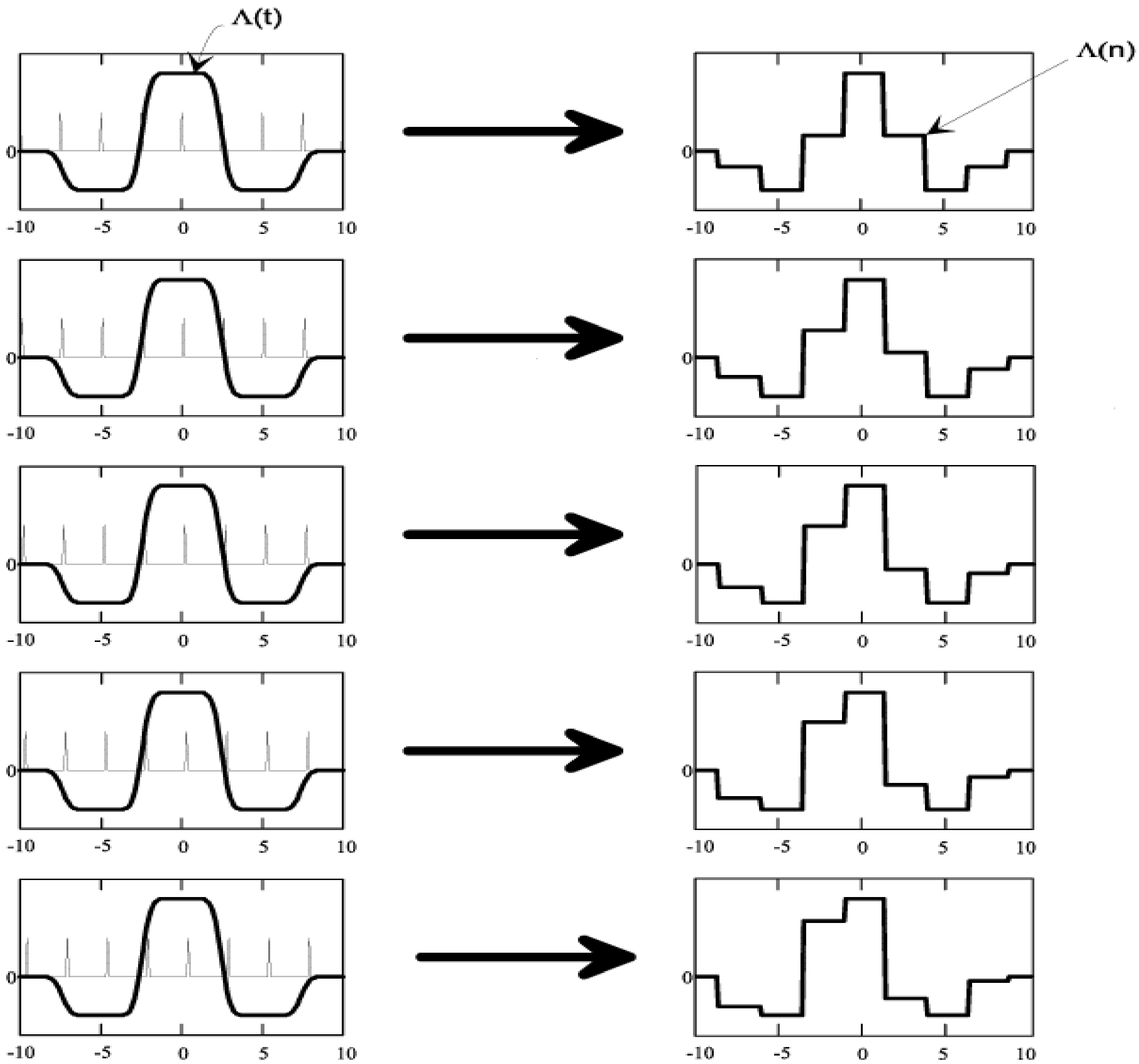

FIGURE 6. The trace labeled λ(t) on the left-hand side is the continuous time cross-correlation function. The trace labeled λ(n) on the right-hand side is the correlation results produced by a Time-Integrating Correlator, with "time sample". Note how the "even" samples (*e.g.* the peak at 0 ns) are essentially unchanged with the relative time shift of the received signal versus the reference code, while the "odd" samples change significantly.

