High Power HF Filter Design

With Applications to SO2R

Jeff Crawford, K0ZR

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Contents

List of Figures xv
List of Tables xviii

Preface **xix**

1 Setting the Stage **1**
- 1.1 Book Philosophy 3
- 1.2 What is Not in this Book 4
- 1.3 What Is in this Book 4
- 1.4 To the Real Trail Blazers 5
- 1.5 SO2R Station at KØZR 6
- 1.6 RF Flooding 7

2 The Filter Concept **9**
- 2.1 The Path to Synthesis 11
- 2.2 Butterworth Polynomials 12
- 2.3 Chebyshev Polynomials 13
- 2.4 Elliptic Approximation Functions 14
- 2.5 Summary 14

3 Important Physics Properties **15**
- 3.1 Skin Depth 15
- 3.2 PCB Ampacity 17
- 3.3 Component Q 19
- 3.4 Q and Bandwidth 23
- 3.5 Power Transfer 24
- 3.6 Quality of Impedance Match 28

4 Components Are Everything **29**
- 4.1 Inductors 29
  - 4.1.1 Air Wound 30
  - 4.1.2 Calculating Coil Inductance 31
  - 4.1.3 Airwound Inductor Construction 33
  - 4.1.4 Toroids 36
  - 4.1.5 Core Saturation 37
- 4.2 Transmission Line Transformers 42
  - 4.2.1 A 4:1 TLT Example 43
- 4.3 Capacitors 44
  - 4.3.1 Example Capacitor Application 45
  - 4.3.2 MLCC Voltage and Current Ratings 47

4.3.3 Numerical Example Illustrating Ampacity Concerns . . . 48
4.3.4 Assembly Precautions With MLCCs . . . 52
4.3.5 Measurement of Components . . . 53

5 Overview of Filter Families 57
5.1 Elliptic Design . . . 57
5.2 Chebyshev Designs . . . 59
5.2.1 Chebyshev Nodal Capacitor Topology . . . 60
5.2.2 Chebyshev Nodal Inductor BPF . . . 60
5.2.3 Chebyshev Shunt Input Topology . . . 61
5.2.4 Chebyshev Mesh Capacitor Topology . . . 62
5.2.5 Constant-k Topology . . . 63
5.3 m-Derived, Cauer Design . . . 66
5.4 Design Comparisons . . . 67
5.5 Design Trades . . . 69

6 Circuit Simulations 71
6.1 Available Circuit Elements . . . 71
6.1.1 Libraries . . . 72
6.2 Post Processing . . . 72
6.3 Circuit Examples . . . 72
6.4 S_{21} and S_{11} from SPICE . . . 75
6.5 Autotransformers and Transmission Line Transformers . . . 76
6.5.1 Other Elements Within SIMetrix . . . 78

7 Challenges With High Power 81
7.1 Planning for Heat Removal . . . 81
7.2 Basics of Heat Transfer . . . 81
7.2.1 First-Order Approximation of Heat Removal . . . 82
7.2.2 Sizing Heat Removal System Basics . . . 83
7.3 Fan Sizing Example . . . 83

8 The Power of Transformations 87
8.1 Narrrowband Transforms . . . 88
8.1.1 RX Transform . . . 88
8.1.2 Autotransformer Technique . . . 89
8.1.3 The Elliptical Transform . . . 93
8.1.4 T- and Pi- Capacitor Networks . . . 94
8.1.5 T-π or Y-Δ Conversions . . . 95
8.2 Norton Transforms . . . 96
8.2.1 Applicability of Norton Across a Filter . . . 98
8.2.2 Putting the Norton Transform to Work . . . 100
8.3 Kuroda Transforms . . . 104
8.4 Impedance and Admittance Inverters . . . 105
8.4.1 Inverter Characteristics . . . 107
8.4.2 J-Inverter to Transform Series Capacitor to Shunt Inductor . . . 108
8.4.3 J-Inverter Applied to Series LC . . . 109
8.4.4 Final Remarks on Inverters . . . 112

