

RF Frequency Analysis Hardware Kit

Medium Grade - Off-the-Shelf Components

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Table of Contents

1. Executive Summary	3
2. Hardware Tier Comparison 4	
3. Recommended Kit Configuration 5	
4. Phased Implementation Plan 6	
5. Software Stack	7
6. Frequency Analysis Workflow 8	
7. Budget Summary	9
8. Learning Resources	10
9. Safety and Legal Considerations 11	
10. Conclusion	12

1. Executive Summary

This document outlines a comprehensive roadmap for building a medium-grade radio frequency (RF) analysis hardware kit using off-the-shelf components. The kit is designed for users transitioning from beginner to intermediate level, providing professional-grade capabilities at reasonable cost.

The recommended configuration centers on the HackRF One, providing full duplex (TX+RX) capability across 1 MHz to 6 GHz with 20 MHz instantaneous bandwidth. Total investment of \$1,000 provides professional-grade analysis capability with a phased implementation approach.

Key Specifications

Specification	Value
Frequency Range	1 MHz - 6 GHz
Bandwidth	Up to 20 MHz
TX Power	0 to +15 dBm
Sample Rate	20 MSPS (8-bit I/Q)
Total Budget	\$1,000 (phased)
Implementation	16 weeks

2. Hardware Tier Comparison

Tier 1: Entry Level (Beginner)

Device	Frequency	Bandwidth	Price	Best For
RTL-SDR V3	24-1766 MHz	2.4 MHz	\$35	Learning
RTL-SDR V4	500k-1.7 GHz	2.4 MHz	\$45	HF + VHF/UHF
Nooelec SMArTee	24-1766 MHz	2.4 MHz	\$40	Low noise

Tier 2: Medium Grade (Intermediate) - RECOMMENDED

Device	Frequency	Bandwidth	TX Power	Price
HackRF One	1-6000 MHz	20 MHz	0-15 dBm	\$300
LimeSDR	100k-3.8 GHz	61.4 MHz	Up to 10 dBm	\$300
LimeSDR Mini	10M-3.5 GHz	30.7 MHz	Up to 10 dBm	\$150
BladeRF x40	300M-3.8 GHz	28 MHz	Up to 6 dBm	\$400

Tier 3: Professional Grade (Advanced)

Device	Frequency	Bandwidth	Price
Ettus USRP B210	70M-6 GHz	56 MHz	\$1,100
BladeRF 2.0 micro	47M-6 GHz	56 MHz	\$540
PlutoSDR	70M-6 GHz	56 MHz	\$230

Frequency Coverage Comparison

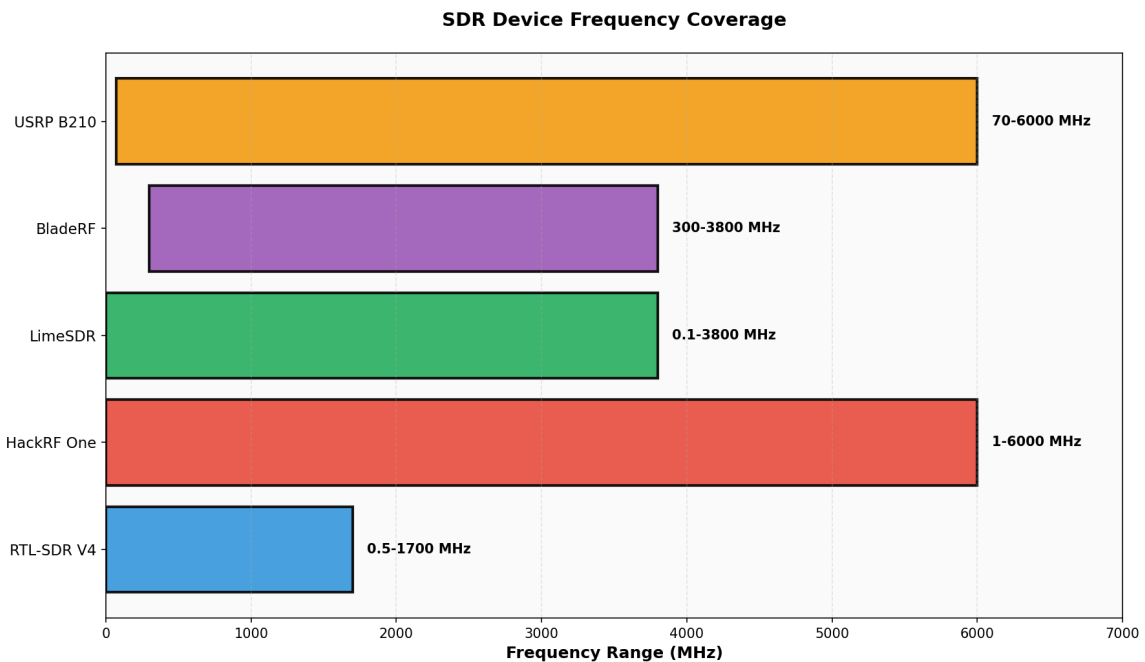


Figure 1: Frequency range comparison across SDR devices.

