Baseband Data Transmission

Binary data transmission by means of two voltage levels is referred to as baseband signaling. Manchester encoding, for example, is used in the Ethernet local area network as the signaling scheme. Here, we consider polar non-return to zero baseband transmission scheme, in terms of probability of error, optimum receiver structure, power spectral density and bandwidth.

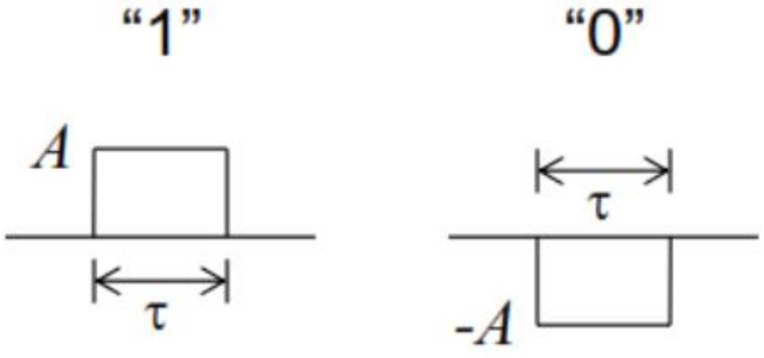
Polar nonreturn to zero (also known as binary pulse amplitude modulation)

Signal Representation

The baseband signals representing digits 1 and 0 are:

$$s_1(t) = A\,, \qquad 0 \le t \le \tau$$

$$s_0(t) = -A\,, \qquad 0 \le t \le \tau$$

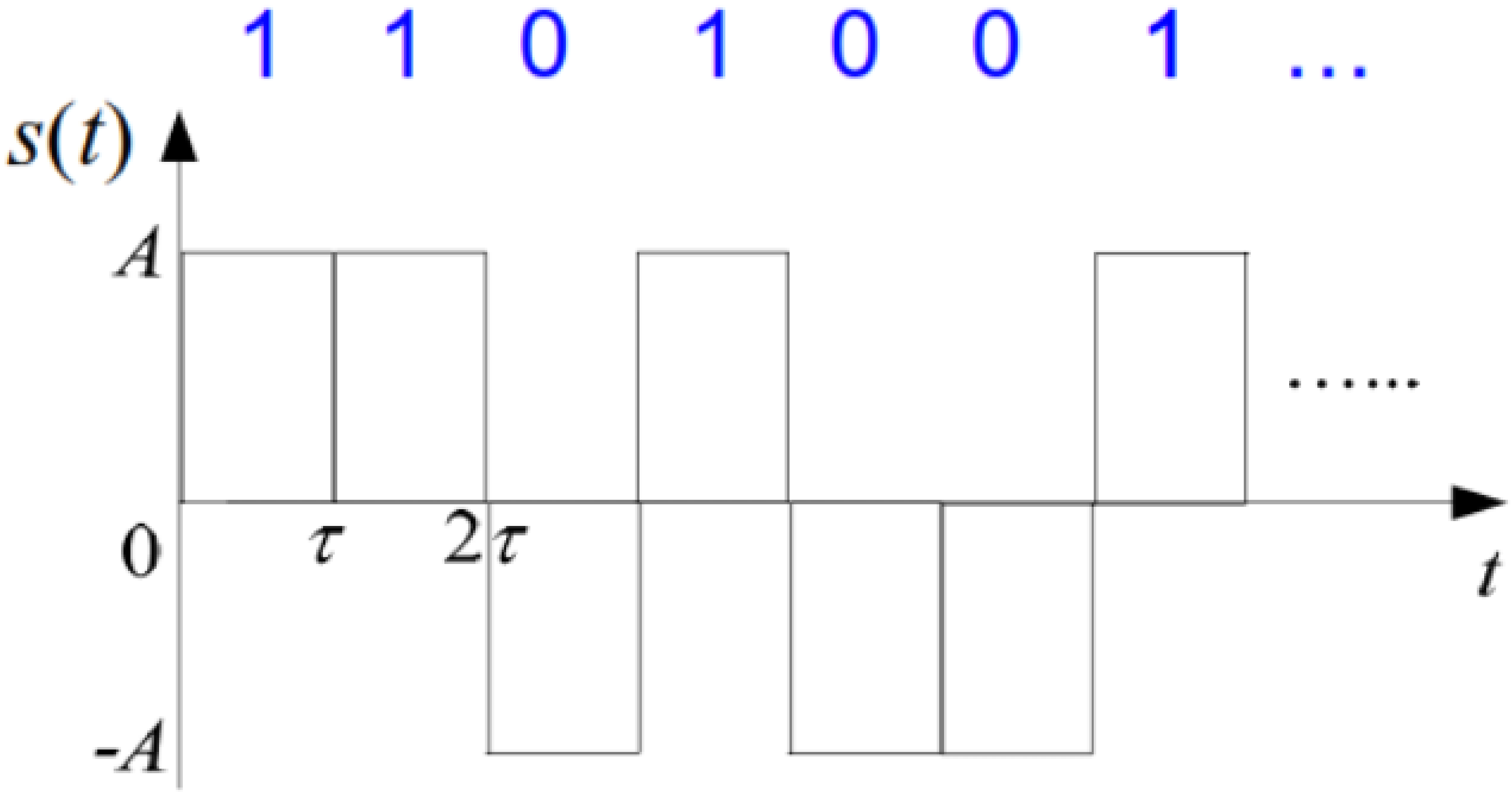


$s_1(t) = A$, $0 \le t \le \tau$ $s_2(t) = -A$, $0 \le t \le \tau$

where, τ is the symbol duration and $R_b = 1/\tau$ is the data rate in bits/sec.

Baseband Data Transmission

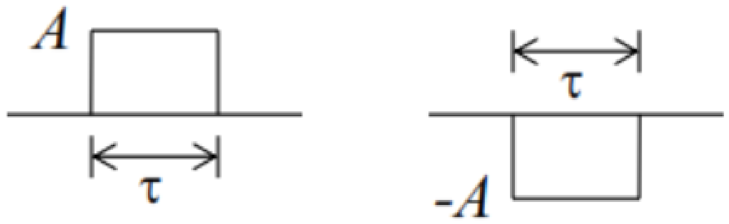
- **Generation: Convert data into polar non-return to zero format**

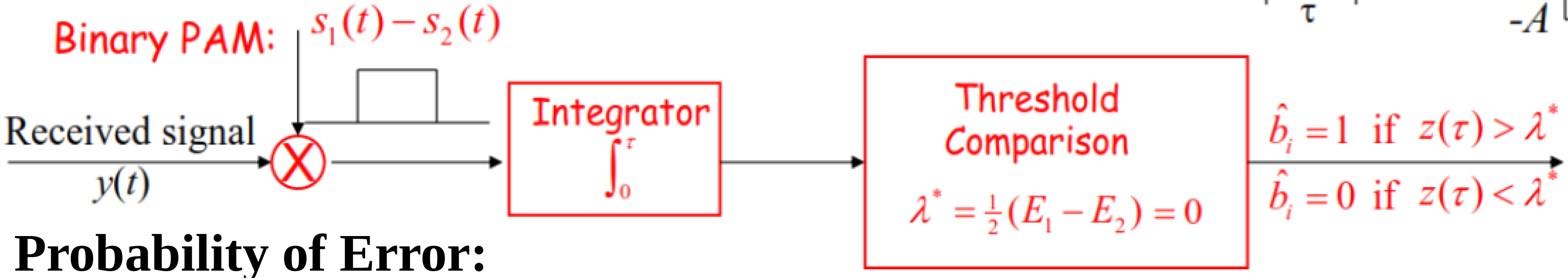


Baseband Data Transmission

Optimum Receiver

The optimum receiver is, of course, the matched filter, also implemented as a correlator, as shown in this figure.





