Radio Direction Finding And Foxhunting Basics

By Jon, George, and Galen

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Hidden transmitter hunting is called:

Fox hunt

Bunny hunt

T hunt

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Why do we RDF?

- Local interference
- Stuck transmitters or intentional jamming
- Search and rescue: ELT/EPIRB
- Animal tracking
- Radio orienteering
- FUN!
- homingin.com is a great source for RDF info

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Type of foxhunts

- Local: park, campus
- On foot
- Multiple foxes
- Mobile
- DX

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National foxhunt weekend

- First week in May
- Annual XARC spring foxhunt
- Fall XARC hunt

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Transmitters

custom/homebrew

Commercial

Improvised

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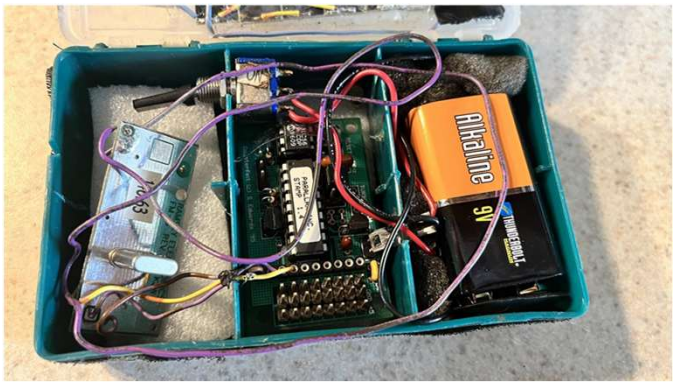
Homebrew foxes

microcontroller, battery, TX

Arduino or similar can generate morse code and key the TX



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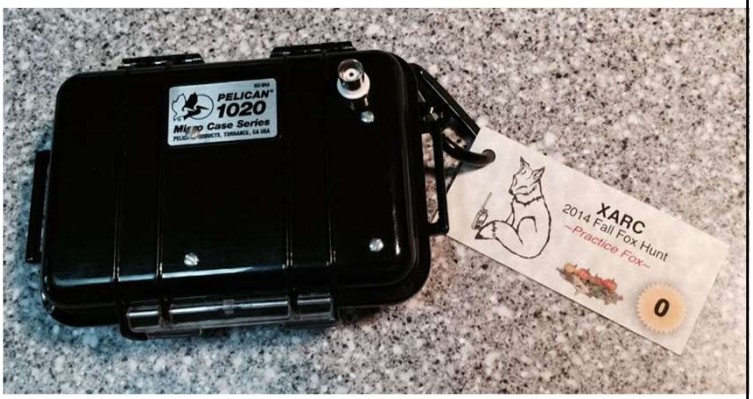
W2VAB/W2NED foxmitter

Couple of XARC members built these for multi-fox hunts



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W2VAB/W2NED foxmitter

.5 watt or 7 watt

4 selectable freqs

Adjustable time delay

Off-the-shelf TX module

Open source controller

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N2JAC small fox

Microcontroller, battery, TX

Programmable but fixed timing in the field

Short range. Very low power

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Homebrew foxes: WO2P

Scary to see chained to a tree in a park, but clearly labeled

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Homebrew foxes: WO2P

Mobile radio and homebrew controller

High or low power, SLA battery

Remote controlled

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Commercial foxes

Byonics PicCon. Same designer as APRS tracker. $70

Integrated TX and controller microfox $100

Adjustable timing, can be used for international formats.

Baofeng version mounts to UV-5R HT

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Improvised fox

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Receivers

Radio

Antenna

Location

Direction

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Antennas

The rubber duck that comes with your HT will work.