9 40m Bandpass Filter Example **115**
9.1 Elliptic vs. Chebyshev 115
9.2 Inverter Application to Chebyshev 118
9.2.1 Inverter Implementation for the Chebyshev 119
9.3 Comparison of Currents 121
9.4 Design Implementation 123
9.4.1 Resonator Currents and Voltages 123
9.4.2 Inductor Details and Physical Sizing 124
9.5 40m Thermal Assessment 133
9.6 Preparing SparkPCB Libraries 133
9.6.1 Customizing Schematics 133
9.6.2 Customizing PCB Footprints 133
9.6.3 PCB Components 134
9.6.4 PCB Development 134
9.7 Build Details 137
9.7.1 Tuning of $L_3 \| C_3$ Resonator 137
9.7.2 Tuning of Autotransformer L_4 and C_4 137
9.7.3 Other Filter Resonators 138
9.7.4 When PCB Mistakes Occur 138
9.7.5 The Total Response Adjustment 139
9.8 Performance 140
9.8.1 Performance Under KW Conditions 140
9.9 Concluding Remarks on the 40m BPF 143
9.9.1 The Truth of the Matter 144

10 15m Bandpass Filter Example **145**
10.1 15m Design Using the Chebyshev Topology 145
10.1.1 High Capacitor Currents With Chebyshev 147
10.2 Alternative Approach - Elliptic Filter Family 147
10.3 Assessment of Filter Currents 148
10.4 Norton Transform Application 150
10.5 Next Phase - Build It 156
10.5.1 Incorporating Non-Exact Inductors 157
10.5.2 How Many Capacitors for Ampacity Needs? 159
10.5.3 First Thermal Estimate 160
10.5.4 Board Layout 161
10.6 Assembly 162
10.6.1 Coil Winding 162
10.6.2 Final 15m Design 163
10.6.3 MLCC Mounting 164
10.6.4 PCB Mounting 164
10.6.5 Bias-Tee Implementation for Remote 1×2 Antenna Switching 167
10.7 Alignment 168
10.7.1 Resonator Adjustment 168
10.7.2 Flux Density Concerns 170
10.7.3 Last Adjustments 170
10.8 Testing and Performance at Completion 171
10.9 15m BPF in Review 173
10.10 Design Improvements 174
10.1115m Operational Results 174

11 Other Important Considerations 177
- 11.1 Capacitor Availability and Prices . . . 177
- 11.2 Filter Housing . . . 177
- 11.3 Filter Troubleshooting . . . 178
- 11.4 Precautions With Autotransformers . . . 180
- 11.5 Augmentation With Tuned Stubs . . . 181
- 11.6 Not a Production Design . . . 182

12 KØZR Catalog of Filters 185

A Mathematics 189
- A.1 Some Mathematics . . . 189
  - A.1.1 Basic Algebraic Operations . . . 189
  - A.1.2 Derivatives . . . 191
  - A.1.3 Integrals . . . 191

B Circuit Concepts 193
- B.1 Voltage and Current Sources . . . 193
  - B.1.1 Thevenin and Norton Equivalents . . . 194
- B.2 Frequency Response of LC Circuits . . . 195

C Two-Port Parameters 201
- C.1 S-Parameters . . . 202
- C.2 ABCD Parameter Set . . . 204

D Norton Transforms 205
- D.1 First NT Development . . . 205
- D.2 Does NT-1 Really Work? . . . 209
- D.3 Modified First Norton Transformation . . . 211
- D.4 Norton Second Transform . . . 214
  - D.4.1 Modified Norton Second Transform . . . 215
  - D.4.2 Evaluation of C_2 and L_2 in Figure D.10 . . . 216
  - D.4.3 Evaluation of C_1 and L_1 in Figure D.10 . . . 217
  - D.4.4 Evaluation of C_3 and L_3 in Figure D.10 . . . 217
- D.5 More Norton Transformation Examples . . . 218
  - D.5.1 Caveat to Norton Transforms . . . 221

E JK Inverters 223
- E.1 J and K Inverter Derivations . . . 223
- E.2 JK Application . . . 227
  - E.2.1 JK Inverter Conclusions . . . 229

F Resonator Tuning 233
- F.1 Adjustment Process . . . 233

G Fano's Theorem on Broadband Matching 235

H S-Parameters in SPICE 237
- H.1 SPICE Implementation . . . 238

I Antenna Coupling and Filtering Assessment 241
- I.1 SO2R Requirements . . . 241
  - I.1.1 10m-40m Antennas at KØZR in 2016 . . . 241
  - I.1.2 Isolation Matrix . . . 243
  - I.1.3 Additional Rejection . . . 244
  - I.1.4 Bandpass Filters for Each Receiver . . . 244

