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Fundamentals of Analogue and Digital Communication Systems

Springer

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To

Roma, Devaki and Agastya

Preface

Engineering Communication is a rapidly expanding, highly mathematical subject. I felt the need to introduce the subject to the average student in a simple and understandable manner. Other texts treat the subject with little or no regard for the *basis* of the subject, which was investigated starting from the early nineteenth century.

In the late twentieth century and in the twenty-first century, Digital Communication has gained tremendous importance. Because of this, the treatment of Analogue Communication, in most books, is sketchy and superficial. However, on giving some thought to the matter, it was apparent that Digital Communication is just an extension of Analogue Communication, and if the latter is not understood properly, there is little probability of understanding Digital Communication, and the subject, to a normal student, would be incomprehensible. The book may be used in a two- or three-semester course: one course on Analogue Communication, another course on Digital Communication (I) and a third on Digital Communication (II).

A note to the student. First, the chapter and material should be read *at least four times*. Next, the solved problems should be worked out without skipping steps, and finally the problems at the back of each chapter may then be worked out. By this method, some grasp of the subject may be obtained.

Hyderabad, Telangana, India — Sunil Bhooshan
April 2021

About This Book

This book is divided into three parts, namely Part I which introduces all the mathematical and some circuit concepts required for the rest of the book, Part II which is Analogue Communication and Part III which consists of Digital Communication.

Part I, Chaps. 2–4, may be read as and when required. Much of it may be read as subsidiary material when attending a course of Signals and Systems. This material is useful for communication systems, but the z-transform or Discrete Time Fourier Transform has not been included. Part II, Chaps. 5 and 6, consists of Amplitude Modulation, and is followed by Frequency and Phase Modulation schemes. These modulations must be read thoroughly and understood well to proceed to Digital Communication.

Part III is mainly Digital Communication (baseband and passband) with additional material on Information Theory and Error Control Coding.

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Nomenclature and Abbreviations

$\tilde{a}(t)$	A sine or cosine function
AM	Amplitude modutation
ASK	Amplitude shift keying
AWGN	Additive white Gaussian noise
$\mathbf{b}$	Parity bits; see Eq. (13.1)
B	Sometimes used for bandwidth
$b(t)$	Bit sequence
BCH	Bose–Choudhuri–Hocquenghem
BFSK	Binary frequency shift keying
BPF	Bandpass filter
BPSK	Binary phase shift keying
$\mathbf{c}$	Code word; see Eq. (13.1)
C	Channel capacity
$c(t)$	PN sequence
$c(t)$	Carrier signal
$C_N(t_1, t_2)$	Covariance function; see Eq. (3.95)
CDF, cdf	Cumulative distribution function
$\delta(t)$	The impulse function
$d(\mathbf{c}_i, \mathbf{c}_j)$	Hamming distance
DM	Delta modulation
DPCM	Differential pulse code modulation
DS	Direct sequence
DSB	Amplitude modutation, double sideband
DSB/SC	Amplitude modutation, double sideband, supressed carrier
DSSS	Direct sequence (DS) spread spectrum
η	Coding efficiency; see Eq. (12.9)
$\mathbb{E}$	Energy of a signal; see Eq. (2.5)
E	An event
$E[X]$	Average or expected value of the random variable X ; see Eq. (3.44)
E^c	Complement of the set E
E_b	Energy per bit

