EEE 461 Communication Systems II

Lecture Presentation 3

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☞ *5.11: Minimum-Shift Keying (MSK) and GMSK*

From last time,

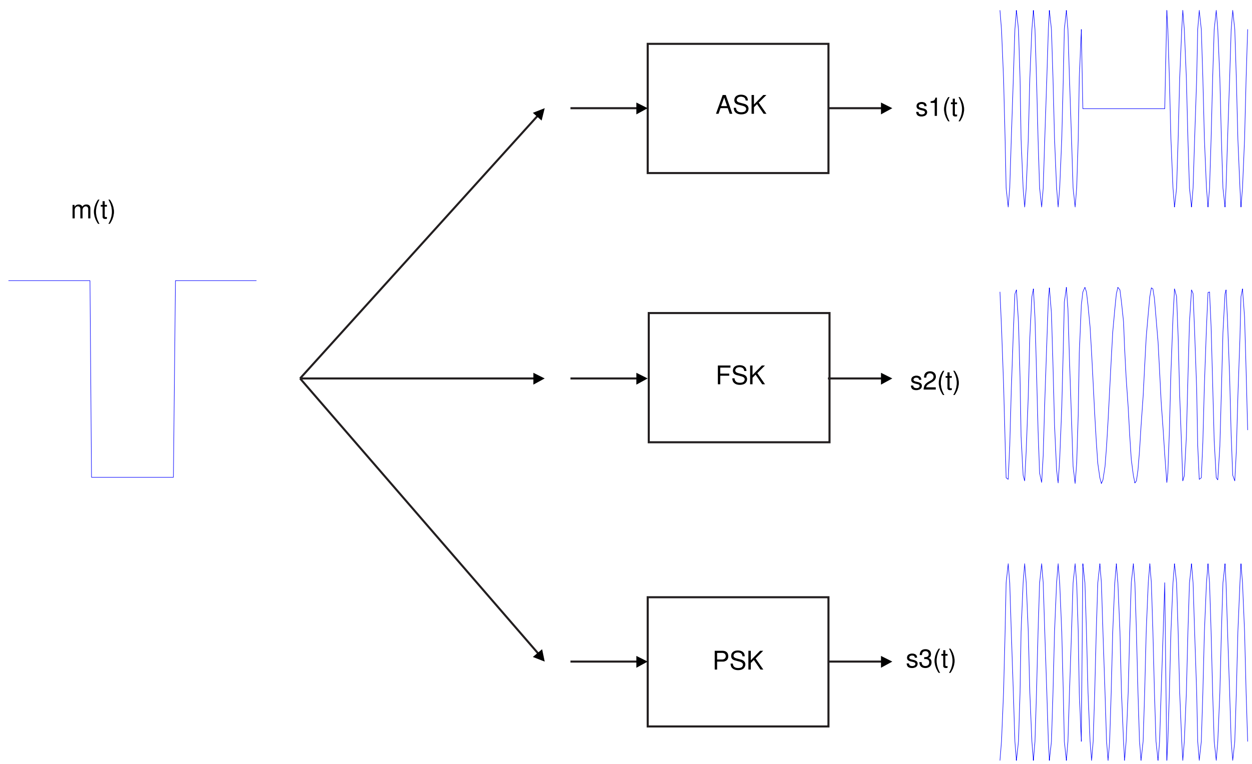

Figure 1: $M = 4$ QPSK

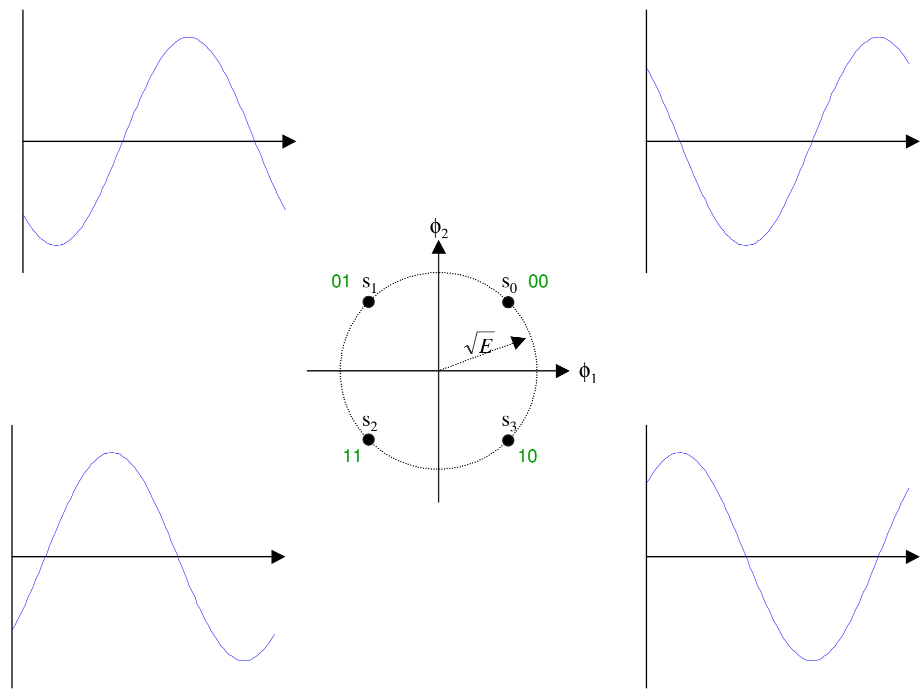

Figure 2: $M = 4$ QPSK

MSK is continuous phase FSK with a minimum modulation index ($h = 0.5$) that will produce orthogonal signaling.

Produces a constant amplitude signal.

