Radio Direction Finding

Gloucester County NJ
Amateur Radio Club
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What is RDF?

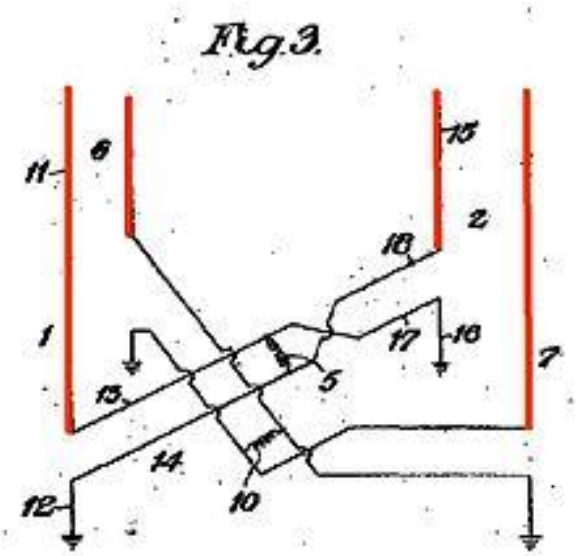
- RDF – Radio Direction Finding
  - Determining the direction from which a received radio signal was transmitted.
- Technology has changed over the decades
- Essential elements of the techniques have not
- Success is still largely up to the skill of the RDF equipment operator

When RDF?

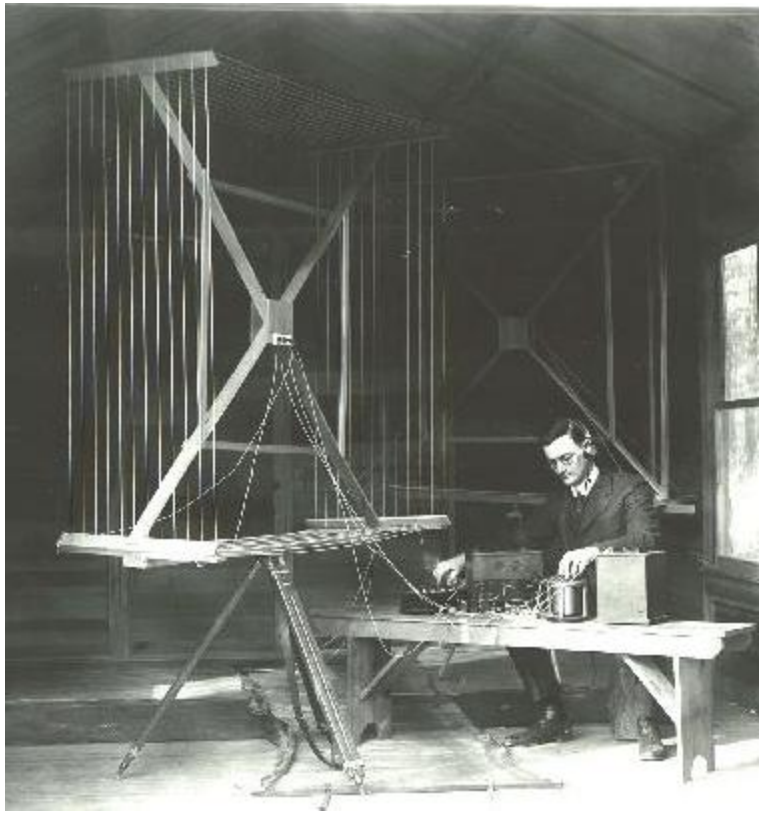
- Searching for sources of radio interference
- Localizing non-authorized transmitter
- Identification of transmitters, known and unknown
- Dealing with spread spectrum techniques, especially in wireless communications
- Military and security forces
- Civilian search and rescue
- Wildlife tracking
- Radiosport!