Price vs Bandwidth Comparison



Figure 2: Price versus bandwidth for different SDR platforms.

3. Recommended Kit Configuration

Primary Device: HackRF One (\$300)

Specification	Value
Frequency Range	1 MHz - 6 GHz
Operating Modes	Half-duplex (TX or RX)
RF Bandwidth	Up to 20 MHz
Sample Rate	20 MSPS (8-bit I/Q)
TX Power	0 to +15 dBm typical
RX Sensitivity	-80 dBm typical
Interface	USB 2.0
Antenna Connector	SMA female

Why HackRF One: Widest frequency range (1 MHz - 6 GHz), transmit AND receive capability, massive community support, open source hardware, excellent documentation and tutorials.

Supporting Equipment

Category	Items	Budget
Antennas	Dipole kit, Discone, Log Periodic	\$100-150
Cables/Adapters	SMA cables, BNC/N adapters, Attenuators	\$50
Accessories	USB hub, Case, LNA, Bias-tee, TCXO	\$80-150
Computing	Laptop (i5+, 8GB RAM, USB 3.0)	\$200-500

Capability Comparison

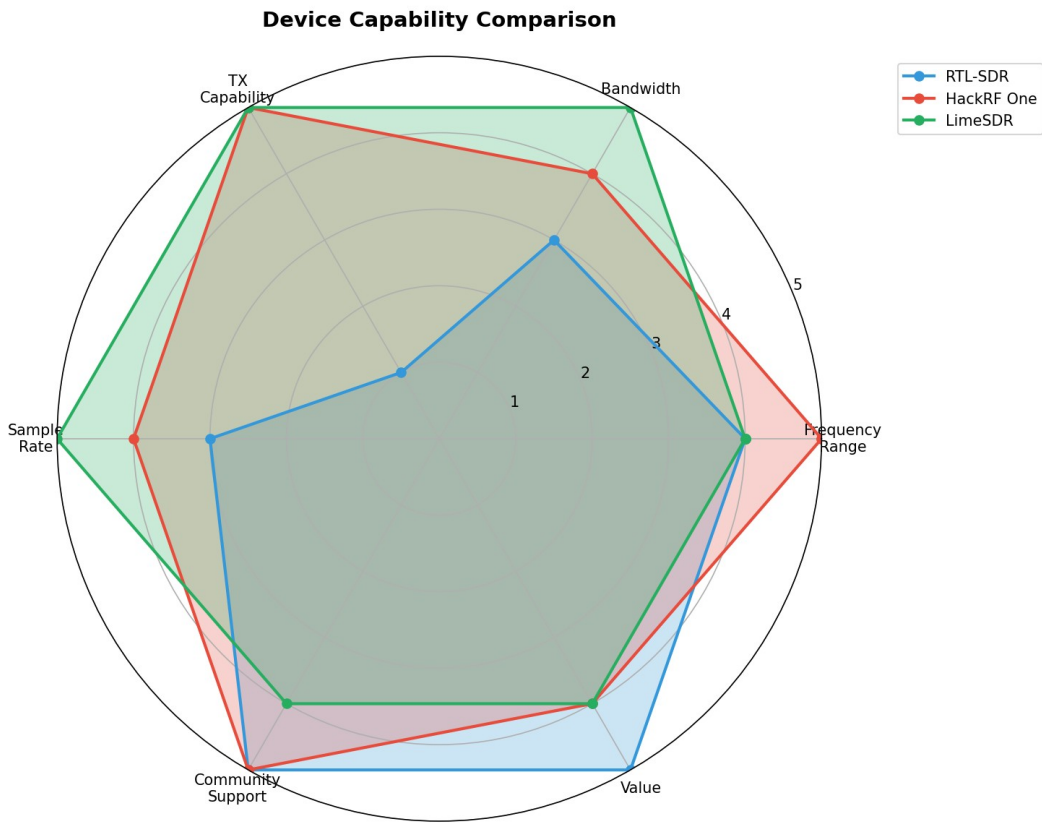


Figure 3: Radar chart comparing device capabilities across key metrics.