MSK is equivalent to OQPSK with sinusoidal pulse shaping. For

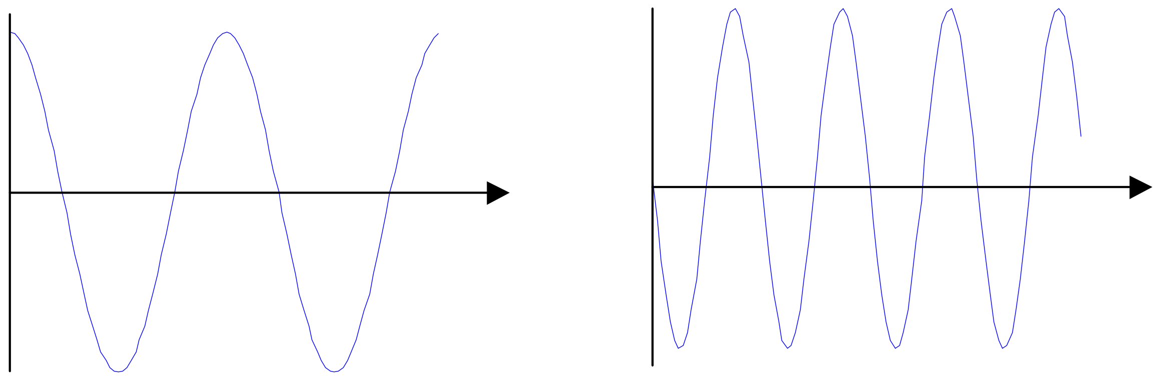

Figure 3: Binary FSK signals

continuous-phase FSK the minimum modulation index is $h = 0.5$.

For discontinuous-phase FSK the minimum modulation index is $h = 1.0$.

The complex envelope of an MSK signal is

$$g(t) = A_c e^{j\theta(t)} = A_c e^{j2\pi\Delta F \int_0^t m(\lambda)d\lambda}$$

where $m(t) = \pm 1, 0 < t < T_b$.

