Comparison of Modulation Schemes

Saravanan Vijayakumaran
sarva@ee.iitb.ac.in

Department of Electrical Engineering
Indian Institute of Technology Bombay

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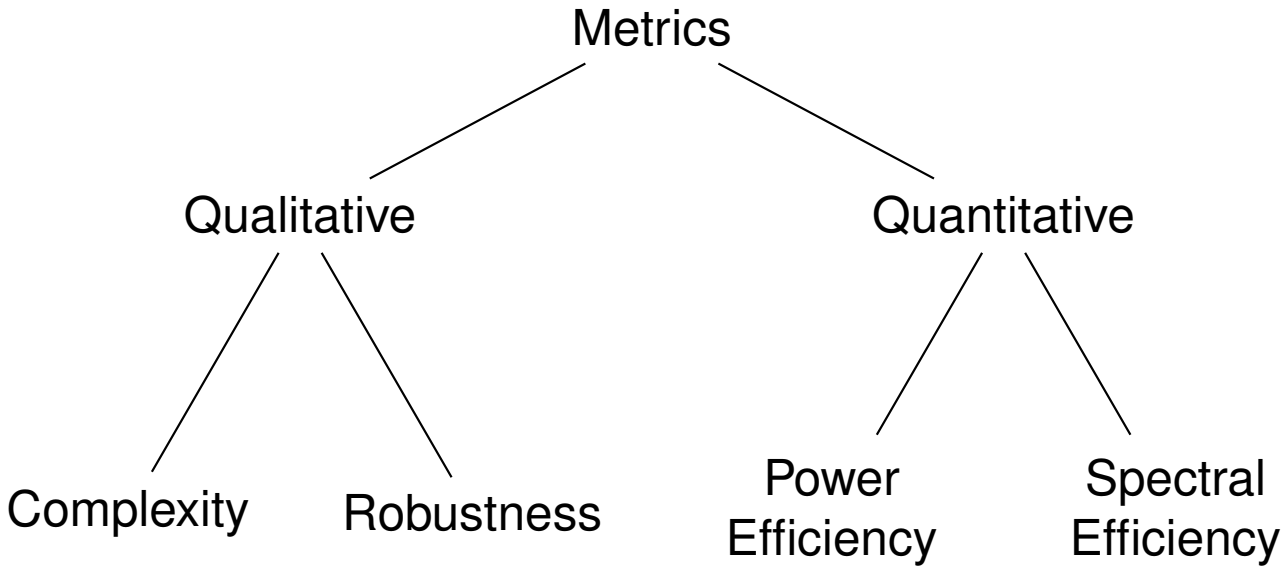
Metrics for Comparing Modulation Schemes



Power Efficiency

- For an M-ary signaling scheme

$$\begin{aligned} P_e &\approx \bar{N}_{d_{min}} Q\left(\frac{d_{min}}{2\sigma}\right) \\ &= \bar{N}_{d_{min}} Q\left(\sqrt{\frac{d_{min}^2}{2N_0}}\right) = \bar{N}_{d_{min}} Q\left(\sqrt{\frac{d_{min}^2}{E_b}}\sqrt{\frac{E_b}{2N_0}}\right) \end{aligned}$$

- The power efficiency of a modulation scheme is defined as

$$\eta_p = \frac{d_{min}^2}{E_b}$$

- The nearest neighbors approximation can be expressed as

$$P_e \approx \bar{N}_{d_{min}} Q\left(\sqrt{\frac{\eta_p E_b}{2N_0}}\right)$$

Power Efficiency of Some Modulation Schemes

Modulation Scheme	η_p
On-off keying	2
Orthogonal signaling	2
Antipodal signaling	4
BPSK	4
QPSK	4
16-QAM	1.6

Spectral Efficiency

Definition (Spectral Efficiency)

The number of bits that can be transmitted using the modulation scheme per second per Hertz of bandwidth.

Remarks

- If a modulation scheme transmits N bits every T seconds using W Hertz of bandwidth, the spectral efficiency is $\frac{N}{WT}$ bits/s/Hz
- We will use null-to-null bandwidth to calculate spectral efficiency

Spectral Efficiency of BPSK

- Let $S_p(f)$ be the PSD of BPSK and let $S(f)$ be the PSD of its complex envelope.

$$S_p(f) = \frac{S(f - f_c) + S(-f - f_c)}{2}$$

(Section 2.3.1 of Madhow's book)

