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ECE3141 Semester 1 2021 - Phase Shift Keying

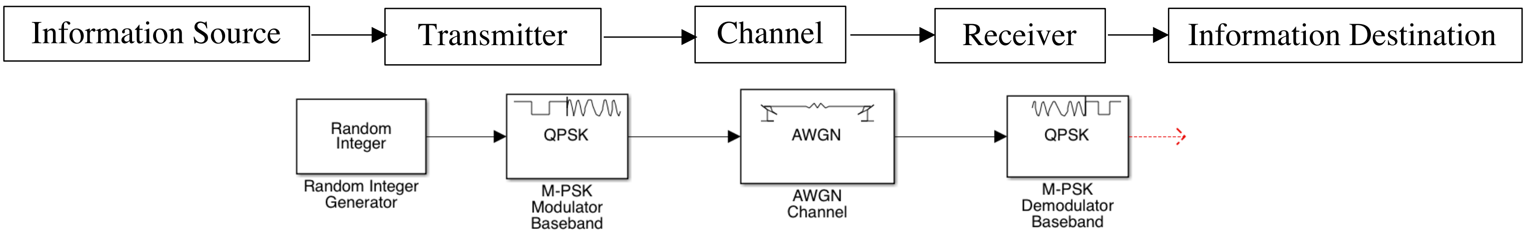

Fig. 1. Digital Modulation in a Simplified Communication System

At the physical layer, one method of transmitting digital information from a source is to use a high frequency signal known as a carrier wave[1]. A carrier wave is ‘modulated’ when one or more properties of the signal, which include its **phase**, amplitude, and frequency, change with respect to a source signal. A communication channel is used to transmit this modulated carrier wave to a receiver which then demodulates the signal as in [1, Fig. 1] [1]. The type of channel used for transmission is assumed to be an Additive White Gaussian Noise (AWGN) channel with a fixed Signal to Noise ratio (SNR) of 10dB.

Multi-Phase Shift Keying (M-PSK) [2] uses M different phase shifted versions of a carrier that represent fixed bit patterns, known as symbols. Each symbol[3] is assigned one of M evenly spaced phases. For example, using a 4-PSK scheme, each symbol is assigned a phase of $\frac{(2n-1)\pi}{4}$ for $n = 1,2, \ldots$, see [4, Appendix I] [1].