The modulated MSK signal is

$$s(t) = x(t)\cos\omega_c t - y(t)\sin\omega_c t$$

where

$$x(t) = A_c \cos\left(\pm 1 \frac{\pi t}{2T_b}\right), \quad 0 < t < T_b$$

$$y(t) = A_c \sin\left(\pm 1 \frac{\pi t}{2T_b}\right), \quad 0 < t < T_b$$

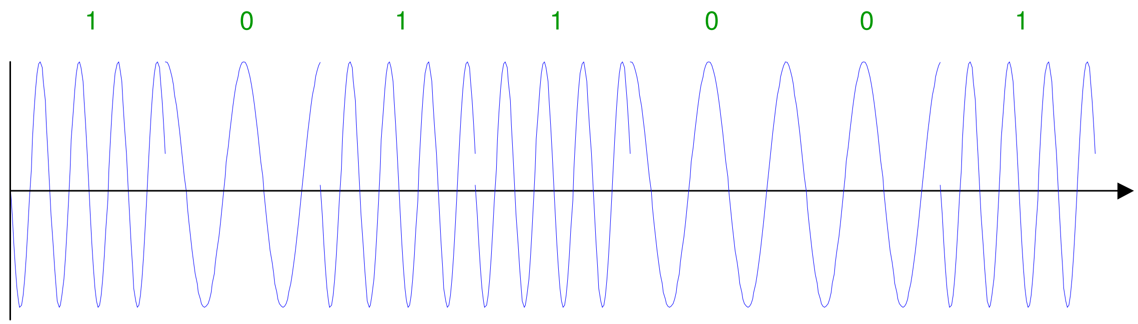

Figure 4: Discontinuous BFSK. $\theta_1 \neq \theta_2$

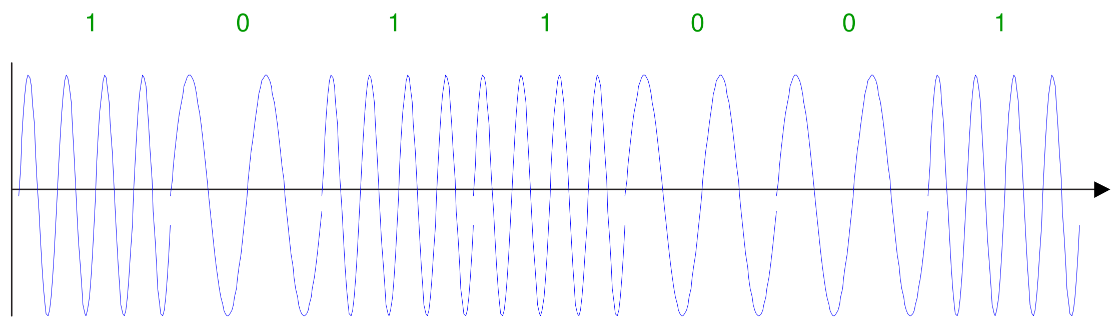

Figure 5: Continuous BFSK. $\theta_1 = \theta_2$

The PSD for the complex envelope is

$$\mathcal{P}_g(f) = \mathcal{P}_x(f) + \mathcal{P}_y(f) = \mathcal{P}_x(f)$$

where $\mathcal{P}_x(f) = \mathcal{P}_y(f)$ because $x(t)$ and $y(t)$ have the same type of pulse shape.

When we use polar NRZ pulse shape the PSD becomes

$$\mathcal{P}_g(f) = \frac{2}{2T_b}|F(f)|^2$$

where $F(f) = \mathcal{F}[f(t)]$ and $f(t)$ is the pulse shape.

For the MSK half-cosinusoidal pulse shape,

$$f(t) = \begin{cases} A_c \cos\left(\frac{\pi t}{2T_b}\right), & |t| < T_b \\ 0, & t \text{ elsewhere} \end{cases}$$

The PSD for the complex envelope of an MSK signal is

$$\mathcal{P}_g(f) = \frac{16 A_c^2 T_b}{\pi^2}\left(\frac{\cos^2 2\pi T_b f}{[1-(4T_b f)^2]^2}\right)$$

5.13 Spread Spectrum Systems

- Multiple access capability
- anti-jam capability
- interference rejection
- secret operation
- low probability of intercept

Simultaneous use of the wideband frequency.

The criteria for a SS system:

- The bandwidth of the modulated signal $s(t)$ is much larger than the message signal $m(t)$.
- The large bandwidth of the modulated signal is caused by the independent sequence waveform $c(t)$ called the spreading signal.

☞ Direct Sequence (DS) CDMA

$m(t)$ is polar from a digital source ± 1.

For BPSK modulation, $g_m(t) = A_c m(t)$.

The spreading waveform complex envelope $g_c(t) = c(t)$ ($c(t)$ is a polar spreading signal).

The resulting complex envelope of the SS signal becomes

$$g(t) = A_c m(t) c(t)$$

The spreading waveform is generated by using PN code generator.

The pulse width of T_c is called the chip interval.