4. Phased Implementation Plan

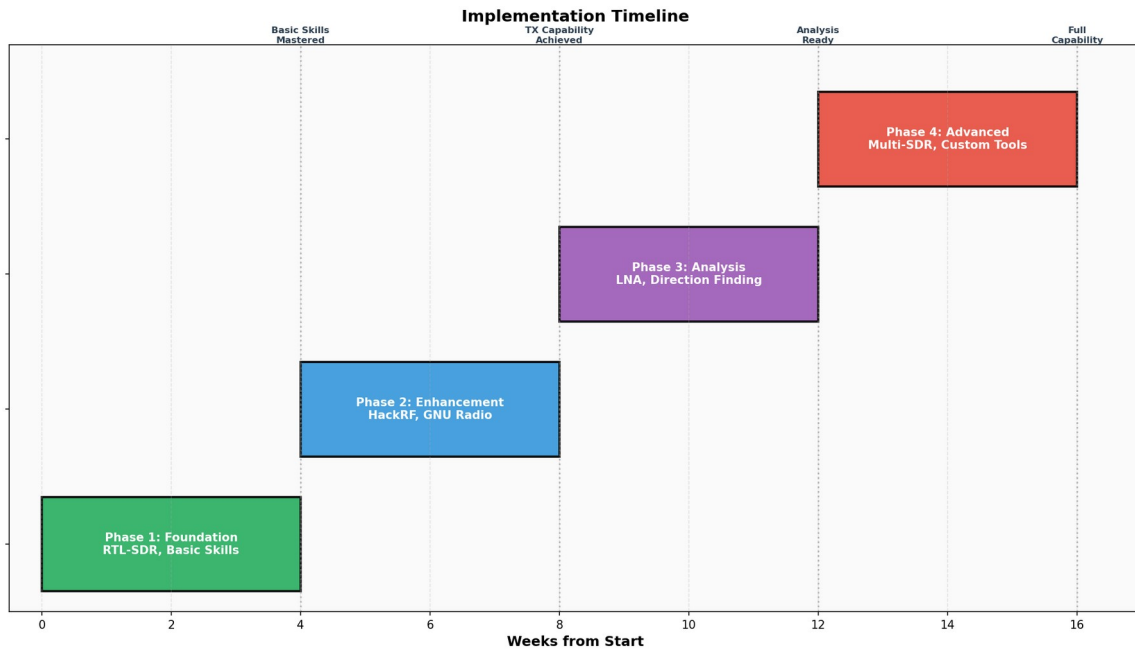


Figure 4: 16-week implementation timeline with milestones.

Phase 1: Foundation (Weeks 1-4) - \$100

Equipment	Cost
RTL-SDR Blog V4 dongle	\$45
Basic dipole antenna kit	\$25
USB cable, SMA adapters	\$30

Skills: Software installation, frequency scanning, signal identification, recording

Phase 2: Enhancement (Weeks 5-8) - \$400

Equipment	Cost
HackRF One	\$300
Discone antenna	\$80
USB 3.0 hub	\$25

Skills: Transmitting signals, GNU Radio basics, modulation analysis

Phase 3: Analysis (Weeks 9-12) - \$200

Equipment	Cost
LNA with bias-tee	\$60
Better cables and adapters	\$50
Directional antenna	\$60
TCXO upgrade	\$30

Skills: Weak signal reception, direction finding, regulatory compliance

Phase 4: Advanced (Weeks 13-16) - \$300

Equipment	Cost
Second SDR (diversity)	\$45
Shielded enclosure	\$50
GPSDO for timing (optional)	\$200

Skills: Coherent reception, advanced GNU Radio, security testing

5. Software Stack

Core Analysis Software

Software	Platform	Purpose	License
GQRX	Linux/Mac	General receiver	GPL
SDR++	Cross-platform	Wideband receiver	GPL
SDR-Angel	Windows/Linux	Multi-mode receiver	GPL
CubicSDR	Cross-platform	Visual spectrum	BSD
GNU Radio	Cross-platform	DSP framework	GPL

Specialized Tools

Software	Purpose
URH (Universal Radio Hacker)	Protocol analysis
SigDigger	Signal analysis
Baudline	Spectral analysis
Fosphor	GPU-accelerated waterfall
QSpectrumAnalyzer	Python spectrum analyzer