If your antenna is not directional, you need a way to make it directional

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Body fade technique

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Antennas

Yagi - tape measure DIY

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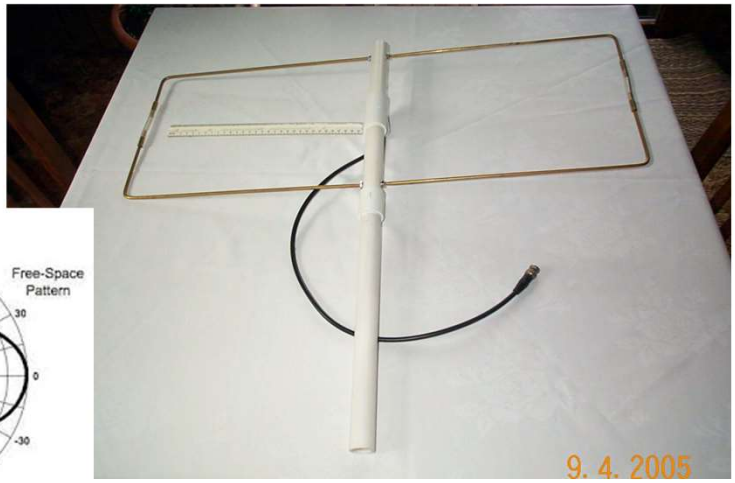
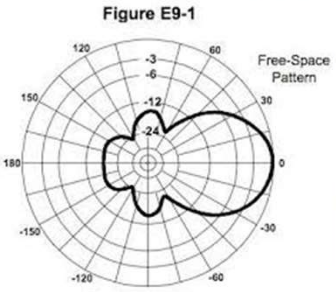
Antennas

Moxon - easy to build

No big peak direction like a yagi, use the null





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Antennas

Quad

This one is mounted to a vehicle with a rotator

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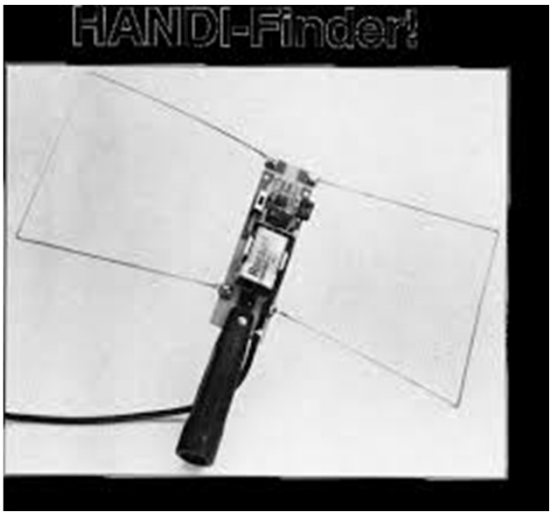
Handi finder

Plans at handi-finder.com

Phase comparison produces two nulls indicating the direction



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Antennas

Phased arrays

Multiple antennas for doppler receive

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Receiver

Basic HT. a good S meter helps

Some dedicated systems have receivers included

Doppler systems use multiple antennas and rely on difference in received signal

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Receive techniques

Hunting close to transmitter can be tricky. Attenuators: passive or active

Metal tube, shield, remove antenna or use a smaller antenna.

Antenna in metal trash can lid

Tune off frequency to reduce received signal if too strong

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Hunting tips

The fanciest or most complicated setup is not always the best.

Foxhunts have been won with an HT and rubber duck.

If there was one perfect hunting solution, everyone would be doing it.

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Hunting tips

First time hunters with just an HT have out-hunted veteran hunters.

Try not to change too much equipment between hunts, so you can get used to your gear

Radio waves won't always behave as you think they should ;^)

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Field day 24

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Radio merit badge 2018

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RARA picnic 2017

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RARA picnic 2016

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New Tech

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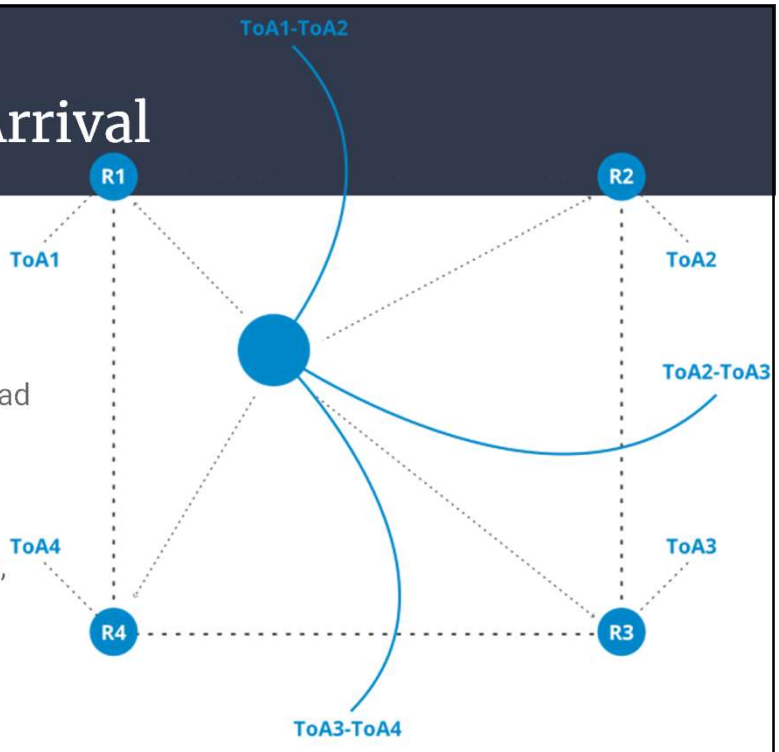
Time Difference of Arrival