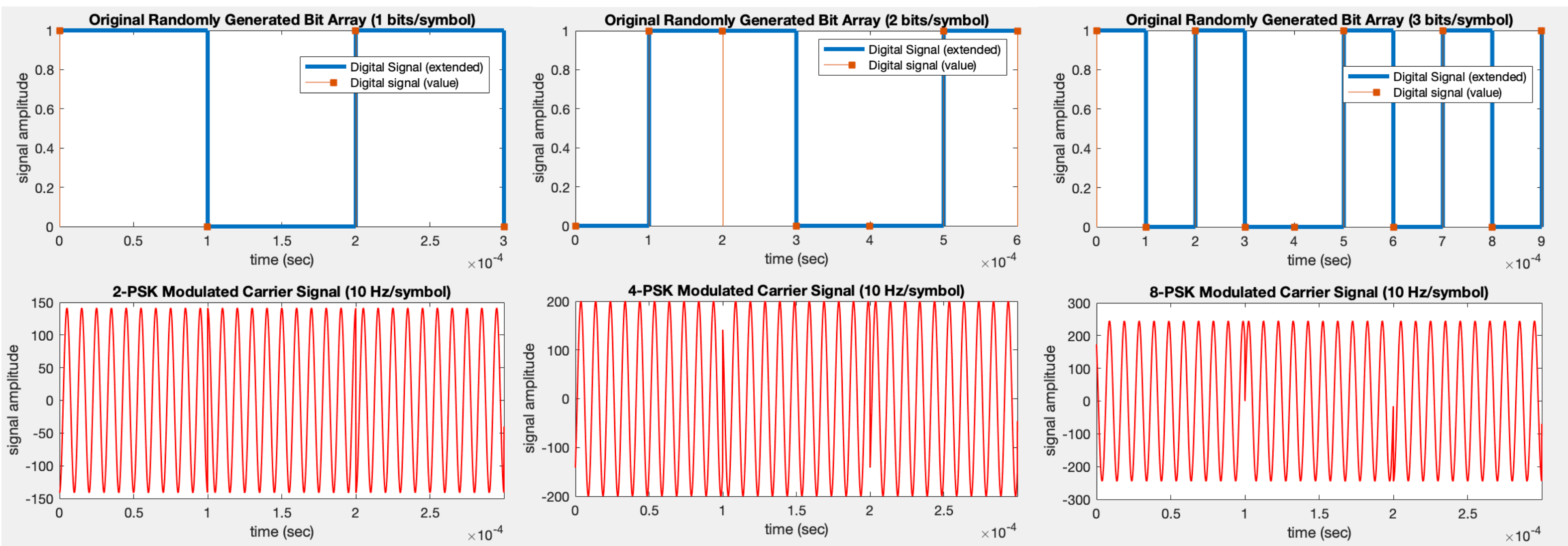

Fig. 2. Digital Signal vs M-PSK waveforms for 3 symbols (a) 2-PSK (b) 4-PSK (c) 8-PSK

The 2-PSK plot [1, Fig. 2 (a)] shows that for every symbol transition (1 bit), there is a π phase shift in the modulated carrier wave. Similarly [1, Fig. 2 (b)], for every symbol change (2 bits) in the 4-PSK example there is a $\frac{(2n-1)\pi}{4}$ phase shift in the modulated carrier wave. The same can be applied to 8-PSK for every 3 bits but with a $\frac{(n-1)\pi}{4}$ phase shift for $n = 1,2, \ldots$. For a larger M, E_s will be higher which increases the amplitude of the modulated carrier wave. However, for a fixed symbol duration (T), the total power will remain the same as the data transmission rate increases which results in a shorter total transmission time.

[1] Usually this is a sinusoid. Compared to rectangular or triangular waveforms, a simple sinusoid will only have one frequency and no other harmonics which can be modulated.
[2] 2- and 4-PSK are the same as B-PSK and Q-PSK respectively
[3] Gray codes are used for mapping bits into symbols such that adjacent symbols only differ by one bit [4, Appendix I]