History

- DF technique is as old as radio
- Heinrich Hertz (1888) experiments with decimetric waves found antenna directivity
- Early patents
  - Stone, 1902
  - Forest, 1909
  - Belini and Tosi, 1909
  - Adcock, 1919



History -WWI

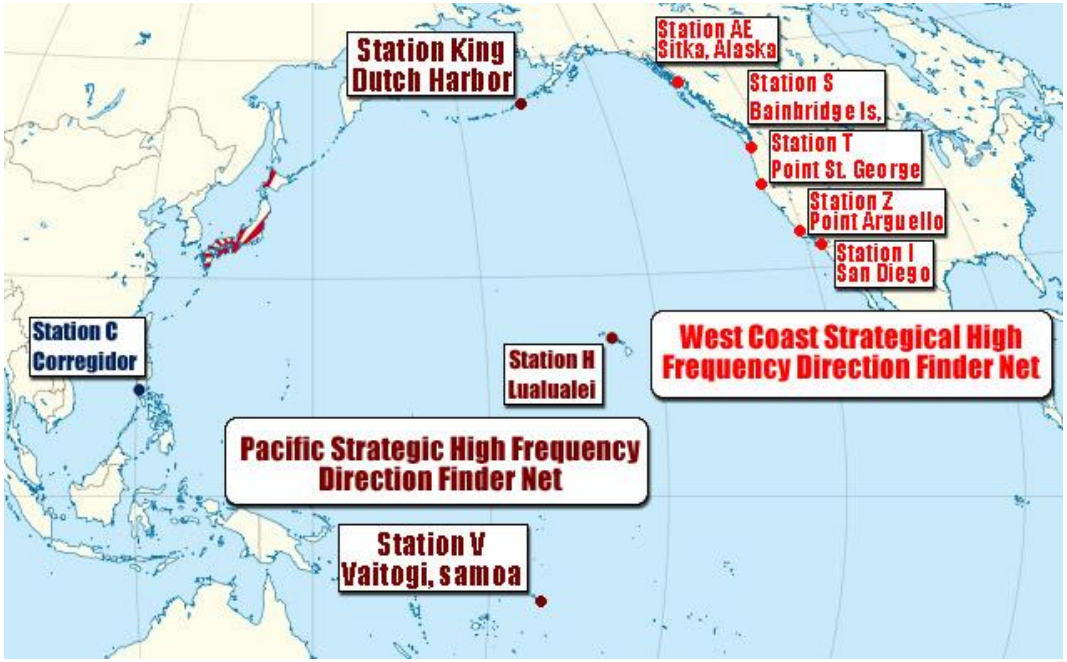


Kensington Maryland field station, circa 1919, NIST Photographic Collection
(http://museum.nist.gov/panels/gallery/radiodf.html)

- DF widely used to pinpoint enemy forces during WWI
- "Radio Compass", prototype for U.S. Navy 1916
- Passive technology, listen in on large military forces keeping in contact with their headquarters
- Manual RDF techniques
  - Rotatable antennas
- RF propagation challenges

  Groundwave, skywave, multi-path, fading, polarization changes, non-white external noise, seasonal and time-varying ionospherics, (don't we know!)

History - WWII



- Accuracy improvement – HF/DF Nets
  - Multiple RDF stations operating together as a “net”
  - Each try get directional fix on callsign heard, noting time and frequency, then coordinate with others
  - Intercept lines drawn on map for all sites that got a fix on target

Ref: http://www.researcheratlarge.com/Pacific/RDF/

WWII, RDF Stories

U.S. Navy DAQ (WWII)

German EP2a

German U-67 DF Antenna

- Pearl Harbor
  - As shown in movie “Tora Tora Tora”, Japan fleet used Honolulu broadcast station as an over-the-horizon beacon for attack on Pearl Harbor
  - Regular Japanese carrier radio operators kept back in Tokyo, generating false traffic
    - their unique styles recognized and located as being in home islands
- Secret Transmitters
  - British Radio Security Service – up to 1700 volunteer interceptors (radio amateurs) recruited to detect illicit transmissions
  - Similar efforts in Europe by the Germans to locate resistance groups
- D-day Deceptions
  - Operation Fortitude, with (fake) First US Army Group, led by George Patton. Radio trickery helped convince Germans real plan for invasion in Calais, not Normandy.
- U-boats
  - U-boat “loop” antenna technology, used in hunting Allied shipping (ref: http://uboat.net/articles/51.html)
  - British ships outfitted with new automatic “HuffDuff” very effective in tracking and hunting short duration German submarine transmissions, helped turn the tide of shipping losses