- "TDoA"
- Many antennas and receivers spread out
- Draw curves for possible locations, find overlaps



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TDoA Requirements

- Precise, accurate, and synchronized clocks
- Similar quality receivers
- Similar antennas

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What if the signal is always on?

- It's probably not constant, signals vary
- Match phase of the signals
- Line up the peaks

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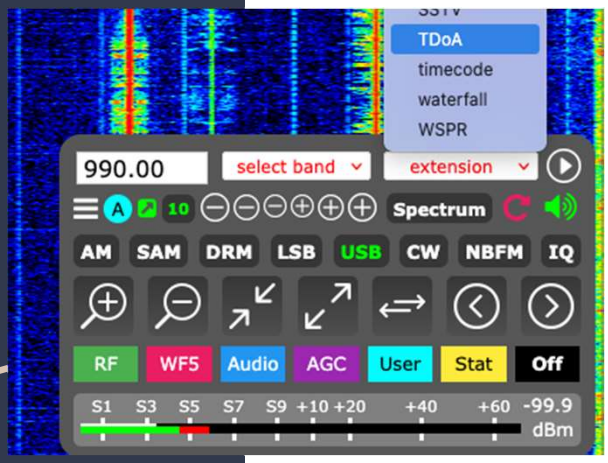
KiwiSDR TDoA



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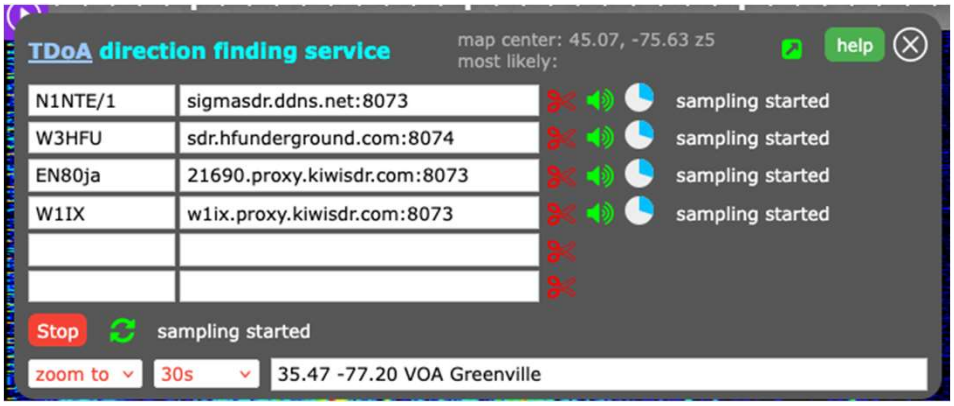
Fill the station list and take samples



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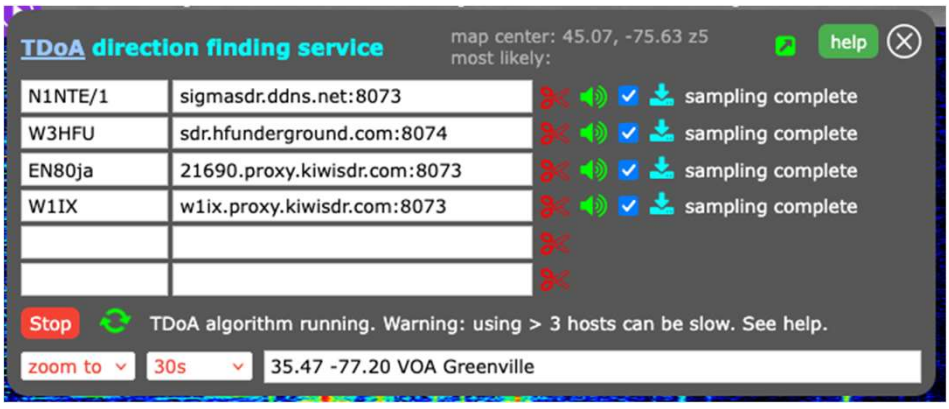
The algorithm will automatically run