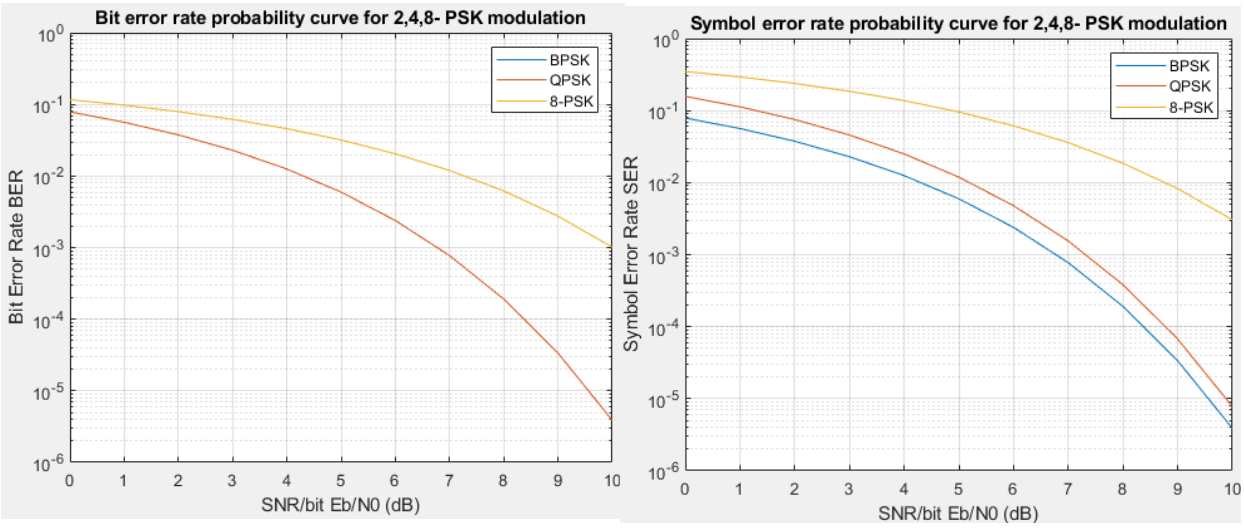

Fig. 3. Bit Error Rate and Symbol Error Rate for 2-,4- and 8-PSK Modulation

The Bit Error Rate (BER) and Symbol Error Rate (SER) decrease when the value of $\frac{E_b}{N0}$, or the SNR per bit, increases as seen in [2, Fig. 3]. However, the rate at which BER and SER decreases with respect to $\frac{Eb}{N0}$ is much higher for smaller values of M. This is because as M increases, the number of signal levels increase and so the threshold that differentiates assigned phases for symbols become smaller. Having phases closer together creates more susceptibility to bit and symbol errors due to noise which results in demodulation errors at the receiver. This can be seen in constellation plots for different M-PSK modulated waves when noise from an AWGN channel is added [5, Appendix II].

Two other notable observations can be made [2, Fig. 3]. The first is that the BER and SER of 2-PSK are the same. This is because only 1 bit is needed to represent both the number of symbols and the number of signal levels (number of symbols = number of bits). The second observation is that the BER is the same for both 4-PSK and 2-PSK.

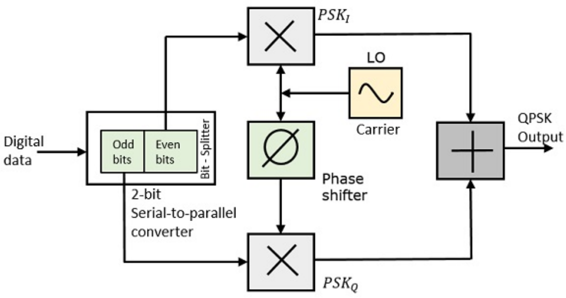

Fig. 4. Overview of 4-PSK [2]

As shown in [2, Fig. 4], a 4-PSK modulated carrier is made up of the sum of two carriers known as PSK_i (in-phase component) and PSK_Q (quadrature component) that have a relative phase difference of $\frac{\pi}{2}$. These two carriers are modulated by even and odd bits and both sets of modulations occur independently which can be viewed as two independent 2-PSK modulations. Therefore, the BER is the same for 2-PSK and 4-PSK [2].

The spectral efficiencies [4] of 2-, 4-, and 8-PSK are 1, 2 and 3 bits/s/Hz respectively. As M increases, the bandwidth efficiency also increases. Hence, PSK is more suitable for bandwidth limited systems as it has efficient utilisation of bandwidth compared to other modulation techniques (ASK and FSK). In addition, the constant envelope characteristic of the M-PSK scheme makes it more suitable for applications such as radio links and satellite channels as amplitude non-linearities may exist [3].

In conclusion, a large M should be chosen if the application requires a greater data transmission rate [5] without needing to increase bandwidth. However, this also means that the application must have a high error tolerance (or use of reliable error correcting techniques) as BER and SER increase with M. A larger value of M could also be used if the data transmission rate needs to remain constant but the range of bandwidth available is reduced. Arguments for choosing a smaller M, depending on the application needs, will be opposite to the reasons listed for choosing a larger M.

[4] Spectral efficiency is the measure of how efficiently a physical layer protocol utilises limited bandwidth.
[5] data transmission rate = spectral efficiencies*bandwidth

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[3]S. Haykin and M. Moher, *Communication Systems*, 5th ed. US: John Wiley & Sons Inc (US), 2009, p. 313.

