



COMMUNICATIONS

SECOND EDITION

RECEIVERS

ULRICH L. ROHDE, JERRY WHITAKER,
AND T.T.N. BUCHER

Table Of Contents

Chapter 1: Basic Radio Considerations

| | |
|---|----|
| Radio Communications Systems | 1 |
| Radio Transmission and Noise | 7 |
| Modulation | 13 |
| Analog Modulation | 15 |
| Modulation for Digital Signals | 22 |
| Radio Receiver Configurations | 35 |
| Superheterodyne Receivers | 40 |
| Tube Versus Semiconductor-Based Receivers | 42 |
| Typical Radio Receivers | 43 |
| Design Example: The EK895 | 43 |
| VHF and UHF Receivers | 49 |
| Bibliography | 52 |

Chapter 2: Radio Receiver Characteristics

| | |
|----------------------------------|----|
| Introduction | 55 |
| Input Characteristics | 55 |
| Gain, Sensitivity, and NF | 56 |
| Selectivity | 62 |
| Dynamic Range | 64 |
| Desensitization | 67 |
| AM Cross Modulation | 67 |
| IM | 68 |
| Reciprocal Mixing | 71 |
| Spurious Outputs | 72 |
| Gain Control | 75 |
| RFI | 78 |
| Output Characteristics | 78 |
| Bandwidth Response and Noise | 79 |
| Harmonic Distortion | 80 |
| IM Distortion | 81 |
| Transient Response | 82 |
| Frequency Accuracy and Stability | 83 |
| Frequency Settling Time | 85 |

| | |
|---|-----------|
| Electromagnetic Interference | 88 |
| Digital Receiver Characteristics | 89 |
| BER Testing | 90 |
| Bibliography | 91 |

Chapter 3: Receiver System Planning

| | |
|---|------------|
| The Receiver Level Plan | 93 |
| Calculation of NF | 94 |
| Noise Factor for Cascaded Circuits | 98 |
| Noise Correlation Matrix | 100 |
| Calculation of IP | 106 |
| Example of NF and IP Calculation | 110 |
| Spurious Response Locations | 111 |
| D-H Traces | 117 |
| Selectivity | 121 |
| Single-Tuned Circuit | 122 |
| Coupled Resonant Pairs | 124 |
| Complex Filter Characteristics | 126 |
| Butterworth Selectivity | 127 |
| Chebyshev Selectivity | 130 |
| Thompson or Bessel Selectivity | 132 |
| Equiripple Linear Phase | 132 |
| Transitional Filters | 134 |
| Elliptic filters | 136 |
| Special Designs and Phase Equalization | 136 |
| Filter Design Implementation | 138 |
| LC Filters | 139 |
| Electrical Resonators | 139 |
| Electromechanical Filters | 143 |
| Quartz Crystal Resonators | 143 |
| Monolithic Crystal Filters | 143 |
| Ceramic Filters | 144 |
| <i>Resistor-Capacitor (RC) Active Filters</i> | 144 |
| Time-Sampled Filters | 147 |
| Discrete Fourier and z Transforms | 151 |
| Discrete-Time-Sampled Filters | 151 |
| Analog-Sampled Filter Implementations | 154 |
| Digital Processing Filters | 157 |
| Frequency Tracking | 162 |
| IF and Image Frequency Rejection | 169 |
| References | 173 |

Chapter 4: Antennas and Antenna Coupling

| | |
|--|------------|
| Introduction | 175 |
| Antenna Coupling Network | 176 |
| Coupling Antennas to Tuned Circuits | 178 |
| Small Antennas | 181 |
| Whip Antennas | 183 |
| Loop Antennas | 185 |
| Active Antennas | 194 |
| Application Considerations | 196 |
| References | 208 |

Chapter 5: Amplifiers and Gain Control

| | |
|---|------------|
| Introduction | 211 |
| Amplifying Devices and Circuits | 212 |
| Representation of Linear Two-Ports | 216 |
| Noise in Linear Two-Ports with Reactive Elements | 223 |
| Wide-Band Amplifiers | 227 |
| Amplifiers with Feedback | 232 |
| Gain Stability | 233 |
| Noise Considerations | 233 |
| Types of Feedback | 237 |
| Mixed Feedback Circuits | 239 |
| Base-Emitter Feedback Circuit | 245 |
| Gain Control of Amplifiers | 247 |
| AGC | 251 |
| AGC Response Time | 254 |
| Effect of IF Filter Delays | 257 |
| Analysis of AGC Loops | 258 |
| Dual-Loop AGC | 265 |
| Digital Switching AGC | 271 |
| Integrated IF Amplifier and AGC Systems | 271 |
| Digital IF Processing | 272 |
| References | 275 |