Receiver Implemented as a Correlator

Probability of Error:

$$P_b^* = Q\left(\sqrt{\frac{\int_0^{\tau}(s_1(t) - s_2(t))^2 dt}{2N_0}}\right)$$

Optimal BER:

Note that: $E_1 = E_2 = \int_0^{\tau} A^2 dt = A^2\tau \Rightarrow \lambda^* = (E_1 - E_2) = 0$

$$P_b^* = Q\left(\sqrt{\frac{2A^2\tau}{N_0}}\right) = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$$

Average Energy per bit: $E_b = \frac{1}{2}(E_1 + E_2) = A^2\tau$

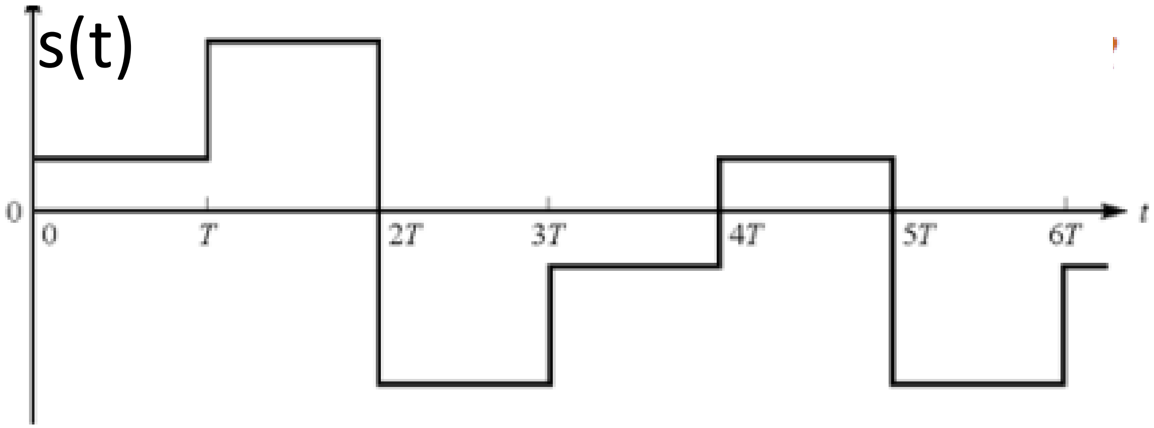
General Result on the Power Spectral Density of a digital M-ary baseband signal

The time-domain representation of a digital M-ary baseband signal is

$$s(t) = \sum_{n=-\infty}^{\infty} Z_n \cdot v(t - n\tau)$$

where Z_n is a discrete random variable with $\Pr\{Z_n = a_i\} = 1/M,\ i = 1,\ldots,M,$

$v(t)$ is a unit-baseband signal, and symbols in different time slots are assumed independent. Under these assumptions, the power spectral density of $s(t)$ is given by



$$G_s(f) = \frac{1}{\tau}|V(f)|^2 \cdot \left(\sigma_Z^2 + \frac{\mu_Z^2}{\tau} \sum_{m=-\infty}^{\infty} \delta\left(f - \frac{m}{\tau} \right) \right)$$

Power Spectral Density of the Polar Non-return to Zero baseband signal

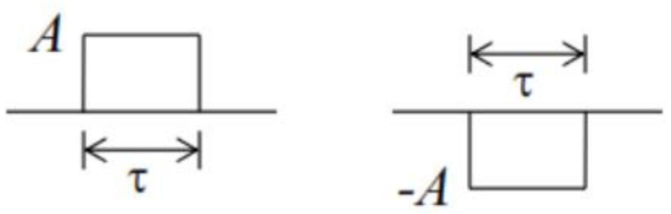
The general result stated above for the M-ary baseand signal can be specialized to the polar nonreturn to zero transmission as follows