When a PN sequence has the maximum period of N chips, where $N = 2^r - 1$, it is called a maximum length sequence (m-sequence)

There are certain very important properties of m-sequences:

- **Balance Property:** In each period of maximum-length sequence, the number of 1s is always one more than the number of 0s.
- **Run Property:** Here, the 'run' represents a subsequence of identical symbols(1's or 0's) within one period of the sequence. One-half the run of each kind are of length one, one-fourth are length two, one-eighth are of length three,etc.
- **Correlation Property:** The autocorrelation function of a maximum-length sequence is periodic, binary valued and has a period T=NT_c where T_c is chip duration.

  The autocorrelation function is

$$R_c(\tau) = \begin{cases} 1 - \frac{N+1}{NT_c}|\tau|, & |\tau| \\ -\frac{1}{N}, & \text{for the remainder of the period} \end{cases}$$

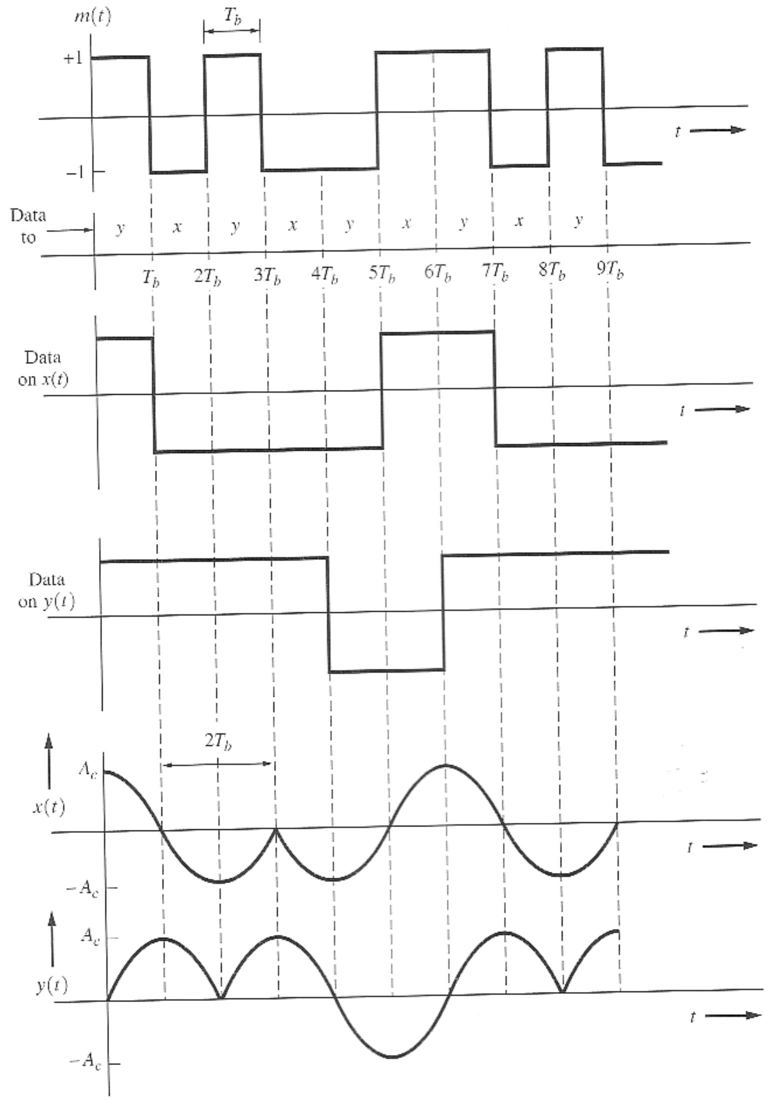

Figure 6: MSK quadrature component waveforms. (Couch 2001)