Cold War

- After WWII
  - From 1950's, US adapted German Wullenweber antenna systems for use in Vietnam, cold-war eavesdropping (FRD-10, AN/FLR-9)
  - Russians deployed similar (Krug), early use included tracking Sputnik
  - OUTBOARD HF/DF systems standardized on U.S. Navy vessels
- New and Improved Technologies
  - Automatic signal search and analysis
  - Combined active/passive systems (e.g. Over the horizon HF radar)

Refs: http://www.answers.com/topic/radio-direction-finding-equipment
AN/FLR-9, ref: http://en.wikipedia.org/wiki/Wullenweber
http://www.engineeringradio.us/blog/2010/10/how-the-cold-war-was-won

Modern Era

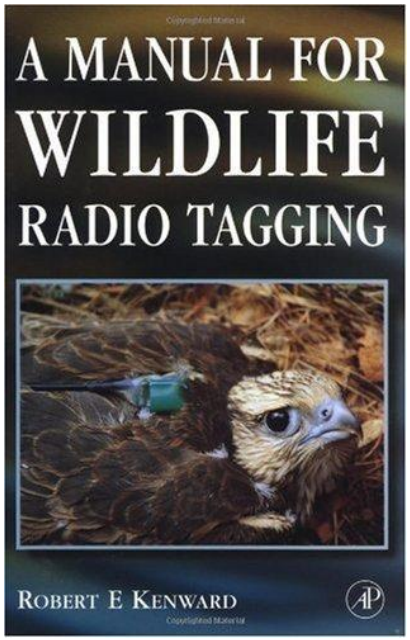
- Military (still)
- Search and Rescue
- Wildlife Tracking
- Spectrum enforcement
- Amateur RDF

Search and Rescue

- Distress Radio Beacons
  - Maritime (EPIRBs)
  - Aircraft (ELTs)
  - Personal (PLBs)
- What about APRS?
  - Has distress packet type, but not guaranteed & not satellite compatible

- Cospas-Sarsat (satellite) compatible beacon frequencies
  - 406.025 Mhz (digital burst, satellite)
  - **121.5 MHz** (analog, short range homer)
  - 243. Mhz (old, phased out since 2009)
- Other systems, not so standard
  - 457 kHz, Avalanche transceiver
  - 216-217 MHz, LoJack 'Safetynet' & law enforcement tracking devices

Wildlife Tracking



- Tracking
  - Micro-transmitters, collars, tagging technologies
  - RDF techniques (fixed-wing, mobile, and on-foot)
- Studies
  - Migration patterns
  - Population studies
- Volunteer opportunities?

Technologies

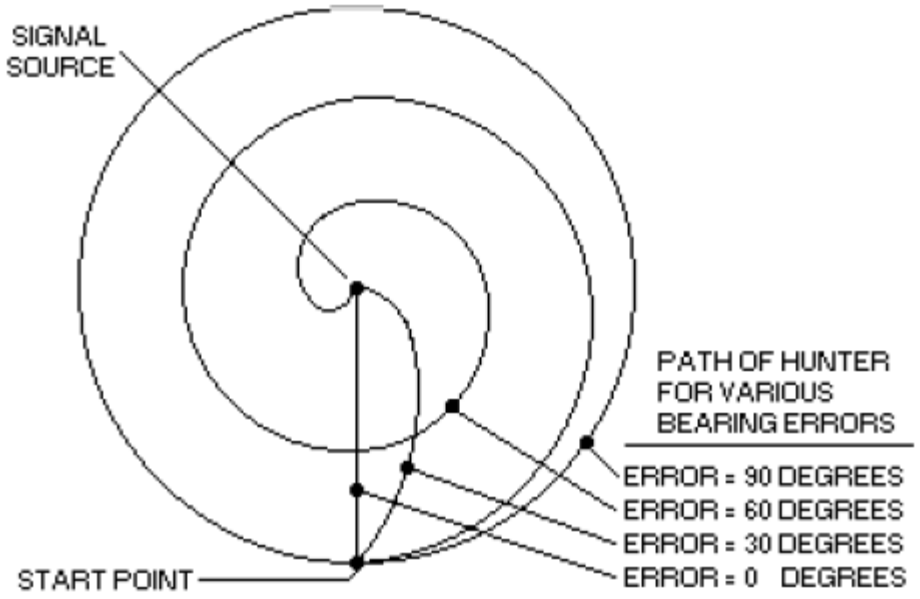
- Spectrum Enforcement
  - If can't ID interfering signal by demodulation, or signal analysis, need radiolocation to locate source
- Radiolocation Technologies
  - Manual Techniques
  - Doppler DF
  - Watson-Watt
  - Time difference of arrival, SRDF