- The complex envelope is given by

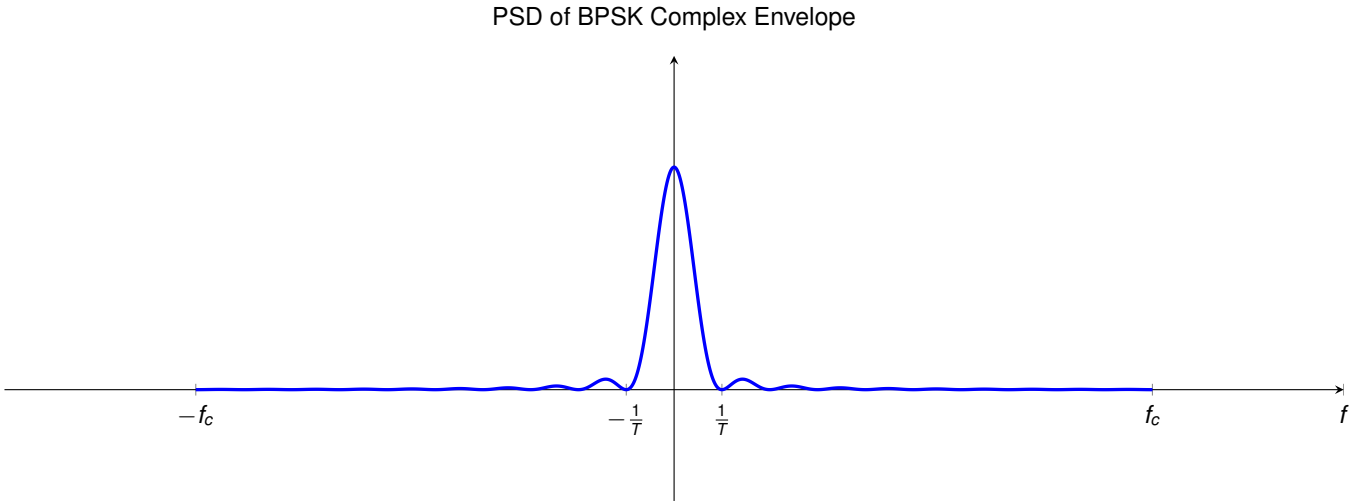
$$s(t) = \sum_{n=-\infty}^{\infty} b_n p(t - nT)$$

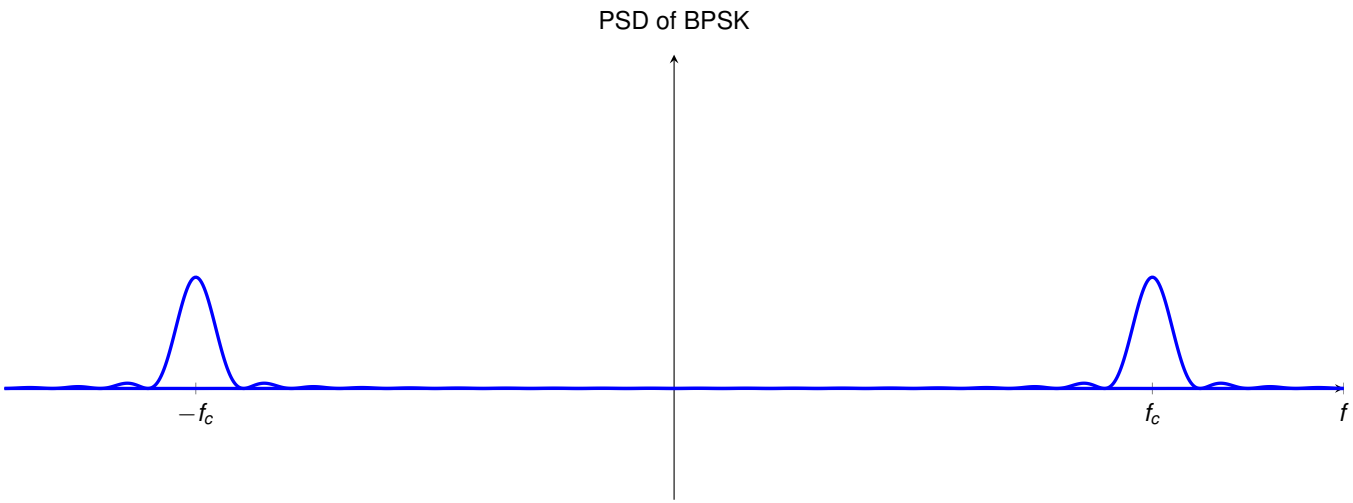
where $p(t)$ is a rectangular pulse of duration T and $b_n \in \{-A, A\}$.

