

THE HOBBYIST'S GUIDE TO THE RTL-SDR: REALLY CHEAP SOFTWARE DEFINED RADIO

**A GUIDE TO THE RTL-SDR AND CHEAP SOFTWARE DEFINED
RADIO BY THE AUTHORS OF THE RTL-SDR.COM BLOG**

SECOND PRINT EDITION

CARL LAUFER

Table of Contents

Preface.....	1
Introduction.....	1
What is Software Defined Radio (SDR)?.....	1
What is the RTL-SDR?.....	1
What equipment do I need to get into RTL-SDR?.....	2
RTL-SDR Technical Specifications.....	3
RTL-SDR ADC.....	3
RTL-SDR Bandwidth.....	3
Input Impedance.....	3
RTL-SDR Minimum PC Specifications.....	4
RTL-SDR Compatible Dongles.....	4
Tips for Buying RTL-SDR Dongles.....	4
R820T/R820T2 Packages.....	5
Other SDRs worth mentioning.....	5
Software Defined Radio Basic Theory.....	6
Setting up and using your RTL-SDR.....	8
SDR# Setup Guide (Tested on Windows Vista/7 + XP).....	8
Troubleshooting And Common Questions Guide.....	10
SDR Sharp Users Guide.....	12
Main Settings and Windows.....	13
Play/Stop Button.....	13
Source.....	13
Configure Menu / RTL-SDR Controller.....	13
Frequency Input.....	13
Volume / AF Gain.....	13
RF Spectrum / FFT Display.....	13
RF Waterfall.....	13
Tuning Bar.....	14
Radio Tab.....	14
Audio Tab.....	16
AGC (Automatic Gain Control) Tab.....	16
FFT Display.....	17
Zoom FFT.....	18
Digital Noise Reduction (DNR).....	18
Noise Blanker.....	18
Recording Tab.....	18
Frequency Manager Tab.....	19
Right hand side sliders.....	19
Configure Window.....	19
Device.....	20
Sample Rate.....	20
Sampling Mode.....	20
Offset Tuning.....	20
RTL AGC.....	20
Tuner AGC.....	20
RF Gain.....	20
Frequency correction (ppm).....	20
Setting the RF Gain.....	21
Setting the Filters.....	22
Setting the PPM Correction.....	23
SDR Sharp Plugins.....	24
SDR# Minoutput Sample rate.....	24
Other General Purpose Scanning Software.....	24
HSDR Setup Guide.....	24
SDR-RADIO.COM V2 Setup Guide.....	28
GQRX.....	31
Installing GQRX on OSX.....	32
CubicSDR.....	32
LINRAD.....	33
Installing the RTL-SDR Drivers on Linux.....	35
RTL_FM.....	36
Examples of RTL_FM use.....	36
RTL_FM Flags.....	36
Receiving WBFM Example.....	37
Narrow Band FM Example.....	37
AM Example.....	37
Scanner Example.....	37
Changing the Audio Sample Rate with Sox.....	37
Installing GNU Radio.....	38
Install Script.....	38
Pybombs.....	38
Package Manager.....	39
Linux Live DVDs with Preinstalled RTL-SDR Software.....	39
KB1OIQ - Andy's Ham Radio Linux.....	39
GNU Radio Live DVD.....	40
Kali Linux.....	40
PENTOO.....	40
Porteus.....	40
BeagleBone Black SDR Image File.....	40
RTL-SDR Misc. Information.....	41