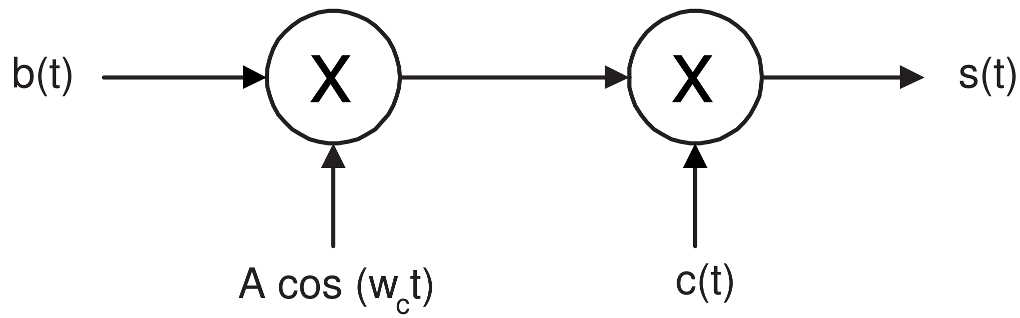

Figure 7: CDMA transmitter

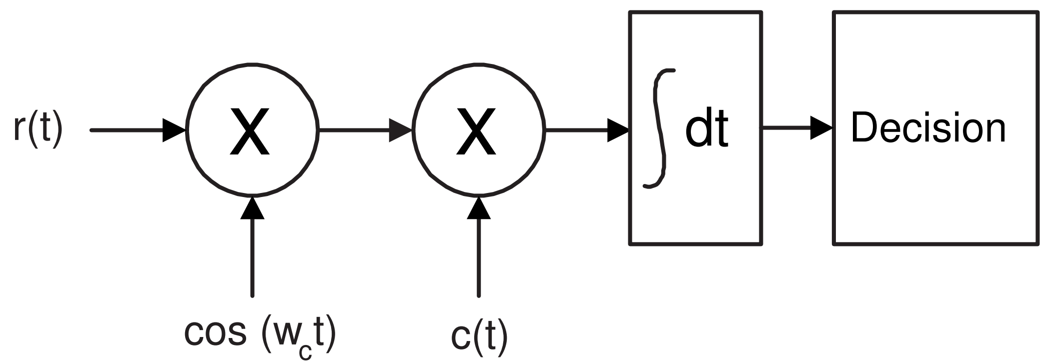

Figure 8: CDMA receiver

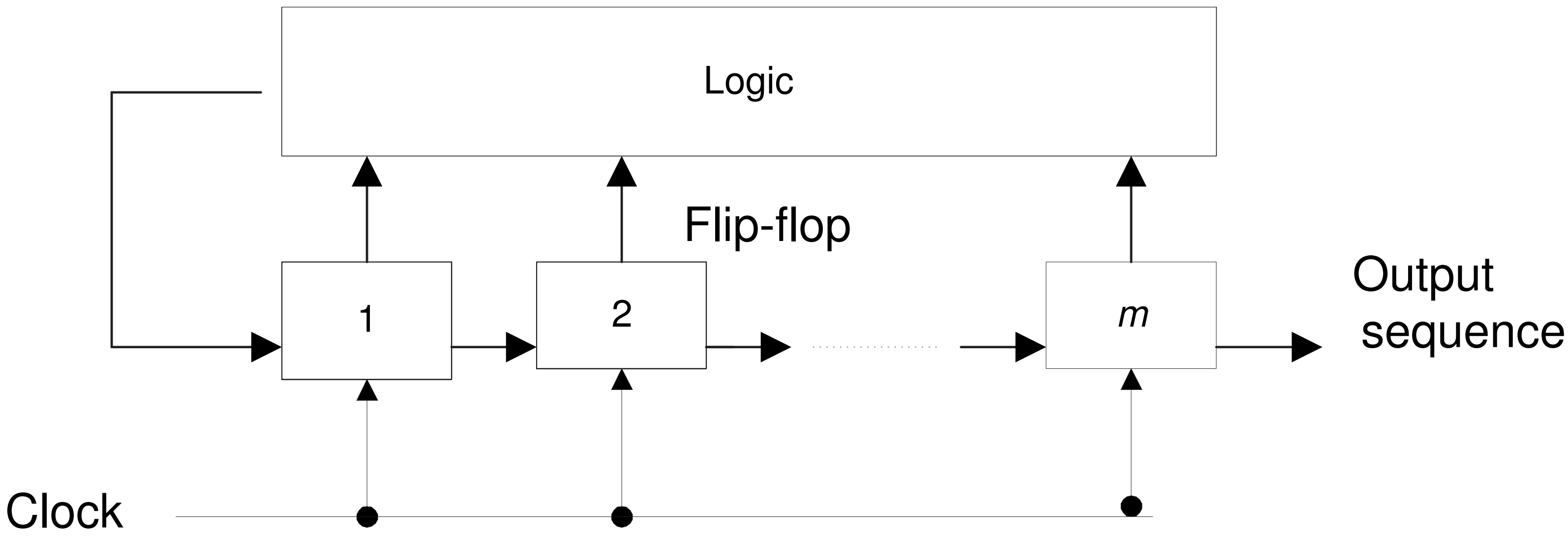

Figure 9: Feedback Shift Register. (A. Kortun)

