Digital Communications Laboratory

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Chapter Three

Principles of Digital Data Transmission

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Autumn 2020

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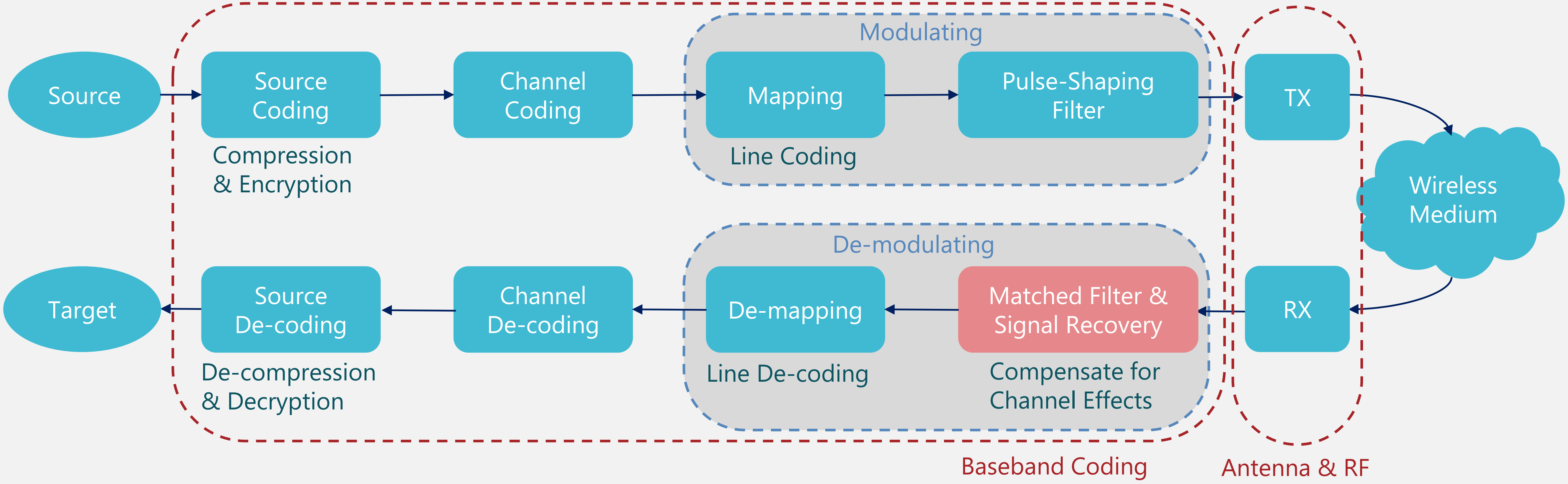
Section A

Linear Modulation Schemes

Wireless Digital Communications



M-ary Linear Modulation Techniques

Instantaneous Transmitted Signal

$$S_m(t) = Real\{A_m g(t) e^{-j(2\pi f_c t + \varphi_m)}\}$$

$$S_{m,BB}(t) = Real\{A_m g(t) e^{-j\varphi_m}\}$$

A_m: amplitude defined by mapping

φ_m: phase offset defined by mapping

$g(t)$: the pulse-shaping filter

Linear Modulation Types

Linear Modulation	A_m	φ_m	Constellation
ASK/PAM	Variable	Fixed	1D
PSK	Fixed	Variable	2D
QAM	Variable	Variable	2D

Transmitted Data

$$X_m = \sum_{n=0}^{N-1} S_m(t - nT_s) = Real\{\sum_{n=0}^{N-1} A_m g(t - nT_s) e^{(2\pi f_c (t - nT_s) + \varphi_m)}\}$$

M-ary Amplitude Shift-Keying (M-ASK)