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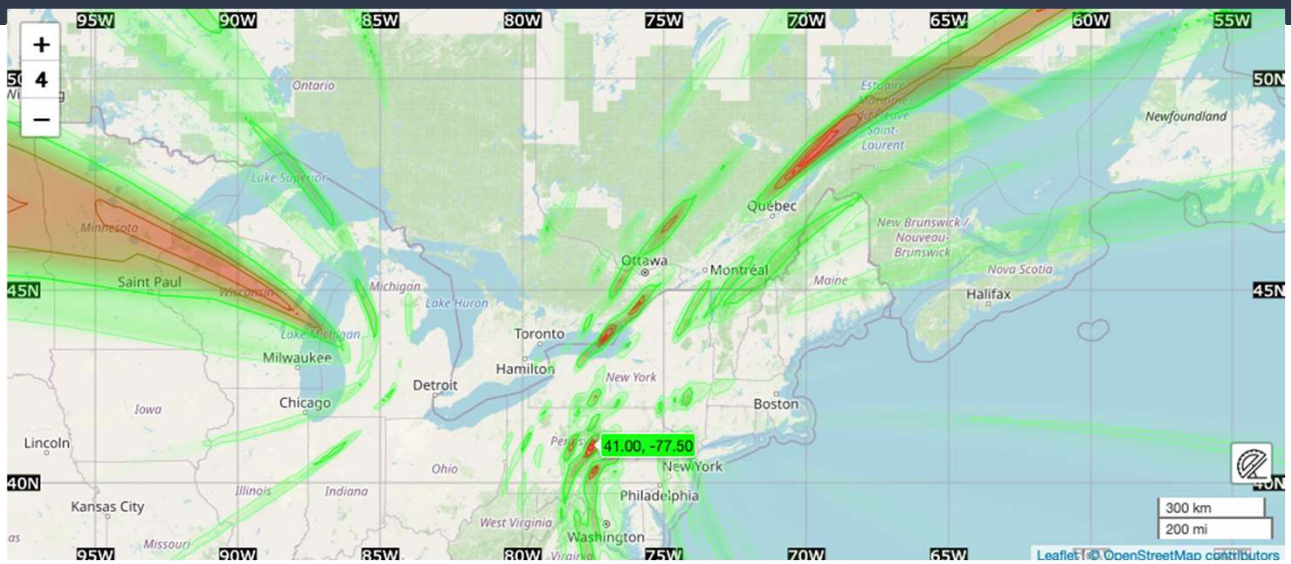
Not always the most accurate



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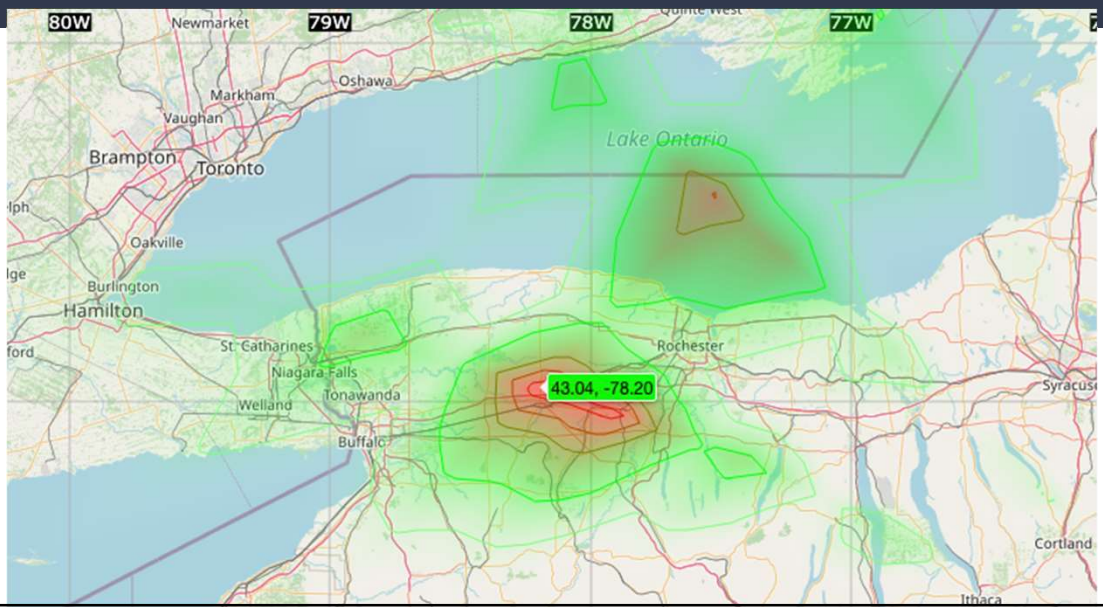
Easy enough to run again