J Stub Performance 247

K Self-Shielding Properties of Toroids 251
- K.1 Magnetic Units . . . 251
- K.2 Self Shielding . . . 252
- K.3 Derivation of B_{Max} for Toroids Using Faraday's Law . . . 253
- K.4 Derivation of B_{max} for Toroids - the DC Case . . . 255

L Determining Inductance 257
- L.1 Inductance Calculation . . . 257

M Transmission Line Transformers 259
- M.1 TLT Defining Equations . . . 259
- M.2 Maximizing Power to the Load . . . 260

N Filtering - An Engineering Perspective 263
- N.1 Poles and Zeros . . . 263
- N.2 Driving Point and Transfer Functions . . . 263
- N.3 Laplace Transform . . . 265
- N.4 Filter Functions . . . 265
- N.5 All Pole Filters . . . 266
  - N.5.1 Butterworth Filter Details . . . 266
  - N.5.2 Chebyshev Filter Details . . . 268
- N.6 Where to From Here? . . . 270
- N.7 Final Remarks on Synthesis . . . 271

O Signal Integrity in the Receiver 273
- O.1 Harmonics and Other . . . 273

Glossary 275

List of Figures

1.1 KØZR in 2023 . . . 6
1.2 Bank of SO2R Filters . . . 6
1.3 SO2R Station . . . 6

2.1 Example Circuit . . . 9

3.1 Wire Cross Section . . . 16
3.2 Late Model 160m Elliptic Lowpass . . . 19
3.3 40m Filter Earliest Construction Methods . . . 20
3.4 Equivalent Circuit of Inductor . . . 21
3.5 Equivalent Circuit of Capacitor . . . 21
3.6 Parallel RLC and Current Source . . . 21
3.7 Series RLC and Voltage Source . . . 21
3.8 Currents in Parallel RLC . . . 22
3.9 Voltages in Series RLC . . . 22
3.10 L and C Voltages at Resonance . . . 23
3.11 Circuits to Measure Q Effects . . . 24
3.12 Bandwidth v.s. C-to-L Ratios . . . 24
3.13 Signal Source and Load R_L . . . 25
3.14 Normalized Power Transfer . . . 25
3.15 Impact of Fano's Theorem . . . 28

4.1 Online Tool for Inductor Calculations . . . 32
4.2 Ten-turn Inductor and Voltages . . . 34
4.3 4-Turn Inductor . . . 35
4.4 3-Turn Inductor of Copper Tubing . . . 35
4.5 6-Turn Inductor of Copper Tubing . . . 35
4.6 10-Turn Inductor . . . 36
4.7 Example Display from SARK Software . . . 36
4.8 Inductor Measurements . . . 37
4.9 Inductor Approaching Series Resonance . . . 37
4.10 Core Loss vs Flux Density . . . 40
4.11 Core Temperature Rise vs Flux Density . . . 40
4.12 Ruthroff TLT . . . 42
4.13 4:1 TLT Example . . . 42
4.14 Currents in 4:1 TLT . . . 43
4.15 Capacitor Regions of Operation [66] . . . 44
4.16 Capacitor Types to Consider . . . 45

4.17 Current Ratings for ATC Series A Capacitors[1] 46
4.18 Vishay Current Rating [69] 50
4.19 Vishay ESR for Package 1111 [69] 50
4.20 SARK110 for Impedance Measurements 53
4.21 Fixture Ready for Etching 54
4.22 Cabled-Up Test Fixture 54
4.23 Example Impedance Measurements 55

5.1 15m Elliptic Directly from ELSIE 58
5.2 SIMetrix Schematic for Figure 5.1 58
5.3 Elliptic Frequency Response 59
5.4 Elliptic Currents 59
5.5 15m Nodal Capacitor Filter ELSIE 59
5.6 Nodal Capacitor Schematic for Figure 5.5 59
5.7 Nodal Capacitor Freq Response 60
5.8 Nodal Capacitor Currents 60
5.9 15m Nodal Inductor Filter ELSIE 60
5.10 SIMetrix Schematic for Nodal Inductor, Figure 5.9 61
5.11 Nodal Inductor Frequency Response 61
5.12 Nodal Inductor Currents 61
5.13 15m Shunt Input Filter ELSIE 62
5.14 SIMetrix Schematic for Shunt Input, Figure 5.13 62
5.15 Shunt Input Frequency Response 63
5.16 Shunt Input Currents 63
5.17 15m Mesh Capacitor Filter ELSIE 63
5.18 SIMetrix Schematic for Mesh Capacitor in Figure 5.17 64
5.19 Mesh Capacitor Response 64
5.20 Mesh Capacitor Currents 64
5.21 15m Constant-k, Shunt-Input Filter ELSIE 65
5.22 Schematic for Constant-k, Shunt-Input Figure 5.21 65
5.23 Frequency Response of Constant-k 65
5.24 Currents in Constant-k 65
5.25 15m m-Derived, Cauer Filter ELSIE 66
5.26 Schematic for m-Derived, Cauer Figure 5.25 66
5.27 m-Derived Freq Response 67
5.28 m-Derived Currents 67
5.29 Comparison of All Designs 68