Instantaneous Transmitted Signal

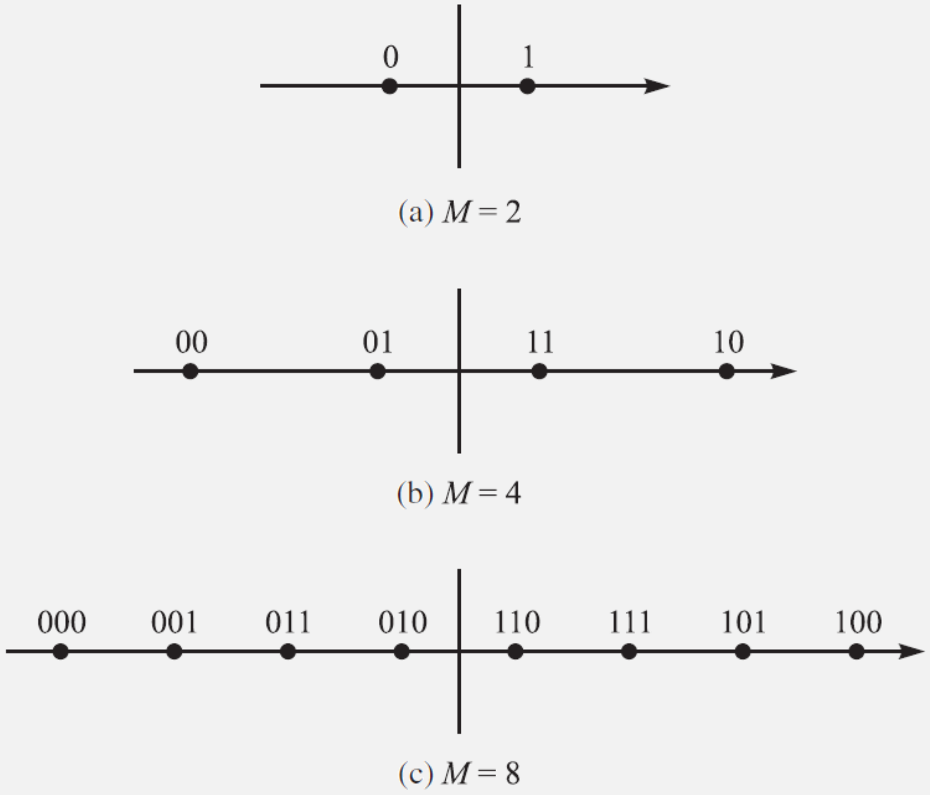
$$S_m(t) = A_m g(t)\cos(2\pi f_c t) = A_m \sqrt{\frac{\varepsilon_g}{2}}\,\varphi(t)$$

M-ary amplitude:

$$A_m = \pm 1, \pm 2, \ldots, \pm(M-1)$$

1D orthogonal basis:

$$\varphi(t) = \sqrt{\frac{2}{\varepsilon_g}}\, g(t)\cos(2\pi f_c t)$$



M-ary Phase Shift-Keying (M-PSK)

Instantaneous Transmitted Signal

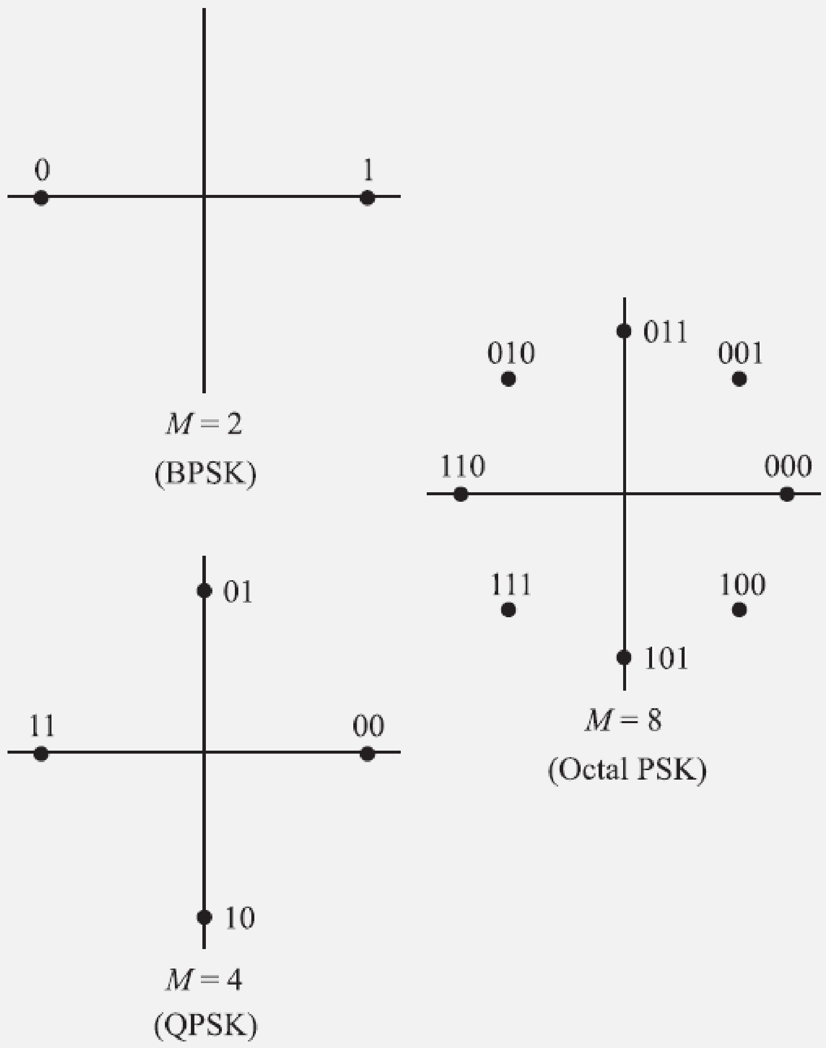
$$S_m(t) = g(t)\cos(2\pi f_c t + \varphi_m)$$