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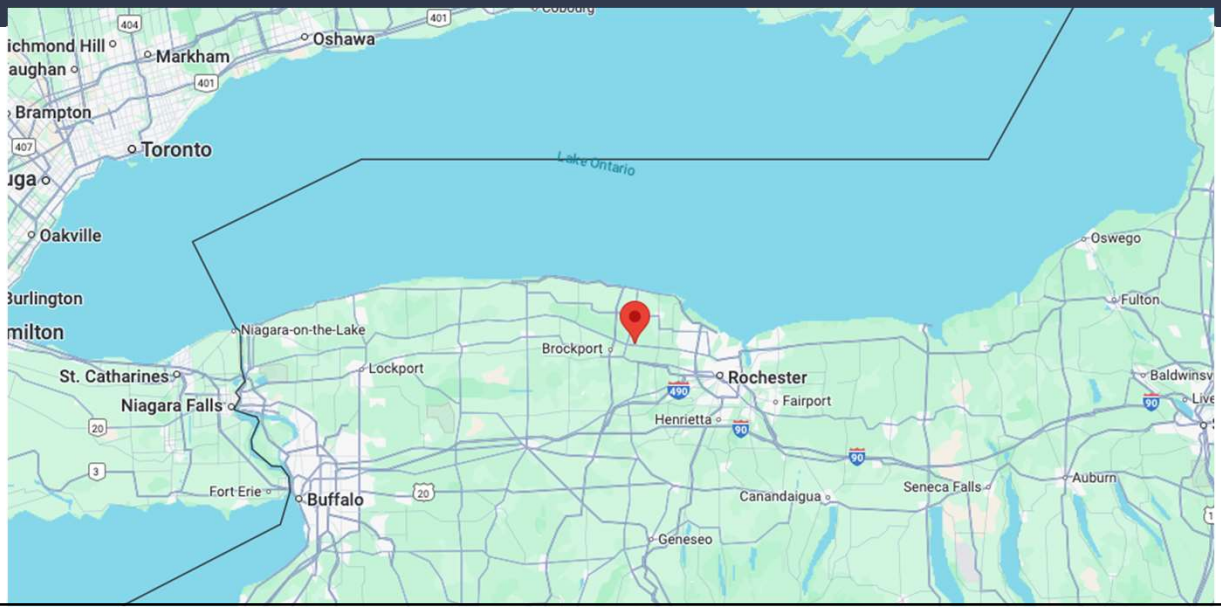
Where Wikipedia says it is



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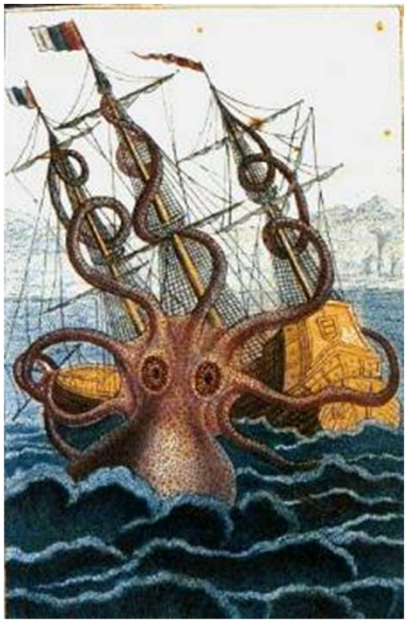
Release the Kraken!