RTL-SDR Crystal Tolerance.....	41
RTL-SDR DC Spike.....	41
RTL-SDR Spurs.....	41
RTL-SDR ADC Bit Depth.....	41
RTL-SDR Sensitivity.....	41
RTL-SDR Images.....	42
RTL-SDR Temperature Frequency Drift.....	42
Using Multiple Dongles with the Same Serial Number.....	42
Max Number of Dongles per USB Port.....	43
Using the RTL-SDR on a Linux Virtual Machine.....	43
Input Static Protection Diode.....	43
RTL-SDR Current Usage.....	43
Remote Control.....	43
Included CD.....	43
Dead on Arrival Failure Rate.....	44
Image of a Typical RTL-SDR Dongle Circuit Board.....	44
RTL-SDR Noise Floor.....	44
RTL-SDR Improvements and Modifications.....	45
Low Noise Amplification.....	45
Receiving LF/MF/HF (0 - 30 MHz).....	45
1) Direct Sampling Mode.....	45
Direct Sampling Instructions.....	46
Direct Sampling Improvements.....	47
2) Upconverters.....	48
How to use an SDR Receiver with an Upconverter.....	48
3) Experimental Drivers.....	48
Direct Sampling with No Hardware Mod Discovery.....	49
Positioning your RTL-SDR Dongle.....	49
1) Use an active USB repeater cable or hub.....	50
2) Use a mini embedded or Remote computer to transmit the signal wirelessly to your PC.....	50
Optimizing Tuning.....	51
Optimizing Decimation - Improving Reception Quality in Software.....	51
Upgrading the RTL-SDR Drivers in SDR#: Keenerds Drivers.....	51
Custom Gain Control and Decimation RTL-SDR Drivers.....	52
Dongle Shielding and Noise Reduction.....	52
Common Sources of Noise.....	52
Dongle USB Cable Grounding Improvement.....	53
Testing Changes to Noise Performance.....	53
USB Cable Ferrites.....	54
Preselector Filters.....	54
Designing Simple Filters with RFSIM99.....	55
Coax Stub Filter.....	56
Adding Phantom Power / Bias Tee.....	56
Improving the Stock Antenna.....	57
Ground plane.....	57
ADS-B.....	58
Coax Choke.....	58
Replace Stock Antenna Coax Cable.....	58
Calibrating the Frequency Offset of the RTL-SDR.....	59
Kalibrate.....	59
LTE Scanner.....	60
Removing the IR Diode.....	60
Reducing USB Noise on HF.....	61
Stabilizing The Frequency Offset.....	61
Removing the static protection diode.....	61
RTL-SDR Project Tutorials.....	62
Audio Piping.....	62
General Frequency Guide.....	62
ACARS Receiving Guide.....	64
ACARS Tutorial (Windows).....	64
Acaresdeco2.....	65
PlanePlotter.....	67
AirNav ACARS.....	68
ACARSD.....	68
Linux Only ACARS Decoders.....	69
Acaresdec.....	70
Rtl_acars_ng.....	70
ADS-B Receiving Guide (Tracking aircraft).....	71
ADS-B Tutorial.....	71
ADS-B Reception Guide.....	71
Software Guide.....	72
Graphical RADAR Display Software for Windows.....	77
Monitoring ADS-B on an Android Device.....	83
Feeding Data to flightradar24.com and flightaware.com.....	84
Real time Cockpit Instrument Display using ADS-B Data.....	84
Monitoring Military Aircraft.....	85
ADS-B for Gliders and Helicopters: FLARM.....	85
NOAA Weather Satellite (APT) Guide.....	86
NOAA Weather Satellite Receive Tutorial.....	86
NOAA Weather Satellite Antennas.....	86
WXtoImg Software Tutorial.....	87
Orbitron Tutorial.....	90
Meteor-M Russian LRPT Weather Satellite Guide.....	94
Receiving MeteoR-M2 Weather Satellite Images: Windows Tutorial.....	94
Receiving MeteoR-M2 Weather Satellite Images in Real Time: Windows.....	97