$$= \sqrt{\frac{\varepsilon_g}{2}}\cos\left(\frac{2\pi}{M}(m-1)\right)\varphi_1(t) + \sqrt{\frac{\varepsilon_g}{2}}\sin\left(\frac{2\pi}{M}(m-1)\right)\varphi_2(t)$$

2D orthogonal basis:

$$\varphi_1(t) = \sqrt{\frac{2}{\varepsilon_g}}\, g(t)\cos(2\pi f_c t)$$

$$\varphi_2(t) = -\sqrt{\frac{2}{\varepsilon_g}}\, g(t)\sin(2\pi f_c t)$$



M-ary Quadrature Amplitude Modulation (M-QAM)

Instantaneous Transmitted Signal

$$S_m(t) = A_m g(t)\cos(2\pi f_c t + \varphi_m)$$

$$= A_{mi}\sqrt{\frac{\varepsilon_g}{2}}\,\varphi_1(t) + A_{mq}\sqrt{\frac{\varepsilon_g}{2}}\,\varphi_2(t)$$

$$A_m = \sqrt{A_{mi}^2 + A_{mq}^2} \qquad \varphi_m = \tan^{-1}(\frac{A_{mq}}{A_{mi}})$$

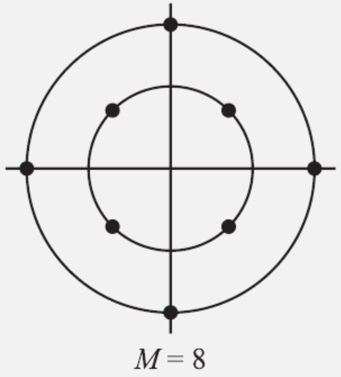
$$M_{QAM} = M_{ASK}\, M_{PSK}$$

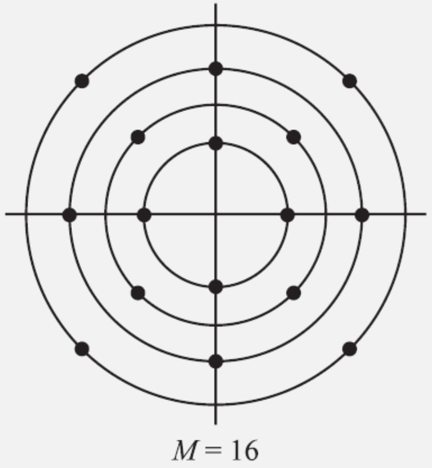
$$K_{QAM} = K_{ASK} + K_{PSK}$$

2D orthogonal basis:

$$\varphi_1(t) = \sqrt{\frac{2}{\varepsilon_g}}\,g(t)\cos(2\pi f_c t)$$

$$\varphi_2(t) = -\sqrt{\frac{2}{\varepsilon_g}}\,g(t)\sin(2\pi f_c t)$$

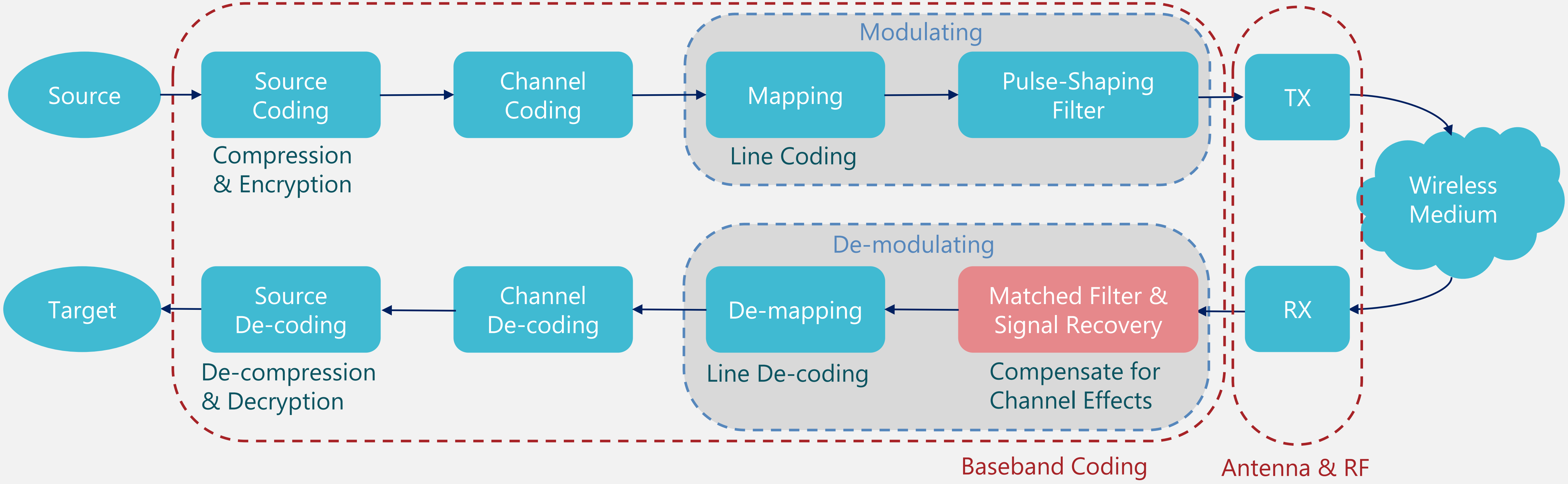




Section B

Non-Linear Modulation Schemes

Wireless Digital Communications



M-ary Non-Linear Modulation Techniques

Instantaneous Transmitted Signal

$$S_m(t) = Real\{S_{m,BB}e^{j2\pi f_c t}\}$$

$$S_{m,BB}(t) = \sqrt{\frac{2\varepsilon}{T}}\ e^{j2\pi m\Delta f t}$$

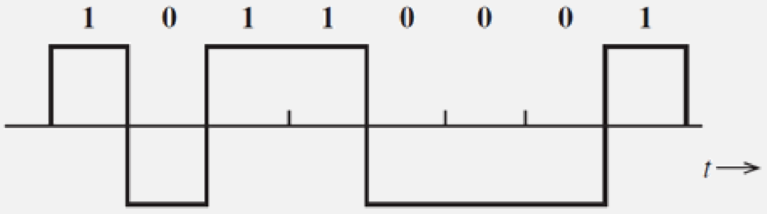
$$0 \leq m \leq M \qquad 0 \leq t \leq T$$

FSK is a special case of the construction of the orthogonal signals.

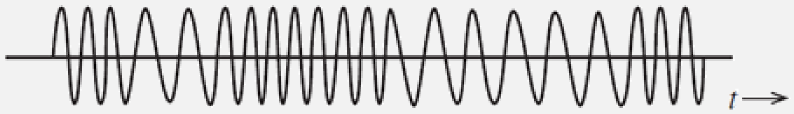
Non-Linear Modulation Types

Non-Linear Modulation	A_m	φ_m	Constellation
FSK	Fixed	Fixed	MD

Signal



BFSK



M-ary Modulation Techniques with Memory

Instantaneous Transmitted Signal

$$S_m(t) = \sqrt{\frac{2\epsilon}{T}} \cos(2\pi f_c t + \varphi(t; I) + \varphi_0)$$