6. Budget Summary

Phased Budget Breakdown

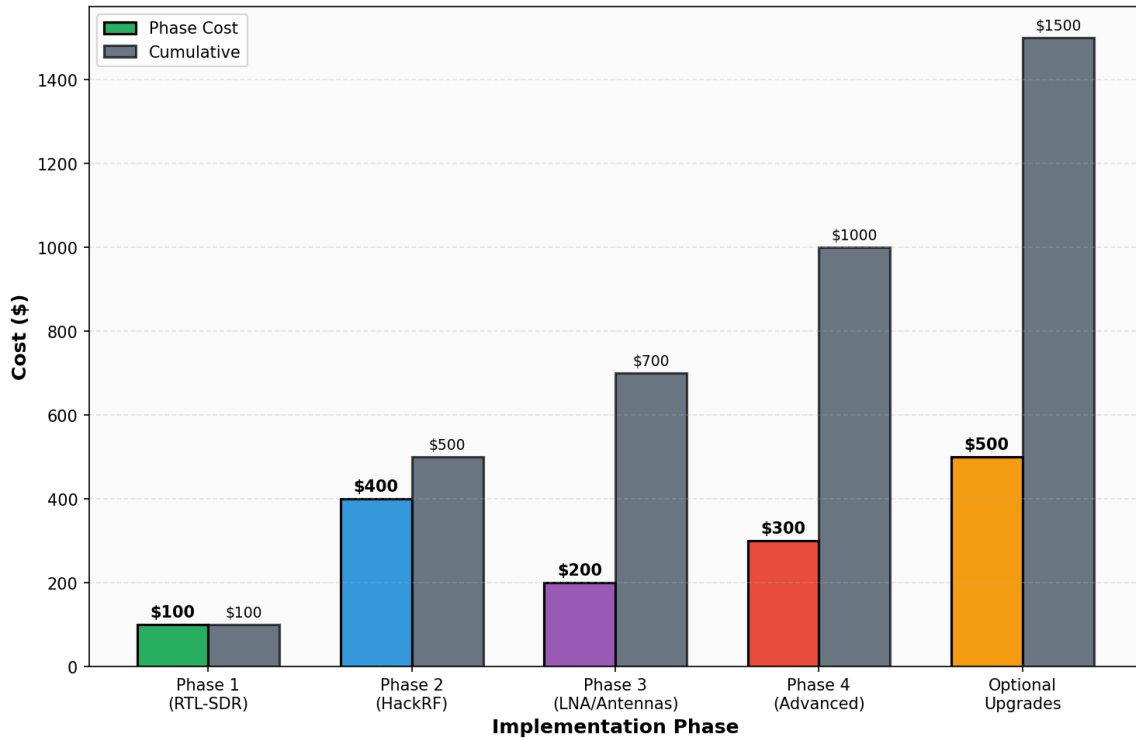


Figure 5: Phased budget breakdown with cumulative costs.

Phase	Equipment	Cost
Phase 1	RTL-SDR kit	\$100
Phase 2	HackRF One + antenna	\$400
Phase 3	LNA, adapters, directional	\$200
Phase 4	Second SDR, shielding	\$300
Total		\$1,000

Budget Options

Configuration	Total Cost	Capability
Minimum Viable	\$450	RTL-SDR + HackRF
Medium-Grade	\$1,000	All 4 phases
Optimal	\$1,500	With upgrades

7. Learning Resources

Free Resources

Resource	URL	Focus
RTL-SDR.com	rtl-sdr.com	Beginner tutorials
Great Scott Gadgets	greatscottgadgets.com/sdr	Video series
GNU Radio Tutorials	tutorials.gnuradio.org	DSP fundamentals
Signal Identification Wiki	sigidwiki.com	Signal database
Radio Reference	radioreference.com	Frequency database

Recommended Books

Book	Author	Price
SDR for Engineers	Analog Devices	Free PDF
GNU Radio Cookbook	Various	Free online
Signals and Systems	Oppenheim	\$120

8. Safety and Legal Considerations

Transmit Restrictions

Band	TX Allowed?	License Required
AM Broadcast	NO	N/A
FM Broadcast	NO	N/A
Amateur Radio	YES	Amateur license
ISM Bands (315/433/915 MHz)	YES	Part 15 compliant
Citizen's Band	YES	None (Part 95)
FRS/GMRS	Partial	GMRS requires license

Best Practices

1. Never transmit on restricted frequencies
2. Use attenuators when testing near transmitters
3. Obtain proper licenses before TX
4. Keep records of all transmissions
5. Respect privacy - do not decode private communications

9. Conclusion

A medium-grade RF analysis kit centered on the HackRF One provides excellent value for intermediate users. The phased approach allows gradual skill development while building capability. Total investment of \$1,000 provides professional-grade analysis capability across 1 MHz to 6 GHz with both transmit and receive functionality.

Key recommendations:

- Start with RTL-SDR for learning (\$45-100)
- Upgrade to HackRF One for TX capability (\$300)
- Add LNA and better antennas for weak signals (\$100)
- Expand to multi-SDR setups for advanced analysis (\$300+)

This kit provides the foundation for RF spectrum analysis, signal identification, protocol reverse engineering, security testing (authorized), amateur radio operation, and regulatory compliance verification.

Appendix: Vendor List

Vendor	Products	Website
RTL-SDR Blog	RTL-SDR V3/V4	rtl-sdr.com
Nooelec	NESDR series	nooelec.com
Great Scott Gadgets	HackRF	greatscottgadgets.com
Lime Microsystems	LimeSDR	limemicro.com
Nuand	BladeRF	nuand.com
Ettus Research	USRP	ettus.com