6.1 DC Bias Annotation 72
6.2 Simple RLC Circuit Example 73
6.3 Node Voltages 73
6.4 Current in Components 74
6.5 Power in Resistors 74
6.6 Butterworth BPF, N = 3 74
6.7 Power in Butterworth Filter 74
6.8 Butterworth Setup for S_{21} and S_{11} 75
6.9 S_{21} and S_{11} Results for Butterworth 75
6.10 Autotransformer Principles 76
6.11 Autotransformer Example 77
6.12 Voltages at Each Wire 77

6.13 Butterworth Monte Carlo Analysis Results 79

7.1 Range of Sound Levels 84
7.2 Fan Size Selection 85
7.3 80 CFM Fan at KØZR 86
7.4 Fan Sizing Steps 86

8.1 Complex RX Circuit 88
8.2 Transformed Series, Parallel RX 88
8.3 Series & Parallel RX Comparison 89
8.4 Frequency Response of Series and Parallel RX 89
8.5 Autotransformer Method 90
8.6 Autotransformer Comparisons 90
8.7 Capacitor Currents 91
8.8 Autotransformer Voltages 91
8.9 Autotransformer Method 92
8.10 Autotransformer Comparisons 92
8.11 With Leakage Inductance 93
8.12 Impact of Leakage Inductance 93
8.13 Elliptic LPF and Transformed BPF 94
8.14 Elliptic Transform 94
8.15 T-to-Pi Capacitance Transformation 95
8.16 Tee-Configuration 95
8.17 Pi-Configuration 95
8.18 Wide Application of Norton Technique 100
8.19 15m Chebyshev Filter for Norton Application 101
8.20 15m Filter After Norton Application 101
8.21 Consolidated 15m Chebyshev After Norton 102
8.22 Chebyshev Node Impedances 102
8.23 Original 15m Chebyshev 103
8.24 Transformed 15m Chebyshev 103
8.25 Original Chebyshev Currents 103
8.26 Currents After Norton 103
8.27 Quarter-Wave Transmission Line Effects 106
8.28 Example Impedance Inverters 106
8.29 K (top row) and J (bottom row) Inverters 107
8.30 J-Block Representation for Shunt-C Load 108
8.31 K-Block Representation for Series-L Load 108
8.32 J-Inverter Application Following the Template of Figure 8.29 109
8.33 Inverter Application to a Filter 110
8.34 J-Block Representation 111
8.35 Schematic Using Series LC Resonator 112
8.36 Nearly-Completed Filter With Admittance Inverters 112
8.37 Comparison of Inverter Types 112
8.38 Filter With Capacitive J-Inverters 113
8.39 Straight Filter - No Inverters 113
8.40 Filter With Inductive J-Inverters 114