Technology

- Manual Techniques
  - Use of receiver and hand-held directional antenna
  - Antenna is moved/rotated to find directions of min and max signal strength, usually based on signal amplitude
  - “Home-in” on signal by moving in direction of signal, then sweep to test possible locations in suspect area
  - Can also plot bearing lines to triangulate general transmitter location
  - Limitations: highly dependent on skill of operator, accuracy poor at distance, difficult to get bearing on short duration signals, difficult to get bearing on frequency agile signals

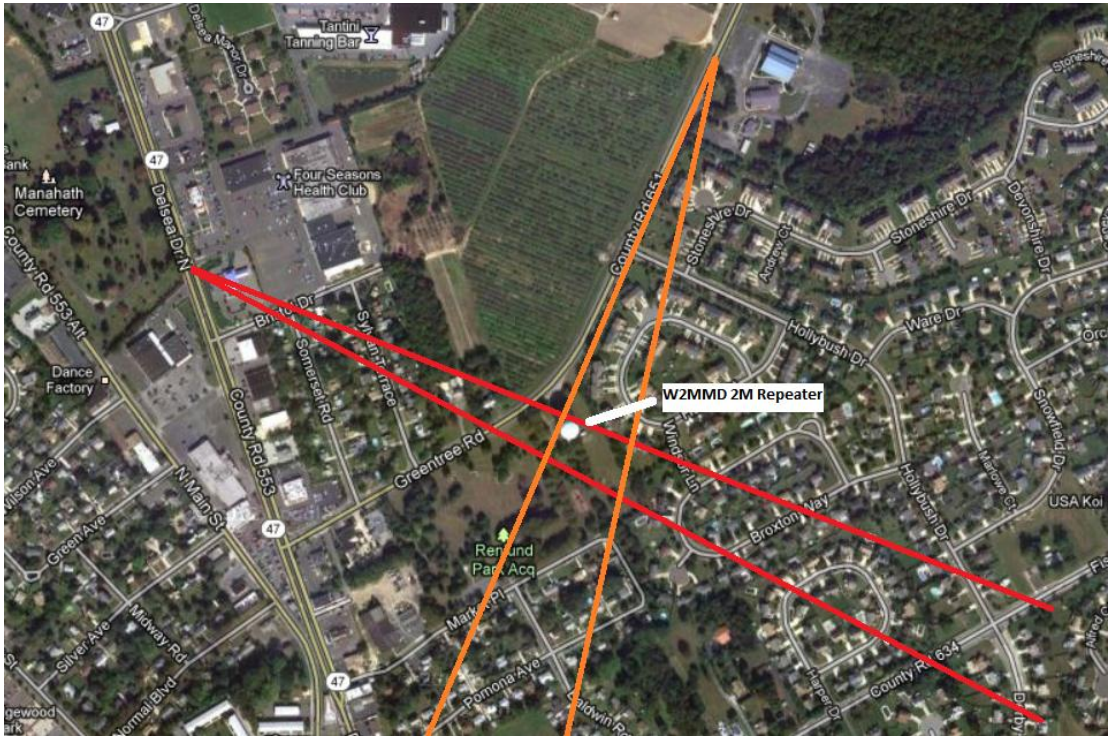
Rohde & Schwarz portable monitoring & RDF