$$\varphi(t; I) = 2\pi \sum_{k=-\infty}^{n} I_k h_k q(t - kT)$$

$$q(t) = \int_0^t g(\tau) d\tau$$

h_k: modulation index

Modulation Types with Memory

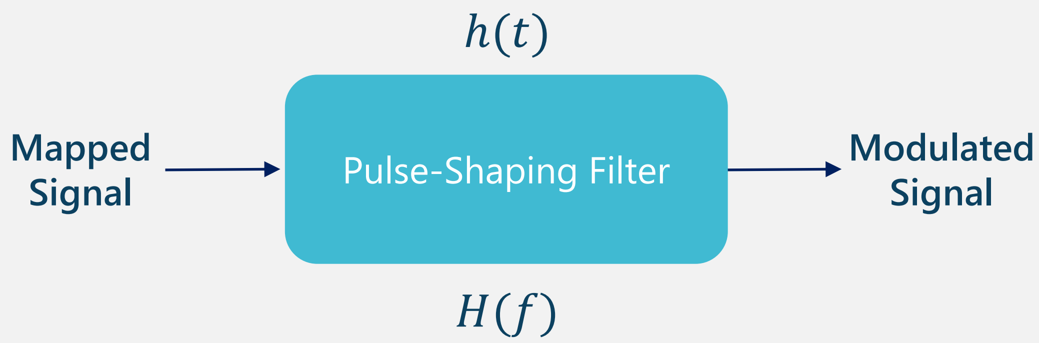
Modulation
CPM
CPFSK
MSK
GMSK
OQPSK

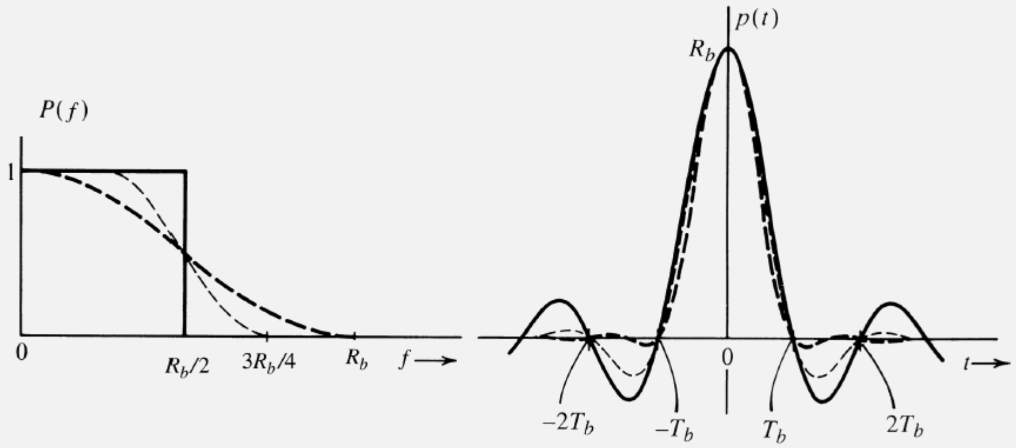
- The phase of the signal is constrained to be continuous.
- This constraint results in a phase or frequency modulator that has memory.
- To avoid the use of signals having large spectral side lobes, the information-bearing signal frequency modulates a single carrier whose frequency is changed continuously.