9.1 ELSIE Elliptic Design 116
9.2 Elliptic Filter Frequency Performance 116

9.3 ELSIE Chebyshev Design . . . 117
9.4 Chebyshev N=5 Filter Performance . . . 117
9.5 Elliptic and Chebyshev Comparison for N=5 . . . 118
9.6 ELSIE Chebyshev Design N = 7 . . . 119
9.7 Chebyshev N=7 Performance . . . 119
9.8 First Admittance Inverter Application . . . 119
9.9 Second Admittance Inverter Application . . . 120
9.10 Completed J-Inverter Chebyshev Design N = 7 . . . 120
9.11 Performance of N=7 J-Inverter 40m Filter . . . 121
9.12 40m Chebyshev Currents . . . 122
9.13 40m Elliptic Currents . . . 122
9.14 Inductors for 40m BPF . . . 125
9.15 Bifilar Toroid - L3 . . . 125
9.16 Mandrel Used to Form Coils . . . 125
9.17 Inductance Change With Frequency . . . 126
9.18 Toroid L and R Fitted Over Frequency . . . 128
9.19 SIMetrix F11 Window . . . 128
9.20 Perfect 40m Original Design . . . 129
9.21 Non-Ideal Toroid Effects . . . 129
9.22 Ideal and Autotransformer Design . . . 130
9.23 Unmounted Autotransformer . . . 130
9.24 Complete 40m BPF Schematic . . . 132
9.25 Autotransformer Schematic . . . 134
9.26 Unmounted Autotransformer . . . 134
9.27 Cost from one PCB Company . . . 135
9.28 Cost from JLC Electronics . . . 135
9.29 Developed UV Sensitized Film on PCB . . . 136
9.30 PCB Etching in Progress . . . 136
9.31 40m PCB Before Drilling and Sizing . . . 136
9.32 Schematic Using the Three Shunt Resonators . . . 139
9.33 Impedance Over Frequency . . . 139
9.34 Completed 40m BPF . . . 141
9.35 Completed 40m BPF . . . 141
9.36 40m VSWR Performance . . . 142
9.37 Thermal Performance . . . 142
9.38 Composite 40m BPF . . . 144

10.1 ELSIE 15m Chebyshev Design . . . 145
10.2 SIMetrix Schematic of 15m Chebyshev Design . . . 146
10.3 15m Chebyshev Frequency Response . . . 146
10.4 Chebyshev Capacitor Currents . . . 147
10.5 ELSIE 15m Elliptic Design . . . 148
10.6 Frequency Response of 15m Elliptic . . . 148
10.7 Elliptic Capacitor Currents . . . 148
10.8 SIMetrix Schematic for 15m Elliptic Design . . . 149
10.9 First Norton Transform . . . 149
10.10 Modified Norton Transform . . . 149
10.11 Locations of Transform Application and Change to Resonator Positions . . . 151
10.12 First Norton Transform . . . 151
10.13 Modified Norton Transform . . . 151

10.14 Transform #1 . . . 151
10.15 Results After First Transform . . . 152
10.16 Transform #2 . . . 152
10.17 Combined Transforms #1 and #2 . . . 153
10.18 Simplification After Both Transforms . . . 153
10.19 Final Transformed 15m BPF . . . 154
10.20 Original Capacitor Currents . . . 155
10.21 Transformed Capacitor Currents . . . 155
10.22 Autotransformer Version of 15m BPF . . . 155
10.23 Autotransformer Version Capacitor Currents . . . 156
10.24 SIMetrix Schematic for Loss Calculations . . . 161
10.25 Coil Using 1/8” Copper Tubing . . . 163
10.26 Bifilar and Trifilar Units . . . 163
10.27 15m Elliptic BPF Schematic Pre-Tuning . . . 165
10.28 Simulated 15m Elliptic BPF Pre-Tuning Performance . . . 166
10.29 PCB Mounting . . . 166
10.30 Filter Attached to Aluminum Backplate . . . 166
10.31 Bias-Tee Implementation in Filter . . . 167
10.32 Remote 1 × 2 Switch . . . 167
10.33 Adjusting a Resonator . . . 169
10.34 Node Impedances in 40m BPF . . . 170
10.35 Node Impedances in 15m BPF . . . 170
10.36 15m Filter S_{21} . . . 171
10.37 15m Filter VSWR . . . 171
10.38 15m PCB Trouble Areas . . . 172
10.39 Completed Elliptic 15m BPF . . . 173
10.40 Winding Spacing . . . 174
10.41 PTFE Spaghetti . . . 174

11.1 80m Bandpass Filter . . . 179
11.2 20m BPF and Stubs . . . 182
11.3 10m Filter and Stubs . . . 182

12.1 160m Elliptic Lowpass . . . 186
12.2 S_{21} for 160m . . . 186
12.3 80m Elliptic Bandpass . . . 186
12.4 S_{21} for 80m . . . 186
12.5 40m Elliptic Bandpass . . . 186
12.6 S_{21} for 40m . . . 186
12.7 20m Elliptic Bandpass . . . 187
12.8 S_{21} for 20m . . . 187
12.9 15m Elliptic Bandpass . . . 187
12.10 S_{21} for 15m . . . 187
12.11 10m Elliptic Highpass . . . 187
12.12 S_{21} for 10m . . . 187

A.1 Arbitrary Math Function and its Derivative . . . 191
A.2 Velocity and Position With Time . . . 192