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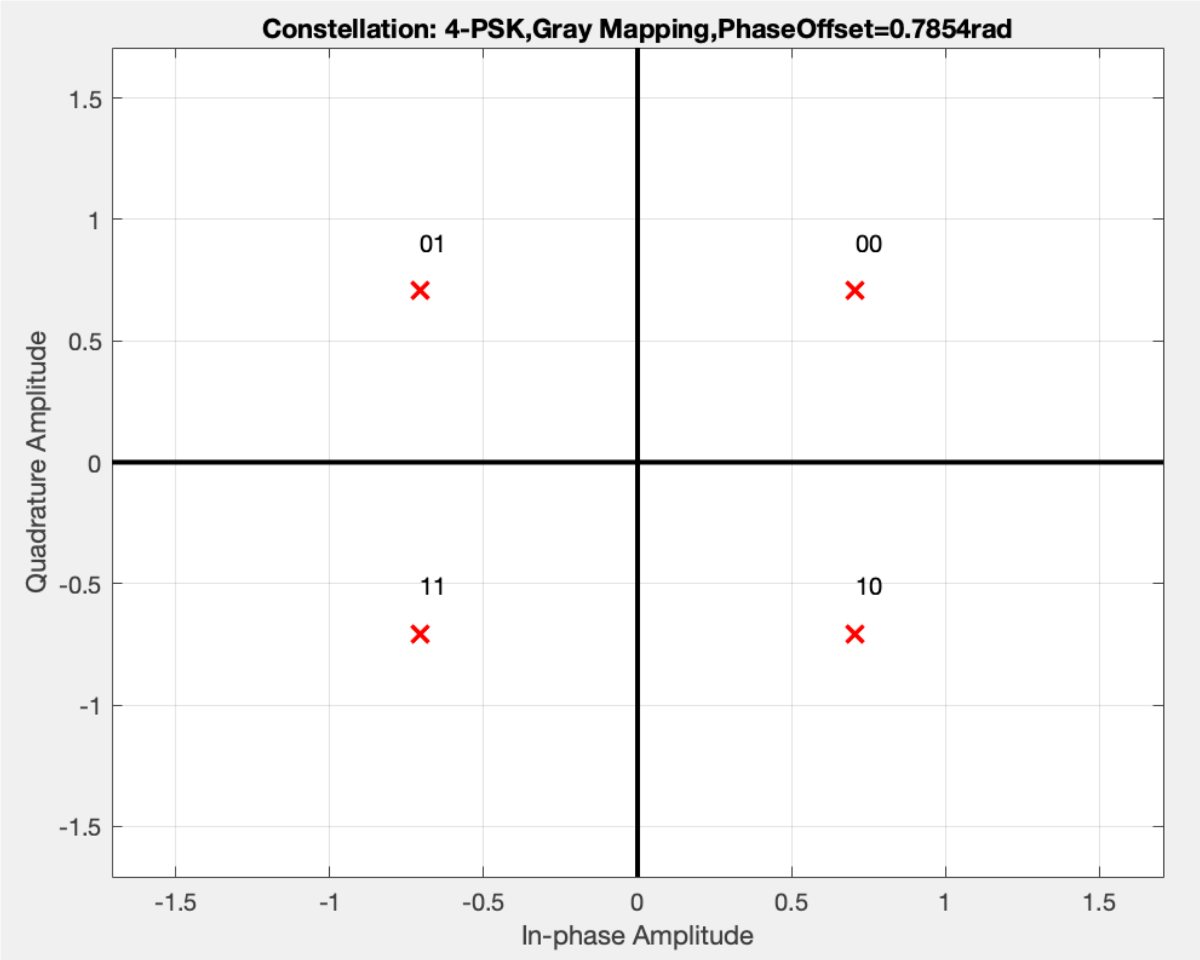
APPENDIX

APPENDIX I
Constellation Diagram for 4-PSK



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APPENDIX II
Effect of AWGN on a Modulated Carrier