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KrakenSDR

Next-Generation Open-Source Radio Direction Finding

Galen Guyer, K9FGT

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What is the KrakenSDR?

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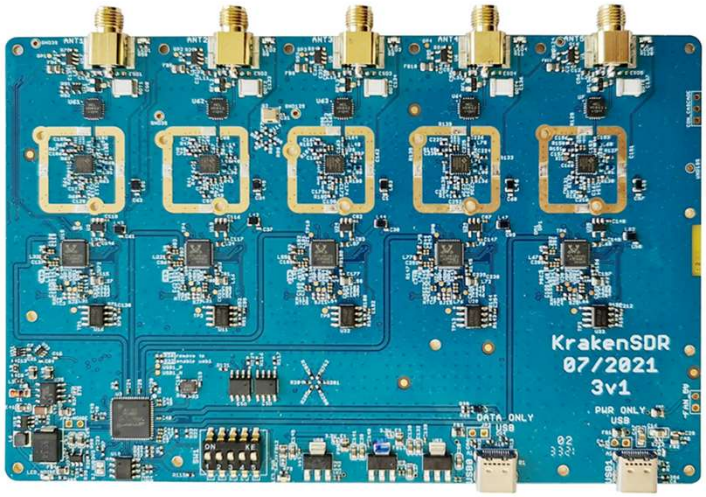
What is the KrakenSDR?

It's 5 RTL-SDRs duct-taped together



https://www.crowdsupply.com/krakenrf/krakensdr

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Why can't I just use 5 RTL-SDRs?

5 RTL-SDRs and some duct tape would be be less than 1/5 the cost of a KrakenSDR

KrakenSDR with Aluminum Case

This fully assembled and tested KrakenSDR comes installed in a custom aluminum enclosure and includes a free copy of the KrakenSDR Android app.

$499 $8 US Shipping / $18 Worldwide

In stock

Add to Cart

Five Magnet-Mounted Antennas

A set of five magnetic, telescopic whip antennas—with 100 MHz to 1 GHz tuning range—that can be used with KrakenSDR for direction finding. The magnets are strong and will be secure on the roof of a moving car. Includes a set of five three-meter, LMR100-equivalent coax cables that have been length matched for better performance.

$199 $8 US Shipping / $18 Worldwide

In stock

Add to Cart

https://www.crowdsupply.com/krakenrf/krakensdr

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Coherence

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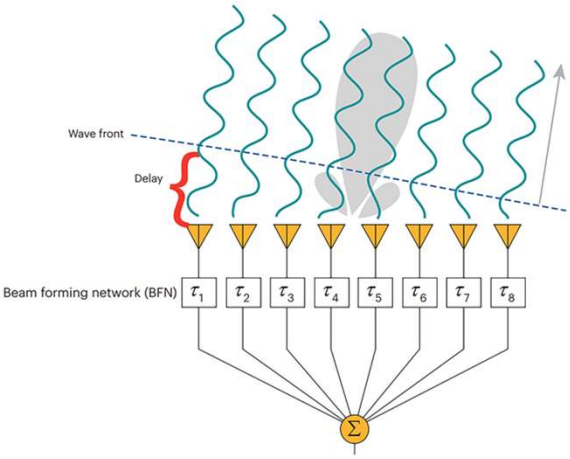
Coherence

or, the importance of precise timing



https://semiengineering.com/the-importance-of-phase-coherent-rf-signal/

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Coherence

or, the importance of precise timing

To achieve phase coherence, KrakenSDR drives all five RTL-SDR radios with a single clock source, and contains internal calibration hardware to allow the phase relationship between channels to be measured precisely and corrected for in our software. Additionally, the overall design of KrakenSDR works to ensure phase stability, with care taken in the areas of heat management, driver configuration, power supply, and external-interference mitigation.

https://www.krakenrf.com/about-krakensdr

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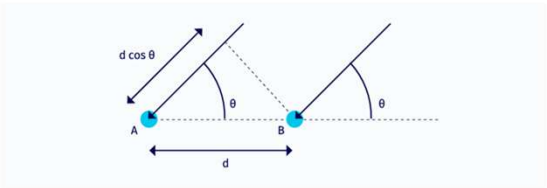
What does that get us?

five antennas
+ phase coherence
+ some math
= an angle of arrival

If we have more than one antenna in an array, we can use the phase difference of the signal received at the antennas to determine the incident angle as follows:



<< *Figure 5*
Additional path length traveled

If two adjacent antennas are separated by a distance d, then the additional path length that the signal needs to travel to reach antenna A compared to antenna B is d cosθ. If the wavelength of the signal is λ, then the phase difference, φ, over that distance will be

$$\phi = \frac{2\pi}{\lambda} d \cos\theta$$

Rearranging to put this in terms of θ, we have

$$\phi = \cos^{-1}\left(\frac{\phi\lambda}{2\pi d}\right)$$

so if we know the phase difference, wavelength and antenna separation, we can determine the angle of arrival. However, this only gives an unambiguous answer if the antenna separation is less than half a wavelength.

https://pages.crfs.com/hubfs/whitepapers/Angle%20of%20Arrival-Direction%20Finding.pdf?hsLang=en

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The MUSIC Algorithm

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The Basics of the MUSIC Algorithm

MUSIC is an abbreviation for
Multiple **Si**gnal **C**lassification

MUSIC is essentially a method of characterizing the range of a self-adjoint operator. Suppose A is a self-adjoint operator with eigenvalues $\lambda_1 \geq \lambda_2 \geq \ldots$, and corresponding eigenvectors $v_1, v_2, \ldots$. Suppose the eigenvalues $\lambda_{M+1}, \lambda_{M+2}, \ldots$ are all zero, so that the vectors $v_{M+1}, v_{M+2}, \ldots$ span the null space of A. Alternatively, $\lambda_{M+1}, \lambda_{M+2}, \ldots$ could merely be very small, below the noise level of the system represented by A; in this case we say that the vectors $v_{M+1}, v_{M+2}, \ldots$ span the *noise subspace* of A. We can form the projection onto the noise subspace; this projection is given explicitly by

$$P_{\text{noise}} = \sum_{j>M} v_j \overline{v_j}^T \tag{1}$$

where the superscript T denotes transpose, the bar denotes complex conjugate, and $\overline{v_j}^T$ is the linear functional that maps a vector f to the inner product $\langle v_j, f \rangle$.

The (essential) range of A, meanwhile, is spanned by the vectors $v_1, v_2, \ldots, v_M$.

The key idea of MUSIC is this: because A is self-adjoint, we know that the noise subspace is orthogonal to the (essential) range. Therefore, a vector f is in the range if and only if its projection onto the noise subspace is zero, i.e., if $\|P_{\text{noise}} f\| = 0$. And this, in turn, happens only if

$$\frac{1}{\|P_{\text{noise}} f\|} = \infty \tag{2}$$

Equation (2) is the MUSIC characterization of the range of A.

We note that for an operator that is not self-adjoint, MUSIC can be used with the singular value decomposition instead of the eigenvalue decomposition.

https://www.math.colostate.edu/~cheney/papers/music.pdf

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Ok what the hell was that

I'm not a math major

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Enrollment Verification as of Feb 24, 2025

Galen Guyer **ID Nbr:**
SSN:

Current Program of Study

Career	**Academic Program**	**Exp Comp Dt**
Undergraduate	UGRD Interdisciplinary Studies	05/09/2025
Academic Plan	**Degree**	
Individualized Program (BS)	BS	
Legal Studies (IM)		

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What does this *actually* get us?

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A guy threatening me, with my address.

In retrospect, I should probably not use my callsign plates when hunting a jammer
(or I should get a P.O. Box)
(or both)

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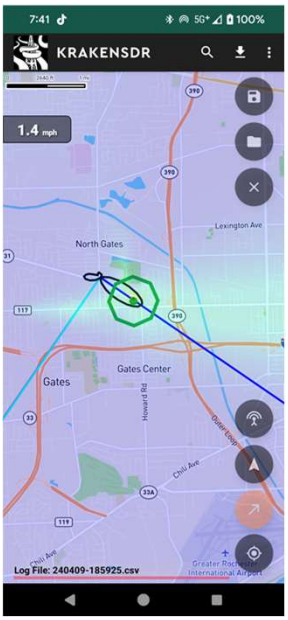
If you can see me

I can see you

With some help from signal strength hunting on a mobile, we got to the same parking lot as a suspected jammer in ~30 minutes

The suspected jammer was mobile, so it's hard to tell exactly how close we were but it was close enough to make visual contact and identify a suspect vehicle

Haven't heard from him since 😉



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