## Contents

Abo	ut the A	uthor	xi
Pref	ace		xiii
Ack	nowledg	ements	XV
I	Funct	tional Principle of Radio Receivers	1
I.1	Some History to Start		1
	I.1.1	Resonance Receivers, Fritters, Coherers, and Square-Law Detectors (Detector Receivers)	1
	I.1.2	Development of the Audion	2
I.2		nt-Day Concepts	4
1.2	<i>I.2.1</i>	Single-Conversion Superhet	4
	I.2.1 I.2.2	Multiple-Conversion Superhet	. 8
	I.2.3	Direct Mixer	14
	I.2.4	Digital Receiver	17
I.3		cal Example of an (All-)Digital Radio Receiver	23
	I.3.1	Functional Blocks for Digital Signal Processing	25
	I.3.2	The A/D Converter as a Key Component	26
	<i>I.3.3</i>	Conversion to Zero Frequency	30
	I.3.4	Accuracy and Reproducibility	33
	<i>I.3.5</i>	VFO for Frequency Tuning	34
	I.3.6	Other Required Hardware	36
	<i>I.3.7</i>	Receive Frequency Expansion by Subsampling	37
I.4	Practical Example of a Portable Wideband Radio Receiver		
	I.4.1	Analog RF Frontend for a Wide Receive Frequency Range	40
	I.4.2	Subsequent Digital Signal Processing	42
	I.4.3	Demodulation with Received Signal Level Measurement	43
	I.4.4	Spectral Resolution of the Frequency Occupancy	45
Refe	rences		46
Furth	er Readi	ng	48

П	Fields of 1	Use and Applications of Radio Receivers	49
П.1	Prologue		49
П.2	Wireless T	Telecontrol	50
	11.2.1 R	adio Ripple Control	52
II.3		c Radio Services	54
	II.3.1 A	ir Traffic Radio	54
	II.3.2 M	laritime Radio	56
	11.3.3 L	and Radio	58
	II.3.4 A	mateur Radio	60
	11.3.5 M	lobile Radio	63
II.4	Radio Intelligence, Radio Surveillance		64
	II.4.1 N	umerous Signal Types	64
	11.4.2 Se	earching and Detecting	69
	II.4.3 M	lonitoring Emissions	75
	II.4.4 C	lassifying and Analyzing Radio Scenarios	78
	11.4.5 R	eceiver Versus Spectrum Analyzer	81
II.5		Finding and Radio Localization	83
	II.5.1 B	asic Principles of Radio Direction Finding	83
	II.5.2 R	adio Reconnaissance and Radio Surveillance	94
	II.5.3 A	eronautical Navigation and Air Traffic Control	98
	II.5.4 M	larine Navigation and Maritime Traffic	100 101
II.6	Terrestrial Radio Broadcast Reception		
II.7	Time Sign	al Reception	104
II.8	Modern R	adio Frequency Usage and Frequency Economy	107
	11.8.1 Ti	runked Radio Networks	107
	II.8.2  C	ognitive Radio	108
	ences		109
Furth	er Reading		112
ш	Receiver	Characteristics and their Measurement	113
III.1	Objectives	and Benefits	113
III.2	Preparation	ns for Metrological Investigations	114
	III.2.1 T	he Special Case of Correlative Noise Suppression	115
	III.2.2 Ti	he Special Case of Digital Radio Standards	116
III.3	Receiver I	nput Matching and Input Impedance	118
	III.3.1 M	leasuring Impedance and Matching	120
		leasuring Problems	121
III.4	Sensitivity		121
		imitations Set by Physics	122
		oise Factor and Noise Figure	123
		leasuring the Noise Figure	125
		quivalent Noise Bandwidth	127
		linimum Discernible Signal	129
		leasuring the Minimum Discernible Signal	130
	111.4.7 In	nput Noise Voltage	131

	III.4.8	Signal-to-Interference Ratio (SIR) and Operational Sensitivity	
		(S+N)/N, SINAD	132
	III.4.9	De-emphasis	136
	III.4.10	) Usable and Suitable Sensitivity	138
	<i>III.4.11</i>	Maximum Signal-to-Interference Ratio	144
	<i>III.4.12</i>	Measuring the Operational Sensitivity and Maximum SIR	145
	III.4.13	Measuring Problems	147
III.5	Spurio	as Reception	147
	III.5.1	Origin of Inherent Spurious Response	147
	III.5.2		148
	III.5.3	Reception and Suppression of Image Frequencies	149
	III.5.4	IF Interference and IF Interference Ratio	151
	III.5.5	Reception of Other Interfering Signals	152
	III.5.6	Measuring the Spurious Signal Reception	153
	III.5.7	The Special Case of Linear Crosstalk	153
	III.5.8		154
	III.5.9	Measuring Problems	155
III.6	Near Se	electivity	156
	III.6.1	Receive Bandwidth and Shape Factor	157
	III.6.2		158
	III.6.3	0	160
	III.6.4		160
	III.6.5	Measuring Problems	161
III.7		cal Mixing	162
	III.7.1	Single Sideband Noise	162
	III.7.2	Non-Harmonic (Close to Carrier) Distortions	166
	III.7.3	Sensitivity Reduction by Reciprocal Mixing	166
	III.7.4	Measuring Reciprocal Mixing	169
	III.7.5	Measuring Problems	171
III.8	Blocking		
	III.8.1	Compression in the RF Frontend or the IF Section	171
	III.8.2	AGC Response to Interfering Signals	172
	III.8.3	Reduction of Signal-to-Interference Ratio by Blocking	172
	III.8.4	Measuring the Blocking Effect	173
	III.8.5	Measuring Problems	174
III.9		dulation	174
		Origin of Intermodulation	174
	<i>III.9.2</i>	Second-and Third-Order Intermodulation	175
	111.9.3	Higher Order Intermodulation	181
	III.9.4	The Special Case of Electromechanical, Ceramic	
		and Quartz Filters	182
	III.9.5	The Special Case of A/D Converted and Digitally	
		Processed Signals	183
	III.9.6	Intermodulation Immunity	185
	111.9.7	Maximum Intermodulation-Limited Dynamic Range	185
	III.9.8	Intercept Point	186
	111.7.0	100000000000000000000000000000000000000	