$\mathcal{F}\{\cdots\}$	Fourier transform
$\mathcal{F}^{-1}\{\cdots\}$	Inverse Fourier transform
$\Phi_X(v)$	Charcteristic function
$f(t)$	An analogue signal or function
$f[n]$	A digital function
$F_X(x)$	Cumulative distribution function of the random variable x
$f_X(x)$	Probability density function of the random variable x
FDM	Frequency division multiplexing
FM	Frequency modulation
FSK	Frequency shift keying
FT	Fourier transform
$\mathbf{G}$	Generator matrix
$g(x)$	Generator polynomial
$\mathbf{h}(X)$	Differential entropy; see Eq. (12.51)
$\mathbf{H}$	Parity check matrix
$\mathcal{H}\{x(t)\} = x_h(t)$	Hilbert Transform of $x(t)$
$H(\mathcal{S})$	Entropy of a source; see Eq. (12.5)
HPF	Highpass filter
$\mathbf{I}(X;Y)$	Mutual information, continuous RVs; see Eq. (12.57)
$\Im[\cdots]$	Imaginary part
$I(\mathcal{X};\mathcal{Y})$	Mutual information, page 606
$I(s)$	Information in bits about a symbol s; see Eq. (12.1)
$I_{th}(t)$	Thermal noise current
IFT	Inverse Fourier transform
ISI	Intersymbol interference
$j(t)$	Jamming signal, page 573
k_a	Amplitude sensitivity; see Eq. (5.39)
k_f	Frequency sensitivity; see Eq. (6.3)
k_p	Phase sensitivity; see Eq. (6.7)
l_k	The lengths of the binary code words
LMS	Least mean squared
LTI	Linear time invariant
LZ	Lempel–Ziv
$\mathbf{m}$	Message bits; see Eq. (13.1)
μ	Modulation index; see Eq. (5.43)
$m(t)$	Message signal
m_X	Average (mean) or expected value of the random variable X
M_{ij}	Mutual inductor; see Eq. (4.14)
ML	Maximum Likelihood
ML	Maximum lemgth
MMSE	Minimum mean squared equaliser
MSK	Minimum shift keying
$\mathcal{N}$	Noise power
$N_0/2$	Magnitude of the PSD of white noise
$n_{\mathrm{NB}}(t)$	Narrowband noise

NRZ	Non-return to zero
ω_0	Fundamental frequency of a Fourier series
$\mathbb{P}$	Power of a signal; see Eq. (2.7)
ϕ	The null set
$P(\cdot)$	Probability of an event
$p(t)$	Any kind of pulse
P_e	Probability of error
$p_s(t)$	Single pulse of width 2τ
$x_+(t)$	Pre-envelope of a function $x(t)$
$\phi_j(t)$	Orthonormal functions
PAM	Pulse amplitude modulation
PCM	Pulse code modulation
PDF	Probability density function
PLL	Phase locked loop
PM	Phase modulation
PPM	Pulse position modulation
PSD	Power spectral density
PSK	Phase shift keying
PWM	Pulse width modulation
QAM	Quadrature amplitude modulation
QPSK	Quadrature phase shift keying
$\text{rect}(t)$	The rect function; see Eq. (2.32)
$\Re[\cdots]$	Real part
r	Code rate; see Eq. (12.46)
$R_N(\tau)$	Autocorrelation function of the random process $N(t)$
R_b	Bit rate
rms	Root mean square
RV	Random variable
$\|s_i\|_v$	Vector norm; see Eq. (10.22)
$\|s_i(t)\|_f^2$	Function norm; see Eq. (10.21)
$\mathbf{s}_i$	Signal vector
$\mathcal{S}$	Sample space
$\mathcal{S}$	Signal power
$\mathcal{S}$	Symbol set
$\mathcal{S}$	A set
$\text{sgn}(t)$	The signum function; see Eq. (2.24)
$\text{sinc}(\omega)$	The sinc function; see Eq. (2.26)
σ_X	Standard deviation of a random variable
σ_X^2	Variance of the random variable X; see Eq. (3.48)
s_k	Source symbols
$S_X(\omega)$	Power spectral density of the random process $X(t)$
SNR	Signal-to-noise ratio
SSB	Amplitude modutation, single sideband
T	Fundamental period of a Fourier series
T_b	Bit width in sec

TDM	Time division multiplexing
$\mathbf{u}_j$	Unit vector
$u(t)$	The unit step function; see Eq. (2.19)
$V_{th}(t)$	Thermal noise voltage
VSB	Amplitude modutation, vestigeal sideband
ω_s	Sampling frequency; see Eq. (7.14)
$w(\mathbf{c}_i)$	Hamming weight
$w(t)$	White noise
WSS	Wide-sense stationary process
$x(t)$	Generally an input signal
$x_T(t)$	A periodic function with period T
$x_+(t)$	Pre-envelope of a function $x(t)$
$x_h(t)$	Hilbert transform of a function $x(t)$
$\langle g_1(t) \cdot g_2(t) \rangle$	Inner product of two functions
$\oplus$	Modulo 2 addition; see Eq. (11.1)
$f(t) * g(t)$	Convolution; see Eq. (2.32)