B.1 Thevenin (a) Norton (b) Equivalents . . . 194
B.2 Voltage Source . . . 194

B.3 Current Source 194
B.4 Identical Responses 195
B.5 Parallel RLC 196

C.1 Various Port Definitions 201
C.2 Port Definitions for S-Parameters 204

D.1 Norton Transform of the First Kind 206
D.2 Component Values for NT-1 209
D.3 Schematic to Prove NT-1 Performance 210
D.4 Xfmr Coupling = 0.99 210
D.5 Xfmr Coupling = 1.00 210
D.6 First NT in Terms of Z 211
D.7 Modified First NT 211
D.8 Progression of NTs 213
D.9 Second Norton Transform, NT-2 214
D.10 Used in Derivation of NT-2 215
D.11 Proof of NT-2 Performance 219
D.12 Xfmr Coupling = 1.00 219
D.13 Schematic for Norton Transform Example 219
D.14 Norton Transform of Series, L‖C 220
D.15 Norton Transform of Series-L 220
D.16 Transformer Placement Impacts Norton Transform 221

E.1 J-Inverter Derivation 225
E.2 J-Inverter With Capacitors Derivation 225
E.3 J-Inverter With Inductors Derivation 226
E.4 Shunt-C Comparison 228
E.5 Series-L Comparison 228
E.6 Shunt-L Comparison 228
E.7 Series-C Comparison 228
E.8 Series LC Comparison 229
E.9 Shunt LC Comparison 229
E.10 Example Schematic to Compare Inverter Types 230

F.1 Two Types of Variable Capacitors 234
F.2 S_{21} Change With Capacitance 234
F.3 S_{21} After Inductance Removal 234

H.1 Definition of S-Parameters 237
H.2 Definition of S_{11} 238
H.3 Setup for S_{11} and S_{21} 239
H.4 Setup for S_{12} and S_{22} 239

I.1 Antenna Installation at KØZR 241
I.2 Complete Antenna Installation 242

J.1 Stub Used on 80m 247
J.2 Stub Used on 40m 248
J.3 Stub Used on 20m 248
J.4 Stub Used on 15m 249

J.5 Stub Used on 10m 249

K.1 Cross Section of Toroid Core 253

M.1 4:1 TLT Model 259
M.2 9:1 TLT 261
M.3 Currents in 9:1 TLT 261

N.1 Complex S-Plane With Poles and Zeros 264

O.1 Third-Order Intercept Point 273

List of Tables

1.1 Antenna Free-Space Coupling Matrix 2
1.2 100 Watt Filters After Each Transmitter 2
1.3 KW Filter Performance 3
1.4 Power Into Adjacent Receiver, dBm 3

2.1 Butterworth Approximation Functions 12
2.2 Chebyshev Approximation Functions 13

3.1 Example Resistivities for Common Materials 15
3.2 Skin Depths for Copper v.s. Wire AWG 16
3.3 Copper Skin Depths and % CSA at 7 MHz 17
3.4 Voltage Drop and Heat for Various PCB Trace Widths 17
3.5 PCB Trace Ampacities for One Ounce Copper 18
3.6 SWR and Associated Terms 27

4.1 Amidon Recommended Maximum Flux Densities 39
4.2 Properties of T200-2 Powdered Iron Core 39
4.3 Core Losses & Temperature Rise vs B Flux 39
4.4 Boundary Conditions by Region for Figure 4.15 [66] 46
4.5 Interrelationships of Capacitor Terms 47
4.6 Electrical Parameters & Characteristics from Kemet 47
4.7 Interrelationships of Capacitor Terms 48
4.8 Capacitors in Earliest 15m Elliptic Filter 51

5.1 Comparison of Seven Designs 68
5.2 Fractional BW of KØZR Filters 69

6.1 SIMetrix Entries for Autotransformer 77

8.1 Autotransformer Comparison 90
8.2 Leakage Inductance Effects 92
8.3 T or Y Network (left) and π or Δ Network (right) 95
8.4 Table of Norton Transformations 97
8.5 Modified Norton Transformations 99
8.6 Second Modified Transformation Values 99
8.7 Norton Forms and Nomenclature 100
8.8 Kuroda Identities 104
8.9 Inverter Applications 107