- The signal amplitude assumes two equally likely values. i.e., $P\{Z_n = \pm 1\} = 1/2$
- The basic unit pulse is $v(t) = \begin{cases} A, & 0 \le t \le \tau \\ 0, & otherwise \end{cases}$
- The Fourier transform of the basic unit pulse is $V(f) = A\tau sinc(f\tau)$
- The mean and variance of Z are: $\mu_Z = 0$, $\sigma_Z^2 = 1$

$$E(Z) = \sum_{all\ z_i} z_i P(Z = z_i)$$

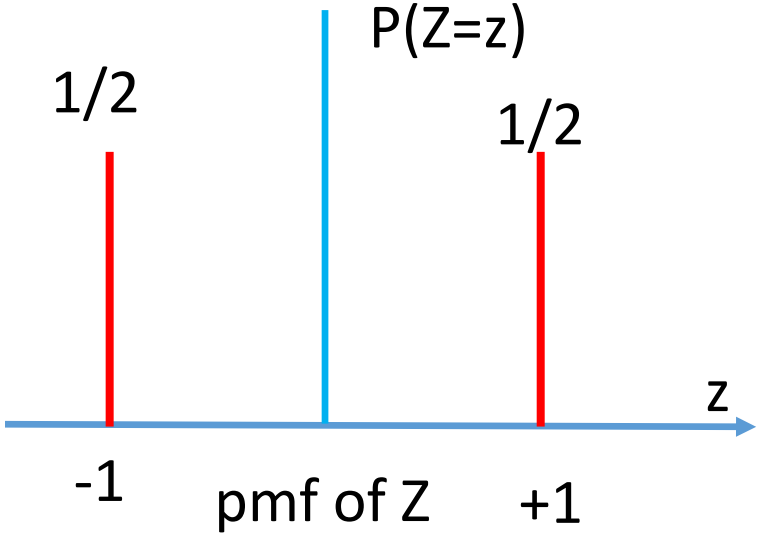
$$Var(Z) = \sigma_Z^2 = \sum_{all\ z_i} (z_i - E(Z))^2 P(Z = z_i)$$

"1" "0"



$s_1(t) = A$ $0 \le t \le \tau$

$s_2(t) = -A$ $0 \le t \le \tau$



pmf of Z

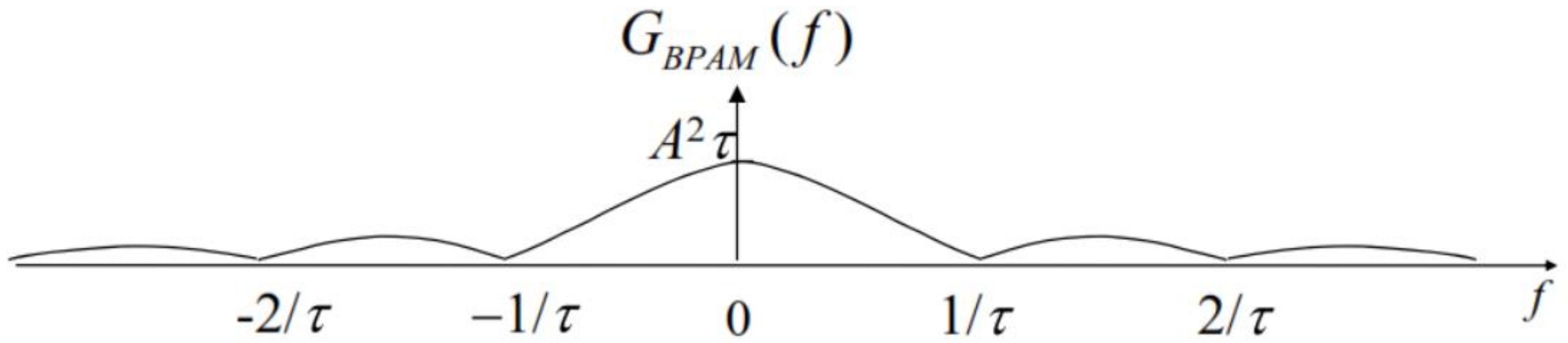
Power Spectral Density of the Polar Non-return to Zero baseband signal