Chapter 6: Mixers

| | |
|-------------------------|------------|
| Introduction | 277 |
| Passive Mixers | 278 |
| Active Mixers | 290 |
| Switching Mixers | 294 |
| IC-Based Mixers | 295 |

| | |
|--------------------------------------|------------|
| Gilbert Cell Mixer | 299 |
| Gilbert Cell Performance Analysis | 303 |
| Wide Dynamic Range Converters | 309 |
| Process Gain | 312 |
| Mixer Design Considerations | 313 |
| References | 317 |

Chapter 7: Frequency Control and Local Oscillators

| | |
|---|------------|
| Introduction | 319 |
| PLL Synthesizer Principles | 320 |
| Transient Response | 327 |
| Loop Components | 327 |
| Frequency Dividers | 329 |
| Phase-Frequency Detector | 334 |
| Loop Optimization | 336 |
| Loop Stability | 338 |
| Programming the Counters | 341 |
| Noise and Performance Analysis Using CAD Tools | 344 |
| A Model For SSB Phase Noise | 346 |
| Spectral Density of Frequency Fluctuations | 347 |
| Residual FM Related to $L(f_m)$ | 349 |
| Allan Variance Related to $L(f_m)$ | 349 |
| Calculation of Oscillator Noise for Linear Model | 353 |
| Nonlinear Model | 362 |
| General Concept of Noise Contribution | 365 |
| Large Signal Condition of the Active Device | 368 |
| Phase Noise Spectrum of the Oscillator | 368 |
| NF of the Mixing Circuit | 369 |
| Calculation of Total Carrier Phase Noise Spectrum | 372 |
| Practical Examples | 373 |
| Noise and Performance Analysis of PLL Systems | 377 |
| Design Process | 383 |
| Fractional Division Loop | 386 |
| Multiloop Synthesizers | 392 |
| Direct Digital Synthesis | 396 |
| Monolithic PLL Systems | 398 |
| Microwave PLL Synthesizer | 399 |
| Oscillator Design | 404 |
| Simple Oscillator Analysis | 405 |
| Negative Resistance | 409 |
| Amplitude Stabilization | 411 |
| Phase Stability | 411 |

| | |
|--|------------|
| Low-Noise Oscillators | 413 |
| Stability with Ambient Changes | 415 |
| Variable-Frequency Oscillators | 417 |
| Voltage-Controlled Oscillators | 418 |
| Diode Switches | 424 |
| Crystal-Controlled Oscillators | 425 |
| Overtone Crystal Oscillators | 434 |
| Dissipation in Crystal Oscillators | 438 |
| Voltage-Controlled Crystal Oscillator | 439 |
| Frequency Stability of Crystal Oscillators | 439 |
| Frequency Standards | 442 |
| References | 446 |

Chapter 8: Demodulation and Demodulators

| | |
|----------------------------------|------------|
| Introduction | 449 |
| Analog Demodulation | 449 |
| AM | 449 |
| DSB Demodulation | 463 |
| SSB and ISB Demodulation | 468 |
| VSB Demodulation | 470 |
| Angle Demodulation | 470 |
| PM Demodulators | 478 |
| FM Demodulators | 482 |
| Amplitude Limiters | 491 |
| FM Demodulator Performance | 495 |
| Threshold Extension | 502 |
| Pulse Demodulation | 513 |
| Digital Data Demodulation | 513 |
| ASK | 514 |
| FSK | 517 |
| PSK and Combined Modulations | 520 |
| Digital Signal Processing | 528 |
| References | 532 |

Chapter 9: Other Receiver Circuits

| | |
|------------------------------------|------------|
| Introduction | 535 |
| Noise Limiting and Blanking | 535 |
| Balancers | 538 |
| Noise Limiters | 540 |

| | |
|-------------------------------------|------------|
| Impulse Noise Blankers | 541 |
| Squelch Circuits | 542 |
| AFC | 550 |
| Diversity Reception | 553 |
| Adaptive Receiver Processing | 566 |
| Adaptive Antenna Processing | 568 |
| Adaptive Equalization | 577 |
| Time-Gated Equalizer | 582 |
| Link-Quality Analysis | 587 |
| Automatic Link Establishment | 589 |
| References | 591 |

Chapter 10: Receiver Design Trends

| | |
|---|------------|
| Introduction | 595 |
| Digital Implementation of Receiver Functions | 595 |
| Digital Receiver Design Techniques | 603 |
| DSP Considerations | 609 |
| Noise Calculations | 614 |
| Noise Cancellation | 617 |
| Spectral Subtraction | 620 |
| Spread Spectrum | 622 |
| Frequency Hopping | 629 |
| Direct Sequence | 633 |
| Performance | 637 |
| Simulation of System Performance | 637 |
| Spectrum Occupancy | 639 |
| Network Response | 640 |
| Medium Prediction | 644 |
| System Simulation | 647 |
| HF Medium Simulation | 647 |
| Simple Simulations | 652 |
| Applications of Simulation | 658 |
| References | 659 |

| | |
|--------------|------------|
| Index | 663 |
|--------------|------------|