9.1 Elliptic and Chebyshev Comparison . . . 118
9.2 MLCCs Planned for 40m Elliptic Filter . . . 124
9.3 40m Inductor Currents . . . 125
9.4 Toroid Changes Over Frequency . . . 127
9.5 Revised MLCCs Planned for 40m Elliptic Filter . . . 131
9.6 Thermal Dissipation in 40m Inductors . . . 133
9.7 Composite 40m Band Performance . . . 143
9.8 2022 CQWW DX Results . . . 144

10.1 Comparison of Capacitor Currents . . . 154
10.2 Inductance of Various T130 Cores; $\mu_r = 1$ . . . 158
10.3 Autotransformer Implementation Plans . . . 159
10.4 MLCCs Planned for 15m Filter . . . 160
10.5 Thermal Dissipation in 15m Inductors for Q $=$ 350 . . . 161
10.6 Resonant Frequencies of 15m BPF . . . 168
10.7 2023 ARRL DX CW Results . . . 175

11.1 Attenuation of SO2R Filters by Band . . . 181

C.1 Z-to-S and S-to-Y Relationships . . . 202
C.2 Two-Port Parameter Families . . . 203

D.1 ABCD Matrices for Elements . . . 207
D.2 ABCD Cascade of Elements . . . 208
D.3 First NT Relationships . . . 208
D.4 NT-1 Example Values . . . 210
D.5 Summary Modified NT-1 Relationships . . . 214
D.6 Summary NT-2 Relationships . . . 215
D.7 Summary NT-2 Relationships . . . 216
D.8 Modified NT-2 Component Values . . . 218
D.9 Formulas to Calculate Norton Transform . . . 219
D.10 Norton Transform Inductor Values . . . 220

E.1 JK Inverter Scenarios . . . 231

G.1 Coefficients for BWIF Calculation . . . 236

I.1 S_{21} Between the Various Antennas . . . 242
I.2 Stubs in Use at KØZR . . . 243
I.3 Bandpasser II Filter Performance . . . 243
I.4 Power Into Adjacent Receiver for 1500 Watt Transmit Power . . . 245

N.1 Classical H(s) Types . . . 266

Preface

Without filters, radio communications would not be possible. Filters are responsible for segregating wanted frequency spans from those areas of the spectrum that are of no interest. The subject area of filters has a lengthy history commensurate with the earliest beginnings of radio.

Only those areas of filter theory important to HF filter design in the 1 MHz to 30 MHz frequency range are considered here. Many of the principles and techniques discussed have applicability to much higher frequencies, even microwave, however the manner in which the theories and principles are applied change significantly between 1 MHz and 1 GHz. The principles and methods advanced herein deal only with lumped element designs compared to *distributed* or *waveguide* forms which find application at frequencies considerably higher than HF.

The subject of filters may seem elementary upon first glance; after all a filter is just a succession of inductors and capacitors. Such an assessment would be highly incorrect in that the mathematics involved behind the scenes is formidable. This text strives to stay away from such deep theories and high level mathematics, even though some readers may form a different opinion upon their first review of this book. Consideration of some of the references such as Matthaei [6], Daryanani [4], Helszajn [64], and Knight [13] offer convincing evidence in support of the aforementioned statement regarding complexity.

This is not an ordinary book on filters in that most of the synthesis details are left to the many references available on the subject, some of which are found in the bibliography. Here, the concentration is on how to design and construct KW filters without having to go to the expensive NOS[1] doorknob capacitors that the majority of KW filter manufacturers use. NOS sources for doorknob capacitors have decreased in recent years and in the wake of the problems in Ukraine, the scarcity of such capacitors has grown more problematic. Through use of the multiple techniques described herein, the need for doorknob capacitors and/or high VAR[2] capacitors is considerably reduced allowing the designer to use less costly and far more plentiful multi-layer ceramic chip capacitors (MLCC).

The book begins with the introduction to Single Operator Two Radio (SO2R) in Chapter 1 and lays the framework for the essential elements of an SO2R station. Chapter 2 sets the stage for filter theory in general, however it does so by introducing some rather complex topics which may be too advanced for some readers; no need for worry due to the use of the ELSIE filter design program. Chapter 2 is included for completeness, however, if the reader chooses to bypass it, this should not impede his understanding and application of the remaining chapters. Chapter 3 discusses several important physics characteristics essential to filter design. One of the most

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[1] New Old Stock

[2] $\text{VAR} = \text{V}_{\text{RMS}} \times \text{I}_{\text{RMS}}$

important chapters in the book, Chapter 4, discusses the electrical and behavioral characteristics of the components used to construct filters. Most of these principles are important from the milliwatt level up to kilowatt level. Chapter 5 does a comparison of seven different filter designs incorporating elliptic, Chebyshev, Constant-k, and m-derived topologies. These comparisons will help the reader formulate the differences to be expected across different filter families. Chapter 6 is a brief tutorial on circuit simulation in general, while Chapter 7 addresses requirements for heat dissipation to guarantee survival at high power and prolong filter life.