Homing-in by Bearing



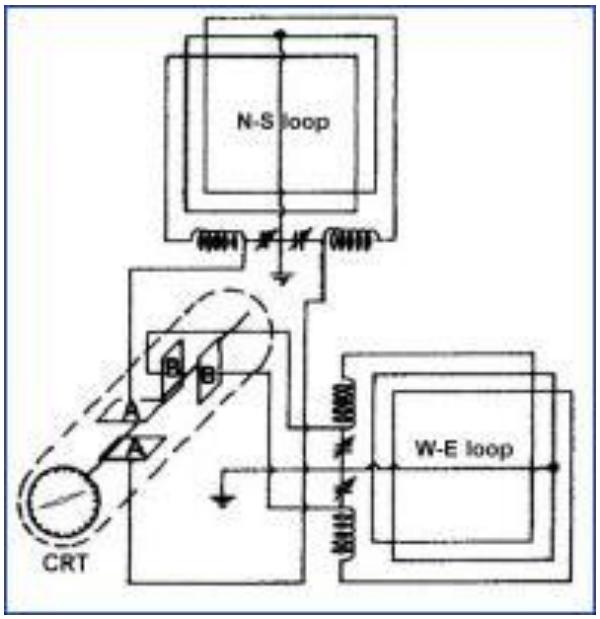
- If mobile, can take bearing, follow it for a bit, then repeat
- Not always shortest path

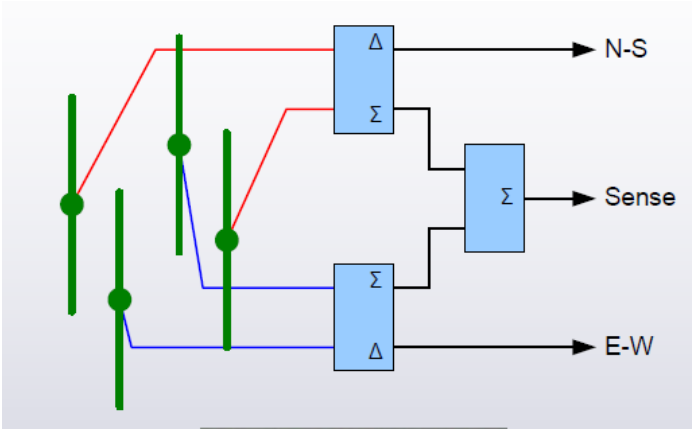
Triangulation



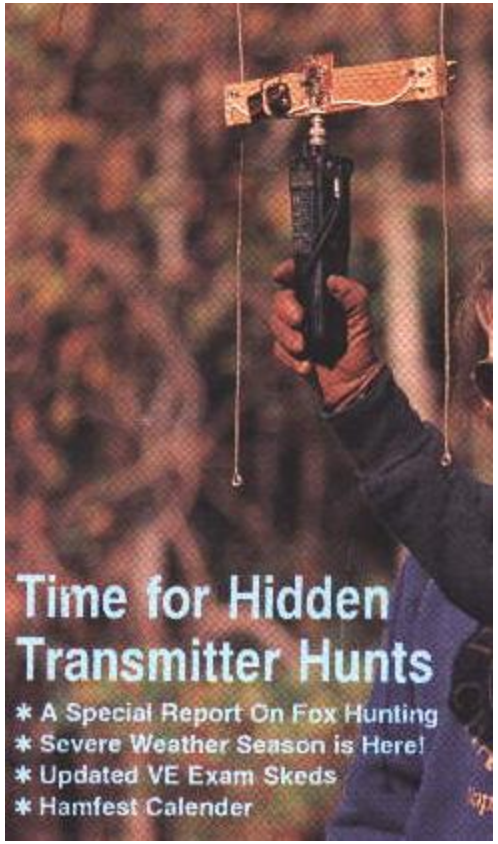
- Narrow search area by triangulating lines of bearing
  - Take directional measurements from several locations
  - Plot bearings on a map, narrow search to where bearings intersect
  - Directional uncertainty at distance, progressively smaller hunt areas
  - Max signal strength (S-meter) when close, attenuate to avoid overload