- The general power spectral density formula

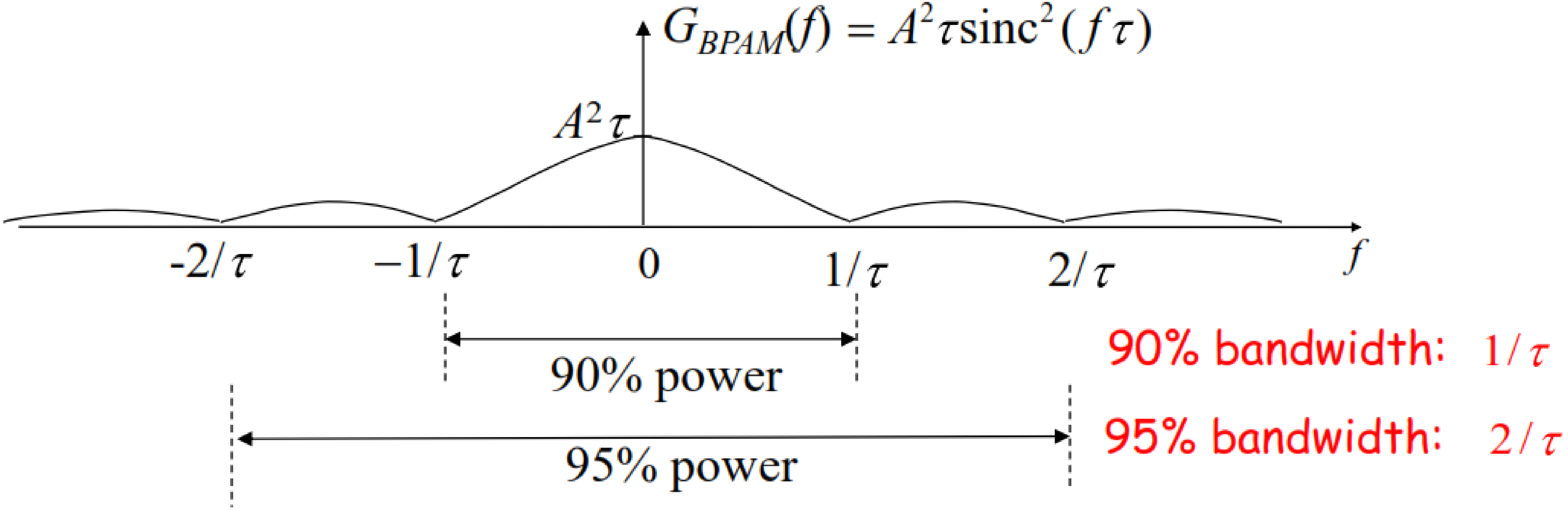
$$G_s(f) = \frac{1}{\tau}|V(f)|^2 \cdot \left(\sigma_Z^2 + \frac{\mu_Z^2}{\tau} \sum_{m=-\infty}^{\infty} \delta\left(f - \frac{m}{\tau} \right) \right)$$

- Substituting: E(Z)=0, Var(Z)=1, and the Fourier transform of the rectangular pulse v(t), we get:

$$G_{BPAM}(f) = A^2 \tau \operatorname{sinc}^2(f\tau)$$



Bandwidth of the Polar Non-return to Zero baseband signal



The 90% power bandwidth $= \frac{1}{\tau} = R_b$ (data rate)

The 95% power bandwidth $= \frac{2}{\tau} = 2R_b$ (twice the data rate)