Chapter 8 is the foundation for KW-level filter design embraced throughout this book. Through the use of the powerful transform methods described here, 'unbuildable' filters become 'buildable', or the time-consuming design of many different inductor values can be simplified through the use of equal size inductors, just two benefits of the information contained in this chapter. The application level equations of the transforms are presented in Chapter 8, with the derivation of several Norton transforms and JK inverter equations relegated to a deeper treatise in the *Appendix*.

Chapters 9 and 10 should be of considerable interest should the reader take on the challenge of building his own KW-level bandpass filters. Chapter 9 deals with a design for 40m while Chapter 10 is dedicated to a 15m design. The two designs incorporate somewhat different approaches and serve to illuminate some of the techniques used by filter designers.

Chapter 11 concludes the primary part of the book, covering other aspects of filter construction not presented elsewhere. The principal topics covered include troubleshooting and filter augmentation with tuned coaxial stubs. A failure of several silver mica capacitors in the KØZR 80m filter are described and the troubleshooting process used in its repair outlined.

This book is the outcome of the author's filter design efforts which began in 2017. Upon venturing into SO2R in 2016, he initially used a variety of coaxial stubs [1] to improve attenuation of neighboring bands by ~ 20 - 25 dB. Due to 10m, 15m, and 20m elements all residing on the same boom of his C31XR tribander, more isolation was desired. The C31XR can be used in a single-feed configuration, although three separate feedlines and driven element modifications are in use for today's SO2R installation. The amount of coupling between 15m and 20m, which is very high, is a byproduct of the original coupled-sleeve approach used in the single-feed system of the C31XR. This Yagi design characteristic begs for more isolation between 20m and 15m in the SO2R station.

The reader will judge for himself whether the full disclosure approach taken in the book is helpful. The techniques and processes which are known to work are discussed at length, however things that do not work or resulted in failure are described as well. The author believes learning takes place in both successful and challenging situations. Chapters 9 and 10 share both types of experiences during the design and construction of two different filters.

The author's venture into amateur radio began at age 13 when he obtained a Drake 2C receiver with the intention of becoming a more serious SWL (shortwave listener). The receiver covered the HF amateur bands; ham radio was discovered in short order. One afternoon a very strong signal on 75m became the center of attention; it was WAØRDZ who, with the help of the author's father, was identified as Ed Askew, a local farmer. Shortly thereafter, Ed became the author's ham radio mentor, which led to his becoming licensed as WAØZRT at age 15.

While in college, a vision of going to medical school transitioned to returning to the family business in Sidney, Iowa, where the author practiced as a funeral director for three years. It was at the end of this period that electrical engineering came knocking, leading to a BSEE from the University of Nebraska-Lincoln, followed by an MSEE from the University of Southern California. The author's career has been RF/microwave design for satellites in support of the intelligence community for the past 40 years. Retirement is yet to be considered although the tug is getting stronger.

It is fitting to give credit where credit is due; this begins with the author's wife Cheryl. In December 2021, the author announced his desire to write this book. While his XYL knew this would be a large commitment of time and energy, she knew it was an important goal and her support has been unwavering over the many months of this project. She spent many hours reviewing the manuscript and her efforts have improved this book overall. Also W4RN, a great friend, the type of friend a person is lucky to find once in a lifetime, has been an omnipresent encourager for many years. His influence in the application of tuned stubs, dedicated Caribbean-facing Yagis for 10, 15, and 20m, contesting hints, and introduction to RTTY contesting have been invaluable.

Amateur radio and his electrical engineering career have strengthened the author's faith in God and the Bible. Both avocations have given him more insight into the complex world around us and reinforced his belief that its existence is possible only through a supreme Creator.

It is the author's hope that should the reader embark on constructing his own filters, this book will help him gauge the complexity involved, prepare him for what lies ahead, and help ensure his success in his DIY project. The satisfaction of completing such an undertaking is worth the effort required to cross the finish line.

Jeff Crawford, K0ZR