Watson-Watt

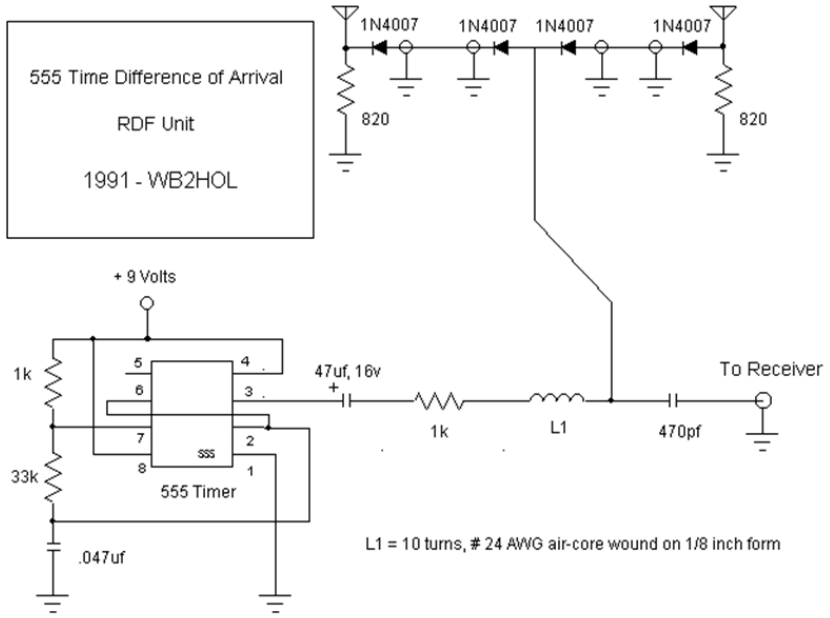




- Amplitude comparison technique, developed after WWII, using crossed loop, or Adcock antennas
- Enabled real-time RDF, even for short duration signals
- Difference signals from N-S, and W-E used to deflect electron beam on CRT
- Basic Adcock/Watson-Watt design is basis of many systems today