Section C

Pulse-Shaping Filters

Pulse-Shaping Filters





Filter Types

- Rectangular
- Gaussian
- Raised Cosine
- Root-Raised Cosine

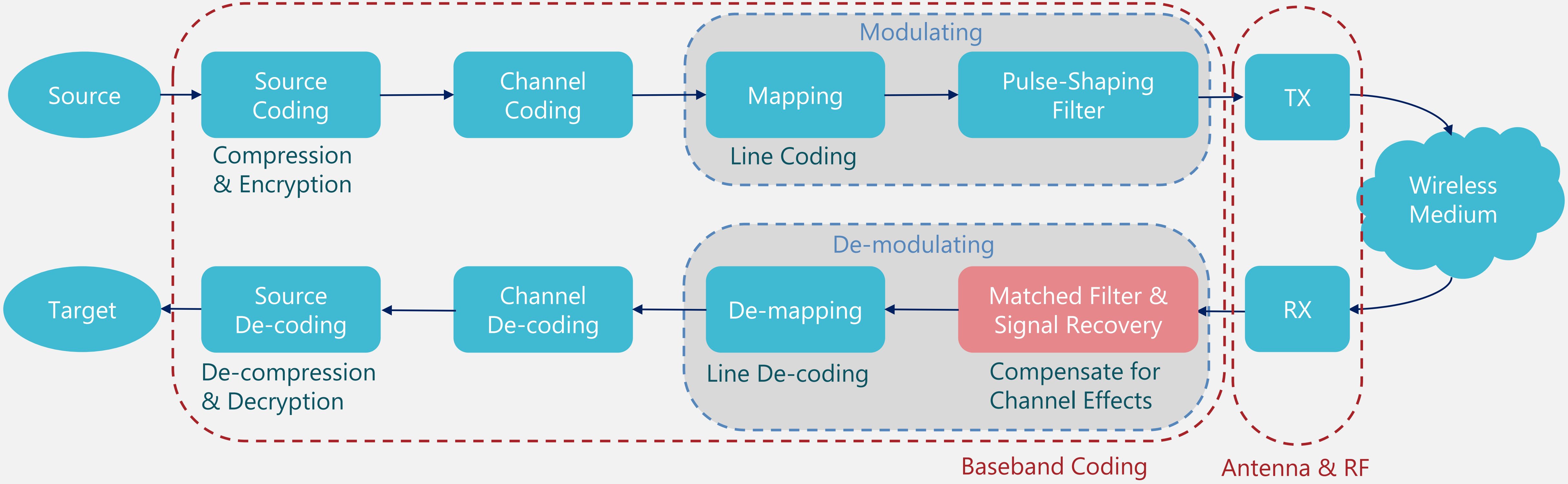
Roll-off factor

$$h(t) = \begin{cases} \frac{1}{T_s}\left(1 + \beta(\frac{4}{\pi} - 1)\right), & t = 0 \\ \frac{\beta}{T_s\sqrt{2}}\left[\left(1 + \frac{2}{\pi}\right)\sin\left(\frac{\pi}{4\beta}\right) + \left(1 - \frac{2}{\pi}\right)\cos\left(\frac{\pi}{4\beta}\right)\right], & t = \pm\frac{T_s}{4\beta} \\ \frac{1}{T_s}\frac{\sin\left[\pi\frac{t}{T_s}(1-\beta)\right] + 4\beta\frac{t}{T_s}\cos\left[\pi\frac{t}{T_s}(1+\beta)\right]}{\pi\frac{t}{T_s}\left[1 - \left(4\beta\frac{t}{T_s}\right)^2\right]}, & \text{otherwise} \end{cases}$$

Section D

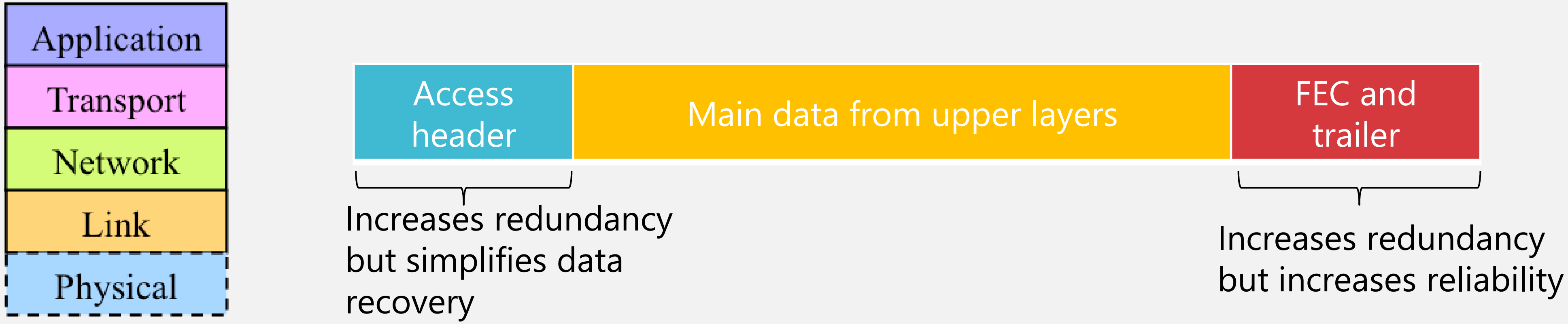
Channel Coding/Decoding

Wireless Digital Communications



Channel Coding/Decoding Techniques

Forward error correction (FEC)	Linear block codes	Block codes	Linear block codes	Cyclic codes
		BCH codes	Reed-Solomon codes	-
	Convolutional codes	-	-	-
	Turbo codes	-	-	-
	Space-time coding	Alamouti	Trellis	-



Section E

GNU Radio and SDR

GRC Example for 4-QAM

Preferred GRC Blocks:

Transmitter	Wireless Channel	Receiver
Wav. file source		
Signal source		
Low Pass Filter		
Packet Encoder		
QAM Modulator		
Throttle		
Time sink		
Frequency sink		
Constellation sink		

Note: You may need other essential blocks.