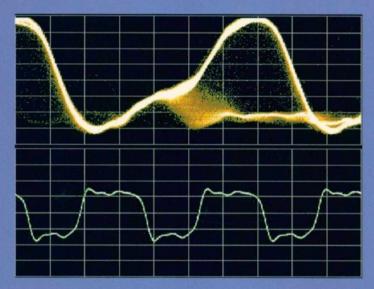
Digital Communication Systems Using MATLAB® and Simulink®

Second Edition



Dennis Silage

Digital Communication Systems Using MATLAB® and Simulink® Second Edition



Digital Communication Systems Using MATLAB® and Simulink® Second Edition

Dennis Silage Electrical and Computer Engineering Temple University



Published by Bookstand Publishing Morgan Hill, CA 95037 2914 6

Copyright © 2016 by Dennis Silage

All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopy, recording, or any information storage and retrieval system, without permission in writing from the copyright owner.

ISBN 978-1-58909-621-9

Printed in the United States of America

Acknowledgements

This Second Edition text would not have been possible without the support of The Mathworks (www.mathworks.com) and their commitment to assist Faculty to prepare the future workforce in the face of a sea change in computer aided design and analysis in digital communication systems. Rick Rosson and Scott Benway of The Mathworks have provided able assistance to our undergraduate and graduate curricula and research efforts in this paradigm. Leonard Colavito and Robert Esposito are my graduate students who have contributed to this understanding in the Department of Electrical and Computer Engineering at Temple University.

This text, though, is dedicated to Professor Victor K. Schutz who is an exemplar of a dedicated Engineering educator.

In general we are least aware of what our minds do best.

-Marvin Minsky

MATLAB* and Simulink* are registered trademarks of The Mathworks, Inc. and is used with permission. The MathWorks does not warrant the accuracy of the text or exercises in this text. The text's use or discussion of MATLAB* and Simulink* software or related products does not constitute endorsement or sponsorship by The MathWorks of a particular pedagogical approach or particular use of the MATLAB* and Simulink* software.

Table of Contents

Chapter 1	Communication Simulation Techniques		
	Capabilities and Limitations of Simulation	1	
	Introduction to MATLAB* and Simulink*	2	
	Model Window	2	
	Temporal Display	5	
	Power Spectral Display	6	
	Correlation Display	10	
	Toolboxes and Blocks	12	
	Data Types	14	
	MATLAB Functions in Simulink	16	
	Modulation and Demodulation	17	
	Analog Modulation	18	
	Amplitude Modulation	18	
	Simulation of Coherent DSB-LC AM	18	
	Simulation of Noncoherent DSB-LC AM	22	
	Frequency Modulation	23	
	Simulation of Coherent FM	23	
	Simulation of Noncoherent FM	26	
	DSB-LC AM with Speech	26	
	Summary	32	
	References	32	
Chapter 2	Baseband Modulation and Demodulation	33	
	Rectangular Pulse Amplitude Modulation	34	
	Simulation of Rectangular PAM	34	
	Rectangular PAM Power Spectral Density		
	Performance of Rectangular PAM in a		
	Simple Receiver in AWGN	39	
	Performance of Filtered Rectangular PAM in a		
	Simple Receiver in AWGN	41	
	Sinc Pulse Amplitude Modulation	44	
	Simulation of Sinc PAM	44	
	Sinc PAM Power Spectral Density	47	
	Performance of Sinc PAM in a		
	Simple Receiver in AWGN	48	
	Raised Cosine Pulse Amplitude Modulation	50	
	Simulation of Raised Cosine PAM	51	
	Raised Cosine PAM Power Spectral Density	53	
	Performance of Raised Cosine PAM in a		
	Simple Receiver in AWGN	55	
	Optimum Baseband Receiver	57	
	Multisampling Receiver	57	
	Correlation Receiver for Baseband Symmetrical		
	Signals	59	

	Probability of Bit Error for Baseband Symmetrical	
	Signals	61
	Performance of Symmetrical PAM for the	
	Optimum Receiver in AWGN	62
	Correlation Receiver for Baseband Asymmetrical	-
	Signals	64
	Probability of Bit Error for Baseband Asymmetrical	04
	Signals	67
		0/
	Performance of Asymmetrical PAM for the	
	Optimum Receiver in AWGN	68
	Multilevel (M-ary) Pulse Amplitude Modulation	69
	Simulation of M-ary Rectangular PAM	69
	M-ary Rectangular PAM Power Spectral Density	70
	Correlation Receiver for M-ary Baseband Signals	72
	Probability of Bit Error for M-ary Baseband Signals	73
	Performance of M-ary PAM for the Optimum	
	Receiver in AWGN	75
	Partial Response Signaling	77
	Duobinary Sinc PAM Signaling	77
	Simulation of Duobinary Sinc PAM	79
	Simple Receiver for Precoded Duobinary	19
		0.1
	Sinc PAM Signals	81
	Simple Receiver for Precoded Modified	
	Duobinary Sinc PAM Signals	84
	Duobinary Sinc PAM Power Spectral Density	86
	Performance of Duobinary Sinc PAM in a	
	Simple Receiver in AWGN	89
	Delta Modulation	90
	Simulation of Delta Modulation	91
	Eye Diagrams	94
	Average Power Spectral Density	100
	Summary	102
	References	102
	references	102
Chapter 3	Bandpass Modulation and Demodulation	103
	Optimum Bandpass Receiver	103
	Correlation Receiver for Bandpass Symmetrical	105
	Signals	104
		104
	Probability of Bit Error for Bandpass Symmetrical	105
	Signals	105
	Correlation Receiver for Bandpass Asymmetrical	0.00
	Signals	106
	Probability of Bit Error for Bandpass Asymmetrical	
	Signals	107
	Binary Amplitude Shift Keying	108
	Simulation of Binary ASK	109
	Binary ASK Power Spectral Density	111
	Performance of Binary ASK for the Optimum	
	Receiver in AWGN	114
	Received iii A WOIN	114