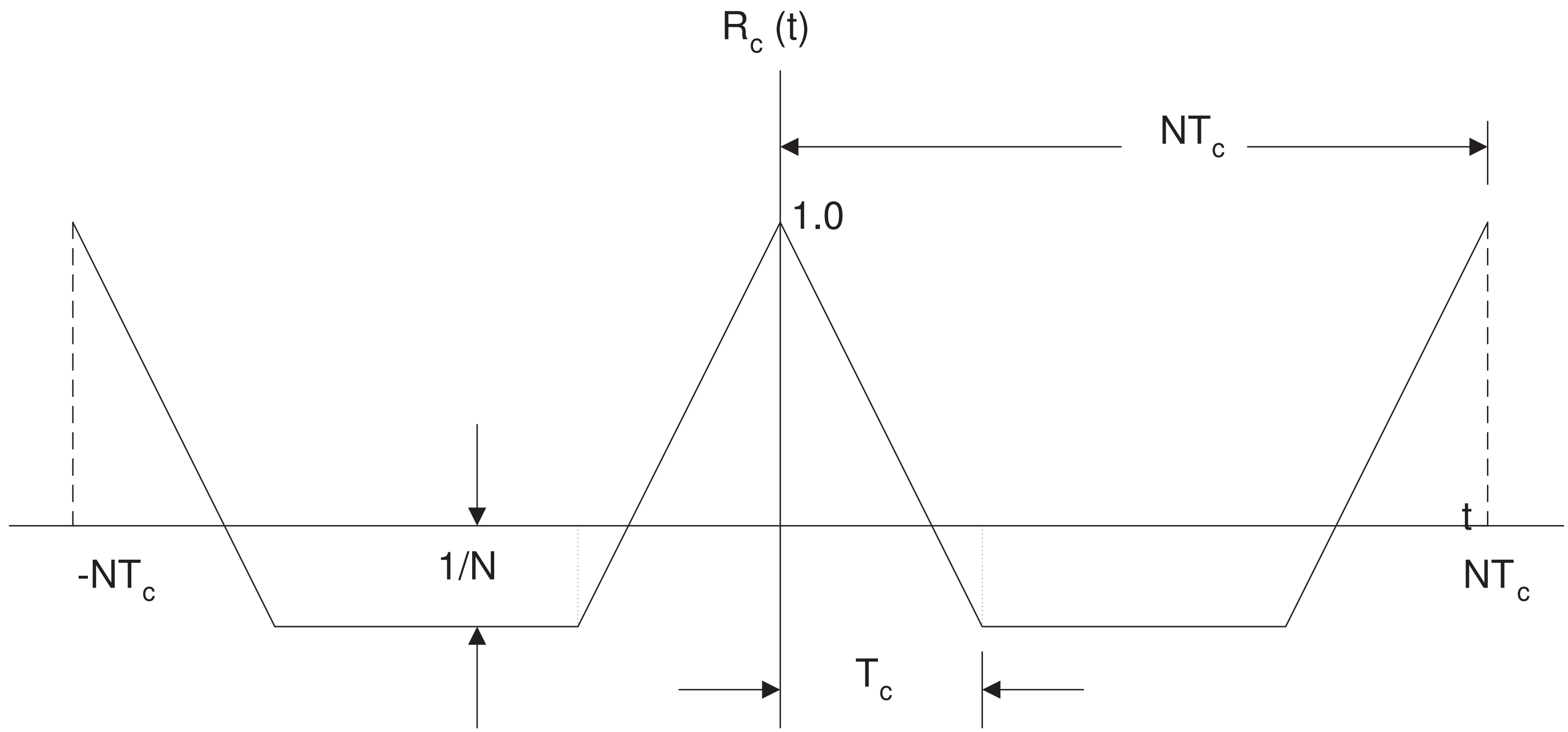

Figure 10: Autocorrelation function. (A. Kortun)