

Peter A. Stark

*Queensborough Community College  
of the City University of New York*

# Communications “101”

Preliminary Edition

Copyright © 1996-2002 by Peter A. Stark

All rights reserved. No part of this book may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or by any information or storage system, without permission in writing from the Author.

Library of Congress catalog number:

Printed in the United States of America.

PRINTING 1 2 3 4 5 6 7 8 9 10 11 12 13 YEAR 234567890

Dedicated with love to my family,  
whose patience and forbearance made this book possible.

# Contents

## **PART I** **The MESSAGE**

### **Chapter 1 - Audio**

- 1 - 1 Sound
- 1 - 2 Harmonics or Overtones
- 1 - 3 Bandwidth
- 1 - 4 Time
- 1 - 5 Summary

### **Chapter 2 - Video**

- 2 - 1 Fax Machines
- 2 - 2 Television
- 2 - 3 Bandwidth
- 2 - 4 Color TV
- 2 - 5 Digital TV
- 2 - 6 Summary

### **Chapter 3 - Digital Data**

- 3 - 1 Digital vs. Analog
- 3 - 2 Binary Numbers
- 3 - 3 Number conversions
- 3 - 4 Hexadecimal numbers
- 3 - 5 Computer Codes
- 3 - 6 ASCII
- 3 - 7 The Eighth Bit
- 3 - 8 Parity
- 3 - 9 Error detection and error correction
- 3 - 10 Conclusion

## **PART II** **The MEDIUM**

### **Chapter 4 - Wired Communications**

- 4 - 1 Wire Communications
- 4 - 2 Characteristic Impedance
- 4 - 3 Reflections
- 4 - 4 Reflections in digital circuits
- 4 - 5 Reflections in analog circuits
- 4 - 6 More complicated cases
- 4 - 7 Measuring VSWR
- 4 - 8 One application — a waveguide
- 4 - 9 Transformers for impedance matching

- 4 - 10 Last thoughts
- 4 - 11 Cable loss
- 4 - 12 Summary

## **Chapter 5 - Fiber Optics**

- 5 - 1 Optical Fibers
- 5 - 2 Transmission Modes
- 5 - 3 Fiber characteristics
- 5 - 4 Core and cladding diameter
- 5 - 5 Attenuation
- 5 - 6 Attenuation vs. Frequency
- 5 - 7 Signal bandwidth
- 5 - 8 NA or Numerical Aperture
- 5 - 9 Connectors and splices
- 5 - 10 Pluggable connectors
- 5 - 11 Splices where the two fibers remain separate
- 5 - 12 Splices where the two fibers join together
- 5 - 13 Light Sources
- 5 - 14 Light Detectors
- 5 - 15 OTDR
- 5 - 16 Conclusion

## **Chapter 6 - Wireless**

- 6 - 1 The dipole antenna
- 6 - 2 Antenna Polarization
- 6 - 3  $\frac{1}{4}$ -wavelength vertical antenna
- 6 - 4 Carriers and Modulation
- 6 - 5 Radiation Patterns
- 6 - 6 Directional antennas
- 6 - 7 Other things to consider
  - Types of feed line
  - The counterpoise
  - Loop antennas
  - Colinear antennas
  - Nonresonant antennas
  - Feed methods
- 6 - 8 Antenna gain
- 6 - 9 Signal Strength
- 6 - 10 Capture Area
- 6 - 11 Dish Antenna Gain
- 6 - 12 Practical Example
- 6 - 13 "Figures lie, and liars figure"
- 6 - 14 Path Loss
- 6 - 15 Propagation
- 6 - 16 The Ionosphere
- 6 - 17 Height and HAAT
- 6 - 18 Some Complications
- 6 - 19 Long distances at very high frequencies
- 6 - 20 Communication Satellites
  - Geo-stationary or Synchronous satellites
  - Low Earth Orbit or LEO Satellites
  - Molniya Orbits