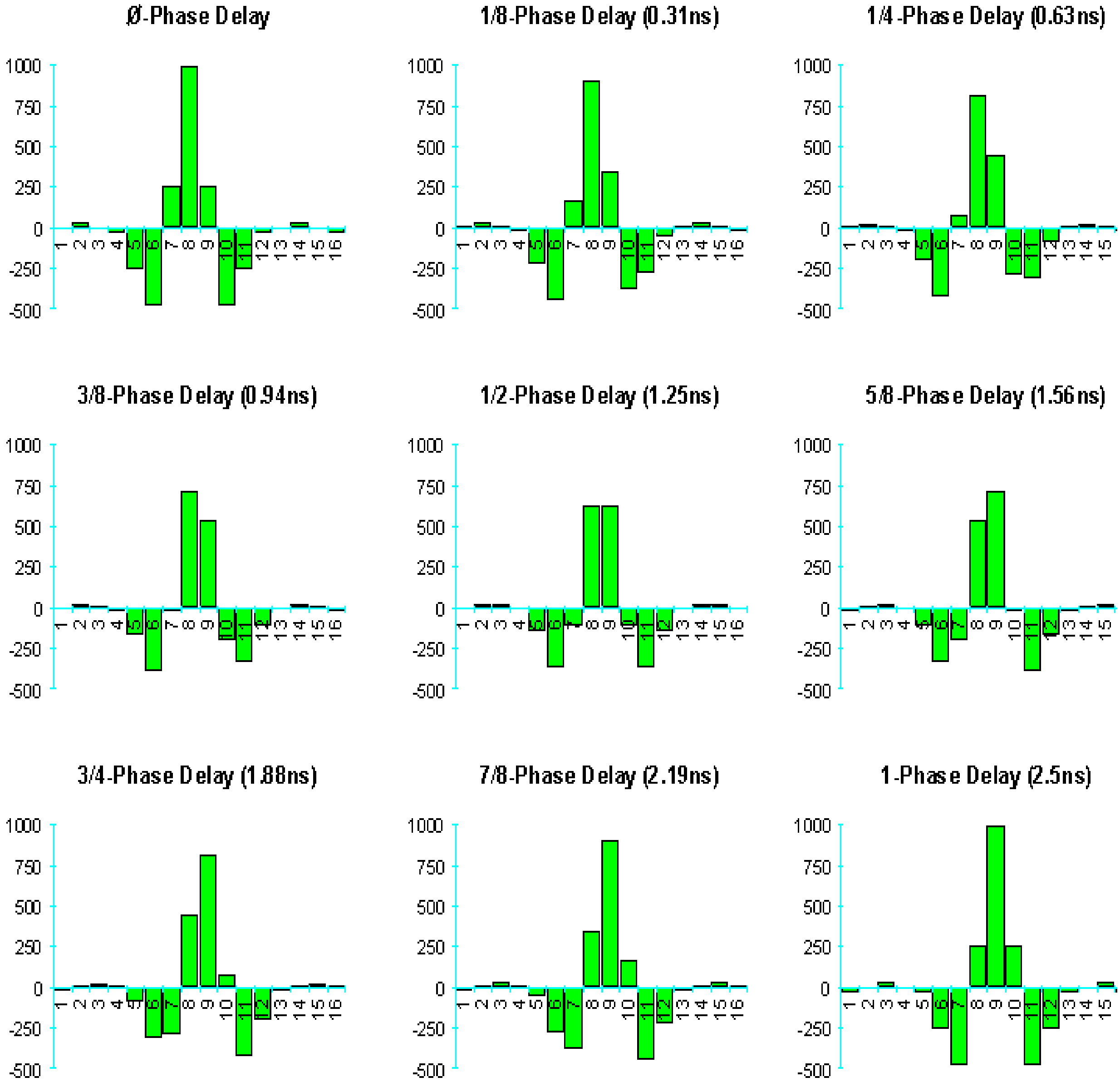

FIGURE 7. Evolution of the pattern of output phases of the Time-Integrating Correlator as the alignment of the received signal and reference code shifts in increments of 1/8-phase.

- MULTIPLEXING AND ADAPTIVE POWER CONTROL

  The use of correlation for reception of different code sequences, in spread spectrum parlance, is Code Division Multiple Access (CDMA), which suffers from what is known as the **near-far problem**. Essentially, a nearby transmitter transmitting at the same time as a far away one can overwhelm the distant signal. We can handle this problem by adaptively reducing their transmit power when communicating with other nearby transmitter.

- COMMUNICATION
  To send information, code sequences have to be modulated in some fashion. The simplest technique is to use "**antipodal**" modulation. This means either a given code sequence or its inverse is sent to represent one bit of information. The receiver will then detect a positive or a negative correlation peak. To eliminate the ambiguity of what is a "Ø" and what is a "1", certain sequences of bits are used as a preamble, yet never appear in the message.

Summary By DIWU
2/18/2002