- Given $S_b(z) = \sum_{k=-\infty}^{\infty} R_b[k] z^{-k}$, PSD of the complex envelope is

$$S(f) = S_b\left(e^{j2\pi fT}\right) \frac{|P(f)|^2}{T} = A^2 T \text{sinc}^2(fT)$$

Power Spectral Density of BPSK





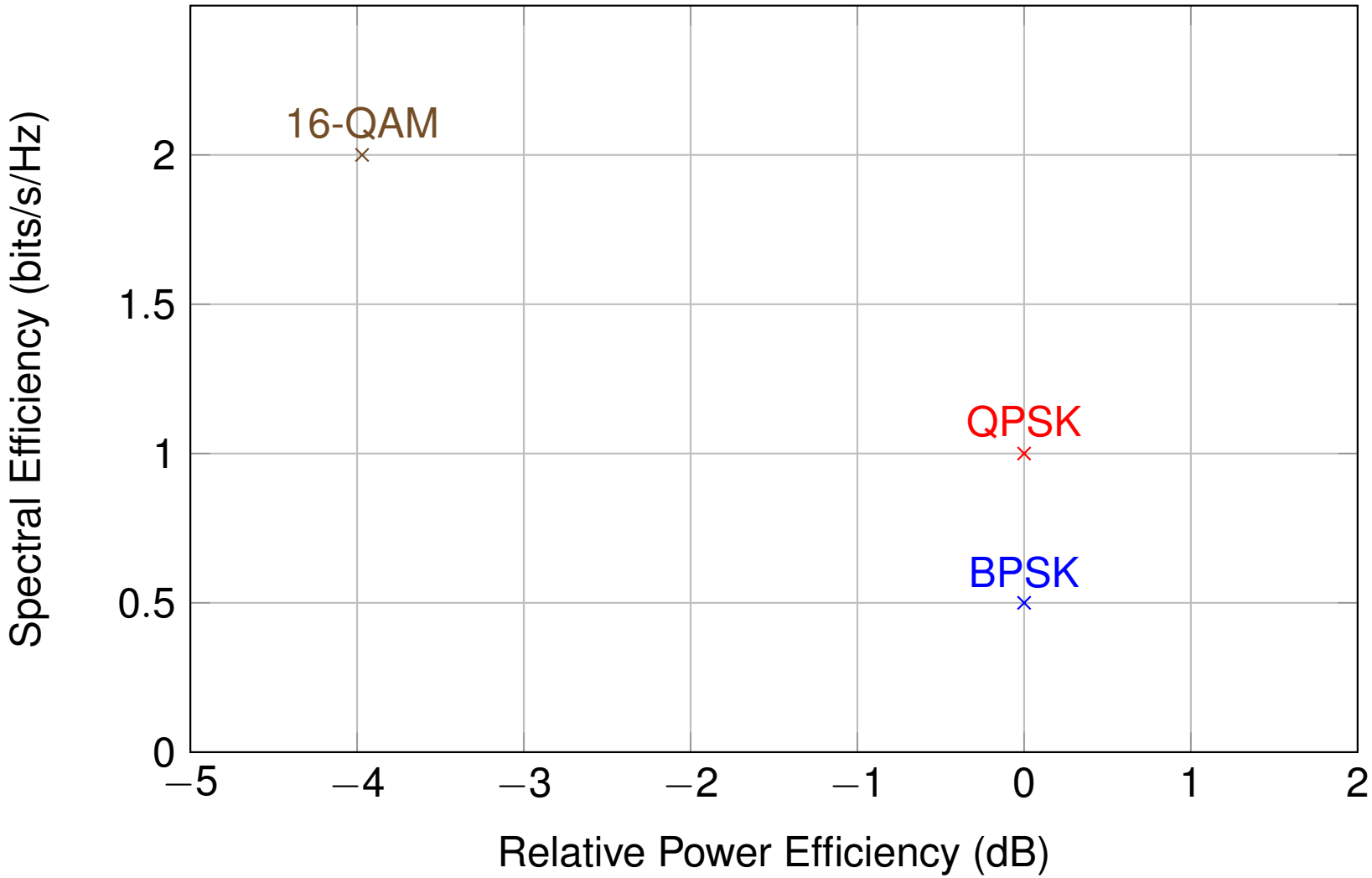
Null-to-null bandwidth of BPSK = $\frac{2}{T}$ (only +ve frequencies)

Spectral Efficiency of BPSK = 0.5

Spectral Efficiency of Some Modulation Schemes

Modulation Scheme	Spectral Efficiency
BPSK	0.5
BPAM	1
QPSK	1
16-QAM	2

Spectral Efficiency vs Relative Power Efficiency



$$\text{Relative Power Efficiency} = 10 \log_{10} \frac{\eta_p}{\eta_{p,\text{BPSK}}}$$

Thanks for your attention