6 - 21 Conclusion

## **PART III TRADITIONAL METHODS**

### **Chapter 7 - Amplitude Modulation**

- 7 - 1 Amplitude Modulation (AM)
- 7 - 2 A simple AM receiver
- 7 - 3 A simple AM transmitter
- 7 - 4 Modulation Percentage
- 7 - 5 AM Sidebands
- 7 - 6 Bandwidth
- 7 - 7 Sideband Power
- 7 - 8 Efficiency
- 7 - 9 Double Sideband (DSB)
- 7 - 10 Single Sideband (SSB)
- 7 - 11 Vestigial Sideband
- 7 - 12 Frequency Division Multiplexing (FDM)
- 7 - 13 Conclusion

### **Chapter 8 - FM and PM**

- 8 - 1 Frequency Modulation (FM)
- 8 - 2 Producing FM
- 8 - 3 Detecting FM
- 8 - 4 FM Sidebands
- 8 - 5 Deviation
- 8 - 6 Modulation Index
- 8 - 7 Bandwidth
- 8 - 8 Channels
- 8 - 9 Phase Modulation
- 8 - 10 Differences between AM, FM, and PM
- 8 - 11 Continuous Tone Squelch
- 8 - 12 Repeaters and Trunking

### **Chapter 9 - The Superheterodyne**

- 9 - 1 Sensitivity
- 9 - 2 Selectivity
- 9 - 3 How do we improve sensitivity and selectivity?
- 9 - 4 The TRF or Tuned Radio Frequency Receiver
- 9 - 5 Superhet to the Rescue!
- 9 - 6 The Converter
- 9 - 7 Variations on a Theme
- 9 - 8 Superheterodyne Sensitivity and Selectivity
- 9 - 9 The Image
- 9 - 10 Summary

### **Chapter 10 - Receiver Fine Points**

- 10 - 1 RF Frequency Range
- 10 - 2 Selectivity
- 10 - 3 Stability

- 10 - 4 Types of Oscillators
- 10 - 5 AGC, AVC, AFC, and BFO
- 10 - 6 PLL — the Phase-Locked Loop
- 10 - 7 Direct Digital Synthesis
- 10 - 8 Subcarriers
- 10 - 9 Stereo FM
- 10 - 10 Spread-Spectrum
- 10 - 11 Frequency Hopping
- 10 - 12 Direct Sequence
- 10 - 13 Digital Signal Processing
- 10 - 14 Duplex operation
- 10 - 15 Conclusion

## **Chapter 11 - Telephone System Overview**

- 11 - 1 POTS History
- 11 - 2 The POTS Network
- 11 - 3 The subscriber loop
- 11 - 4 Dialing
- 11 - 5 NANP — the North American Numbering Plan
- 11 - 6 NANP Changes
- 11 - 7 Splits and Overlays
- 11 - 8 Central Office Equipment
- 11 - 9 Switches
- 11 - 10 Long Distance Calls
- 11 - 11 SS7 — Signalling System 7
- 11 - 12 LATAs
- 11 - 13 1-Plus Dialing
- 11 - 14 The effect of competition

## **Chapter 12 - Modems**

- 12 - 1 The Modem
- 12 - 2 The Bell 103 modem
- 12 - 3 DPSK Modems
- 12 - 4 QAM
- 12 - 5 Modern Modems
  - Negotiation and line probing
  - Echo Suppression
  - Scrambling
  - Trellis coding
  - Viterbi detection
- 12 - 6 28,800 bps Modems
- 12 - 7 56K modems

# **PART 4 DIGITAL METHODS**

## **Chapter 13 - Digital Fundamentals**

- 13 - 1 Parallel Data Transfer
- 13 - 2 Asynchronous Serial Data
- 13 - 3 RS-232 and EIA-232
  - The official RS-232

- De-facto RS-232
- 13 - 4 Hayes Command Set
- 13 - 5 The UART
- 13 - 6 Timing errors
- 13 - 7 Synchronous Serial Data
- 13 - 8 Synchronizing transmitter and receiver clocks
- 13 - 9 Self-Clocking codes
- 13 - 10 Bandwidth