Download the software.....	97
Synchronizing Windows Time.....	97
Orbitron and SDR# Setup.....	98
QPSK Plugin and LRPTOfflineDecoder Setup.....	100
Receiving Meteor-M2 Weather Satellite Images: Linux Tutorial.....	100
Removing the Fisheye Effect of the Color Image.....	101
Weather Balloon (Radiosonde) Guide.....	103
Radiosonde Receiving Tutorial.....	103
Radiosonde Antenna Tutorial.....	103
Software Tutorial.....	103
Additional Links.....	105
Marine Automatic Identification System (AIS) Guide.....	107
AIS Tutorial.....	107
AIS Antenna Guide.....	107
Software Tutorials.....	108
AisDeco2.....	108
Other Windows software and methods.....	110
AISMon Tutorial.....	110
ShipPlotter Tutorial.....	111
AisDecoder.....	113
rtl_ais.....	114
Gr-ais.....	115
PNAIS.....	115
AISRec.....	115
MarineTraffic.com.....	115
References and Additional Links.....	115
Decoding VHF Data Link Mode 2 (VDL2).....	116
Decoding VDL2 with MultiPSK.....	116
MultiPSK PlanePlotter Interface.....	118
VDL2-Display.....	118
References and Additional Links.....	118
Air Traffic Control / Scanning Guide.....	119
SDR# Frequency Scanner.....	119
Known Frequency Scanning.....	119
General Frequency Scanning.....	119
Digital Audio Broadcasting (DAB) Radio Guide.....	121
DAB Receive Tutorial With SDR-J.....	121
DAB Receive Tutorial with DAB Player.....	121
Receiving Analogue TV (PAL/NTSC) Guide.....	123
Guide to Listening to Trunked Radio: Analogue and Digital P25.....	124
Unitrunker Voice Trunking Following Tutorial.....	124
Setting up the Signal (Control Channel) Receiver.....	124
Setting up the Voice Channel Receiver.....	127
Monitoring Multiple Control Channels with Multiple VCOs.....	128
Monitoring with only One Dongle.....	128
Priority and Lockout.....	128
Troubleshooting.....	129
Alternative Trunk Following Software.....	129
Decoding Digital Voice (P25/DMR/Mototrbo/NXDN/ProVoice).....	129
Some Tips.....	130
Decoding Digital Voice with DSD+ and SDR#.....	131
Tuning DSD+.....	131
MOTOTRBO Location Request Response Protocol (LRRP) Decoding.....	132
CTCSS Trunked Radio.....	132
DCS Trunked Radio.....	132
LTR Trunked Radio.....	132
Fleetsync II.....	133
Pager Decoding Guide.....	134
Tutorial.....	134
Other Decoders.....	135
Analyzing GSM Signals.....	136
Installation of GR-GSM.....	136
Decoding GSM Messages and Voice.....	138
Listening to and Analyzing TETRA Signals.....	139
Listening to Unencrypted TETRA.....	139
Install Decoder Software.....	139
Running the Decoding Software.....	140
Troubleshooting.....	142
Analyzing TETRA.....	142
Radio Astronomy Guide.....	143
Observing the Hydrogen Line and Galactic Plane.....	143
Meteor Scatter Detection.....	144
RTL_POWER.....	145
HROFFT.....	145
Baudline.....	146
Spectrum Lab.....	146
Meteor_Detector.....	146
Solar Interferometry.....	146
Other Simple Radio Astronomy Experiments.....	146
Doppler Passive Radar.....	147
Dual Coherent Passive Radar.....	147
HF Modes Decoding Guide.....	148
Shortwave Broadcast Radio.....	148
CW (Morse Code).....	148
RTTY.....	149

STANAG 4285.....	149
Decoding STANAG 4285: Sorcerer.....	149
Decoding STANAG 4285: Sigmira.....	150
Decoding STANAG 4285: Other Decoders.....	151
SSTV.....	151
Digital SSTV.....	152
WSPR.....	152
Marine HF Modes.....	152
WeatherFax (HFFAX) Decoding Guide.....	152
Synop.....	153
GMDSS DSC.....	154
Navtex.....	155
SITOR.....	155
Differential GPS (DGPS).....	155
Decoding Marine Modes with MultiPSK.....	155
Using MultiPSK for Marine Modes.....	156
Digital Radio Mondiale (DRM) Guide.....	157
How to Receive and Decode DRM Signals.....	157
HFDL Decoding Guide.....	158
MultiPSK.....	159
Listening to D-STAR Amateur Radio.....	160
Compiling the Latest DSD Version on Windows.....	160
RTL-SDR for Android.....	162
SDR Touch.....	162
Wavesink.....	162
FlightAware FlightFeeder.....	163
USB ADSB RTL-SDR.....	163
ADS-B Receiver.....	163
SDR Weather.....	163
Receiving 10 GHz Beacons.....	163
GNU Radio Introduction.....	164
GNU Radio Program: FFT Display.....	164
GNU Radio Program: WBFM Receiver.....	165
Explanation of WBFM Flow Graph.....	166
GNU Radio Program: Compiling a WBFM-RDS Receiver.....	167
References and Additional Links.....	168
Compiling RTL-SDR Drivers from Source on Windows.....	169
Compiling with MingW.....	169
Compiling using Visual C++ 2010.....	171
RDS Receiving Guide.....	172
Listening to SCA/SCMO FM Subcarrier Channels.....	176
APRS Guide.....	177
QTMM AFSK1200.....	177
MultimonNG.....	177
APRSISCE/32.....	178
AGW Packet Engine and Tracker.....	180
Other APRS Software.....	181
Mobile Data Terminal (MDT) Decoding Guide.....	182
Panadapter Guide.....	182
Using multimonNG on Linux and Windows.....	183
Using RTL_TCP.....	184
Streaming MP3 FM With Linux: RTL_FM.....	185
Heat Map Band Scan.....	186
RTL_POWER Flags.....	187
RTL_Power GUI.....	187
RTLSDR Scanner.....	188
Radio Direction Finding with RTLSDR Scanner.....	188
DECODING INMARSAT STD-C EGC MESSAGES.....	191
Equipment and Software.....	193
Tutorial.....	195
How to Modify a GPS Antenna for Inmarsat Reception.....	196
What else is at L Band?.....	197
Decoding Emergency Alert System (EAS) SAME Messages.....	198
Train Telemetry Data Decoding.....	199
Decoding Funcube Satellite Telemetry.....	201
Decoding Orbcomm Satellites.....	204
References and Additional Links.....	204
ISS Satellite Reception.....	205
Weather/Temperature Sensor Decoding Guide.....	205
Decoding Smart Power Meters.....	206
NRF24L01+ Decoding.....	207
Analyzing Unknown Signals.....	207
Reverse Engineering Analysis Projects.....	207
Audacity.....	208
MiniModem.....	208
OOK-Decoder.....	208
Measuring the Characteristics of RF Filters with an RTL-SDR and Noise Source.....	209
Characterizing Filters.....	209
Equipment.....	209
Software.....	209
Characterizing Filters Tutorial.....	210
Characterizing Coax Notch/Stub Filters.....	212
Determining the Velocity Factor of Coax.....	213
Downloads.....	213
Measuring the VSWR of an Antenna with a Noise Source and RTL-SDR.....	213