	III.9.9 Effective Intercept Point (Receiver Factor or)	187
	III.9.10 Measuring the Intermodulation Immunity	188
	III.9.11 Measuring Problems	190
	III.9.12 In-band Intermodulation and Non-Linear Crosstalk	195
	III.9.13 Measurement of the In-band Intermodulation	198
III.10	Cross-Modulation	199
	III.10.1 Generation	199
	III.10.2 Ionospheric Cross-Modulation	201
	III.10.3 Measuring the Cross-Modulation Immunity	203
	III.10.4 Measuring Problems	204
<b>III</b> .11	Quality Factor of Selective RF Preselectors under Operating Conditions	204
	III.11.1 Increasing the Dynamic Range by High-Quality Preselection	205
	III.11.2 Measuring the Frequency Response	207
III.12	Large-Signal Behaviour in General	209
	III.12.1 Concrete Example	209
	III.12.2 The IP3 Interpretation Fallacy	212
III.13		213
	III.13.1 AF Frequency Response	213
	III.13.2 Measuring the AF Frequency Response	214
	III.13.3 Reproduction Quality and Distortions	214
	III.13.4 Measuring the Demodulation Harmonic Distortion	217
	III.13.5 Measuring Problems	218
III.14	Behaviour of the Automatic Gain Control (AGC)	218
	III.14.1 Static Control Behaviour	218
	III.14.2 Measuring the Static Control Behaviour	219
	III.14.3 Time-Dynamic Control Behaviour	219
	III.14.4 Measuring the Time-Dynamic Control Behaviour	221
III.15	Long-Term Frequency Stability	223
	III.15.1 Measuring the Long-Term Frequency Stability	224
	III.15.2 Measuring Problems	225
III.16	Characteristics of the Noise Squelch	226
	III.16.1 Measuring the Squelch Threshold	227
III.17	Receiver Stray Radiation	227
	III.17.1 Measuring the Receiver Stray Radiation	229
	III.17.2 Measuring Problems	230
III.18	(Relative) Receive Signal Strength and S Units	230
	III.18.1 Definitions and Predetermined Levels of S Units	233
	III.18.2 Measuring the Accuracy of the Relative Signal Strength Indication	234
	III.18.3 Measuring Problems	234
III.19	AM Suppression in the F3E Receiving Path	236
	III.19.1 Measuring the AM Suppression	237
III.20	Scanning Speed in Search Mode	238
	III.20.1 Measuring the Scanning Speed	239
Refere		240
Furthe	r Reading	242

IV	Practical	Evaluation of Radio Receivers (A Model)	245
IV.1	Factual Si	tuation	245
IV.2		Evaluation of Characteristics in Practical Operation	245
		lardly Equal Conditions	247
		o Approximation Possible	247
IV.3		on Gained in Practical Operation	249
	IV.3.1 H	lelp of a Reference Unit	252
	IV.3.2 A	Fine Distinction is Hardly Possible or Necessary	253
IV.4	Interpretat	ion (and Contents of the 'Table of operational PRACTICE')	253
	IV.4.1 T	he Gain in Information	254
IV.5	Specific E	quipment Details	255
Refere	ences		255
Furthe	r Reading		255
v	Concludin	g Information	257
<b>V</b> .1	Cascade of	f Noisy Two-Ports (Overall Noise Performance)	257
V.2		f Intermodulating Two-Ports (Overall Intermodulation	
	Performance		260
		verall Third-Order Intercept Point	261
		verall Second-Order Intercept Point	262
		omputer-Aided Calculations	263
V.3		cal Description of the Intermodulation Formation	264
		econd-Order Intermodulation	265
	V.3.2 Th	hird-Order Intermodulation	266
	V.3.3 Of	ther Terms in the Transfer Characteristic Polynomial	267
V.4		d Derivation of Spurious Reception	269
		ixing = Multiplication	269
		nbiguous Mixing Process	271
V.5	Characteris	stics of Emission Classes According to the ITU RR	272
V.6	Geographic	c Division of the Earth by Region According to ITU RR	272
<b>V</b> .7		n of dB Levels	272
	V.7.1 Vo	oltage, Current and Power Levels	276
	V.7.2 El	ectric and Magnetic Field Strength, (Power) Flux	
	$D \epsilon$	ensity Levels	278
Refere	nces		278
Furthe	Reading		279
List of	Tables		281
Index			283