## **Chapter 14 - D-A and A-D Conversion**

- 14 - 1 Digital-to-Analog Conversion
- 14 - 2 Analog-to-Digital Conversion
- 14 - 3 Voltage limits
- 14 - 4 Sample-and-Hold
- 14 - 5 Sampling
- 14 - 6 Sampling Rate
- 14 - 7 Sampling accuracy
- 14 - 8 PCM: Pulse Code Modulation
- 14 - 9 A-law and  $\mu$ -law compression
- 14 - 10 DPCM: Differential PCM
- 14 - 11 APCM and ADPCM
- 14 - 12 Delta Modulation
- 14 - 13 Delta-Sigma converters

## **Chapter 15 - Multiplexing and TDM**

- 15 - 1 FDM: Frequency Division Multiplexing
- 15 - 2 WDM: Wavelength Division Multiplexing
- 15 - 3 Spread Spectrum
- 15 - 4 PAM: Pulse Amplitude Modulation
- 15 - 5 TDM: Time Division Multiplexing
- 15 - 6 PWM: Pulse Width Modulation
- 15 - 7 PFM: Pulse Frequency Modulation
- 15 - 8 Purely digital TDM
- 15 - 9 Synchronous TDM
- 15 - 10 Statistical TDM
- 15 - 11 Buffer performance
- 15 - 12 Synchronous vs. Statistical TDM
- 15 - 13 Frames
- 15 - 14 Packets

## **Chapter 16 - Analog and Digital Subscriber Loops**

- 16 - 1 POTS
- 16 - 2 The subscriber loop
- 16 - 3 Your telephone set
- 16 - 4 The Line Card
- 16 - 5 ISDN — Integrated Services Digital Network
- 16 - 6 Basic Rate Interface ISDN
  - NT-1 and the U Reference Point
  - NT-2 and the S and T Reference Points
  - TE-1 ISDN Devices
  - TE-2 Non-ISDN devices

- Multiple devices
- 16 - 7 Primary Rate Interface (PRI)

## **Chapter 17 - Network Fundamentals**

- 17 - 1 Networks
- 17 - 2 Topology
- 17 - 3 Network Interconnections
- 17 - 4 Collisions and Timing  
(Still in process)

## **Chapter 18 - T Carrier**

- 18 - 1 DS-0
- 18 - 2 DS-1 Frame
- 18 - 3 The D-1 Channel Bank
- 18 - 4 The Superframe
- 18 - 5 Extended Superframes
- 18 - 6 T-1 Facility
- 18 - 7 The “Too Many ZEROs” problem
- 18 - 8 Non-Channelized T-1
- 18 - 9 B8ZS
- 18 - 10 T-1 equipment
  - Channel banks
  - CSU and DSU
  - Repeaters and phantom power
  - Digital Cross Connects
- 18 - 11 T-1 Variations
  - HDSL and HDSL-2
  - Fractional T-1
  - Voice compression
- 18 - 12 E-1
- 18 - 13 Timing problems
- 18 - 14 DS-2 / T-2
- 18 - 15 DS-3
- 18 - 16 T-3
- 18 - 17 DS-4 and T-4

## **Chapter 19 - Digital Subscriber Line (DSL)**

- 19 - 1 Remote Terminals
- 19 - 2 Digital vs. Analog DSL Modems
- 19 - 3 xDSL  
(Still in process)

## **Appendix A - Decibels**

- A - 1 Definition of dB
- A - 2 Converting dB to a gain ratio
- A - 3 A More general use for dB
- A - 4 dBm
- A - 5 dB for Voltage and Current Ratios

## **Appendix B - Tuned Circuits**

- B - 1 Resonant Circuits
- B - 2 Bandwidth
- B - 3 Quality or “Q”
- B - 4 Example
- B - 5 Conclusion

### **Appendix C - Cyclic Redundancy Check (CRC)**

- C - 1 A simple example of error detection
- C - 2 Similarity to the CRC
- C - 3 How is CRC implemented?
- C - 4 The CRC Circuit

### **Appendix D - Queuing Theory and Erlangs**

- D - 1 Offered Traffic
- D - 2 Poisson Distribution
- D - 3 Utilization Factor
- D - 4 Basic program