Equipment.....	213
Measuring the VSWR of an Antenna Tutorial.....	214
Downloads.....	215
Receiving and Tracking GPS with the RTL-SDR.....	216
Active GPS Antennas and Bias-T's.....	219
Projects for the Future and Better SDR's.....	220
HRPT.....	220
HD Radio.....	220
Software DVB-T Decoding.....	220
DECT Cordless Phones.....	220
Other Software Not Mentioned Yet.....	220
RTL-Airband.....	220
WebSDR.....	220
RTL Entropy.....	221
SWSCAN.....	221
Other Interesting Projects People Have Done with the RTL-SDR.....	222
Unknown Signal Identification.....	223
DVB-T HDTV on Linux.....	223
Drivers.....	223
DVB-T TV Watching Software.....	223
DVB-T on Windows.....	224
Quick Way to Change between DVB-T and SDR Drivers on Windows Vista/7/8.....	225
Antenna Guide.....	226
Antenna ESD Safety.....	226
Antenna Adapter Guide.....	226
Coaxial Cable Guide.....	228
Coax Losses.....	228
Velocity Factor.....	228
Materials.....	228
Antenna Gain/Directivity.....	228
Radiation Patterns.....	229
Antenna Design Frequency.....	229
Standing Wave Ratio (SWR).....	230
Antenna Polarization.....	230
Antenna Reciprocity.....	231
Antenna Positioning.....	231
Common Mode Chokes.....	231
Vector Network Analyzer.....	232
VHF/UHF Example Antennas.....	233
Discone.....	233
Scantenna.....	235
Planar Disk Antenna.....	235
Quarter Wave Monopole ground plane.....	236
Whip/Monopole.....	237
Dipole.....	239
J-Pole / Slim Jim.....	240
Collinear.....	242
Archimedian Spiral.....	244
Turnstile / Cross Dipole.....	247
Quadrifilar Helix (QFH).....	248
Active GPS Patch.....	250
Yagi Uda.....	250
PCB ADS-B Monopole Antennas.....	251
HF Antennas.....	252
Long Wire/Random Wire.....	252
Magnetic Loop.....	252
Miniwhip.....	253
4NEC2 Tutorial.....	253
How to Simulate an Antenna Radiation Pattern.....	253
How to Simulate SWR.....	254
Changing The Simulated Antenna Ground.....	255
Changing Antenna Dimensions/Height.....	255
Appendix A: Audio Piping.....	257
Stereo Mix.....	257
VB Cable.....	258
Hi-Fi Cable.....	258
Virtual Audio Cable.....	258
Setting the Audio Sample Rate.....	259
Appendix B: Radio Basics.....	260
Propagation.....	260
Baseband Signal.....	261
Bandwidth.....	261
Modes.....	261
Decibels (dB) to Times.....	261
Appendix C: Multimode Decoders List.....	263
Last Words.....	264
Where to Get More Help.....	264
Errata And Updates.....	264
Legal Stuff.....	266