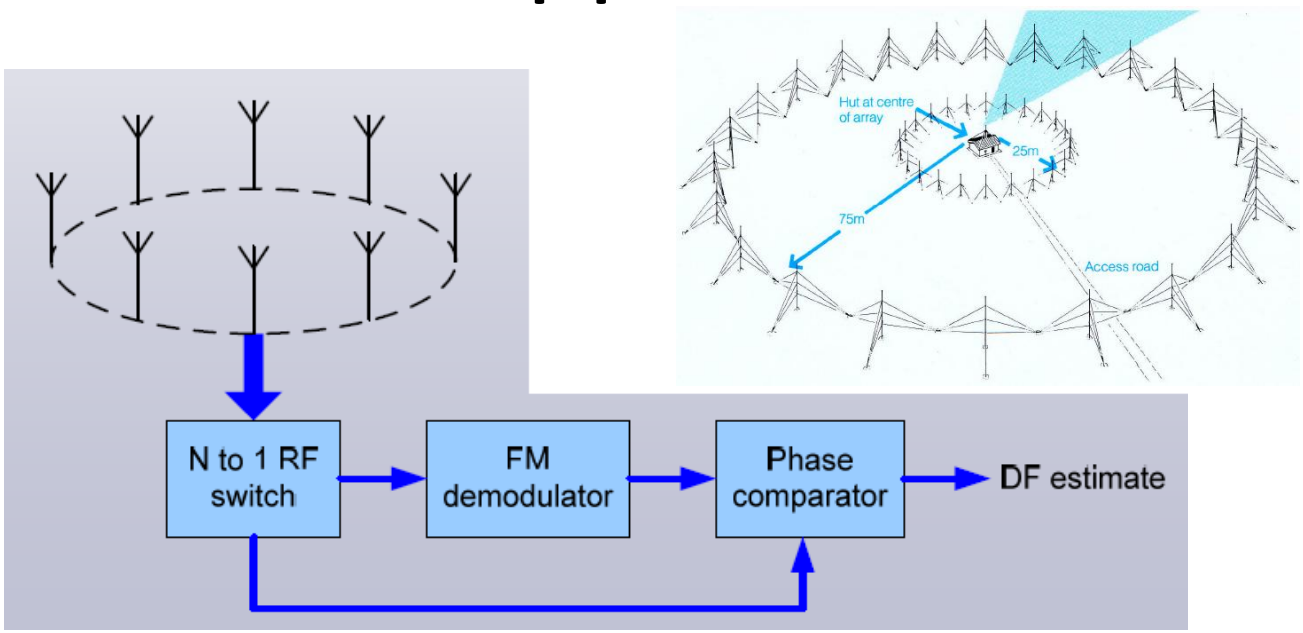


TDOA



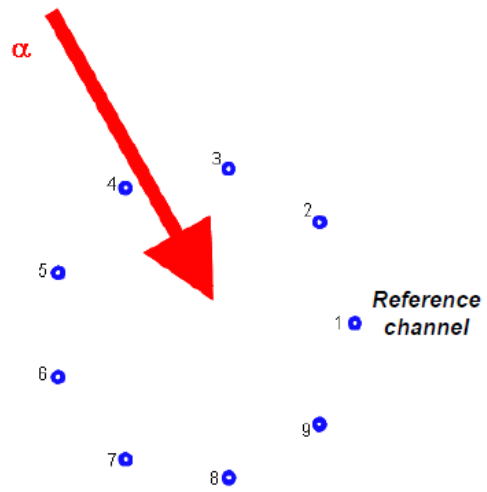
- Time difference of arrival (TDOA)
- Works on detecting a phase difference, not amplitude difference
  - Useful for close-in work, when amplitude schemes overload
- FM tone when signal not arriving at antennas at same time
  - Turn antenna unit until find null (180 degree ambiguity)

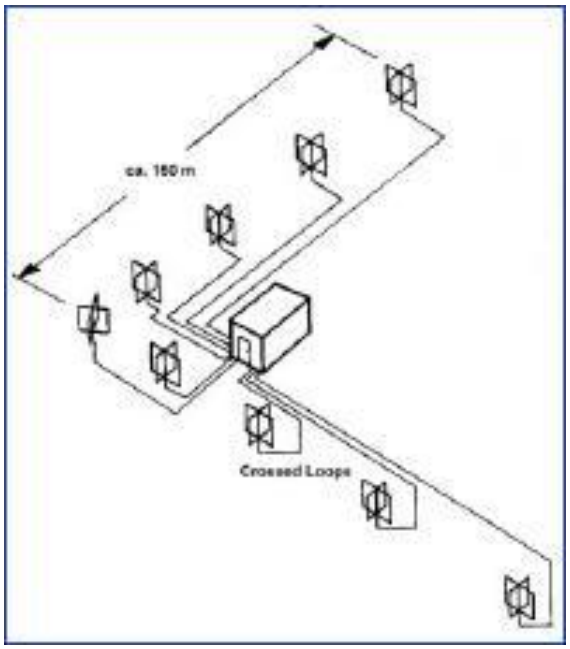
Doppler DF

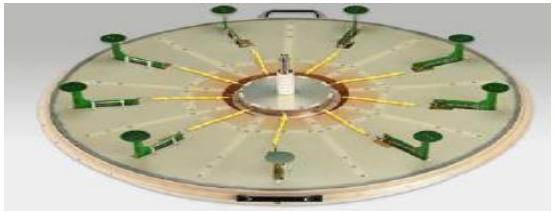


- Doppler shift
  - Circular array, electrically rotating antenna (goniometer, CDAA)
  - Single receiver, rotational FM tone demodulated
  - Closer to signal: frequency shifts up, away: shift down
  - Phase offset of recovered tone vs. original is direction of arrival

Correlation Interferometer RDF

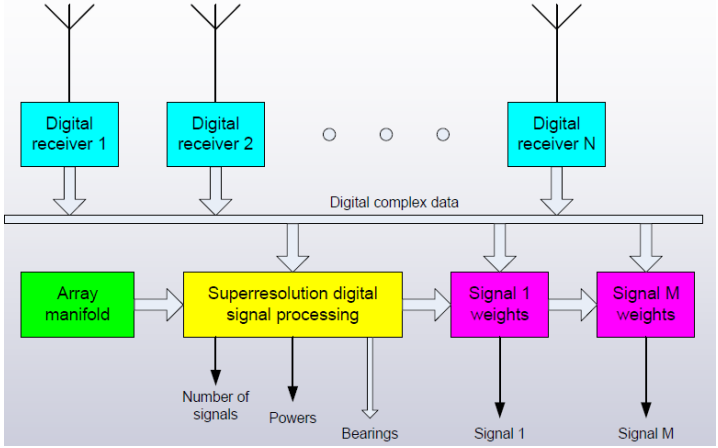


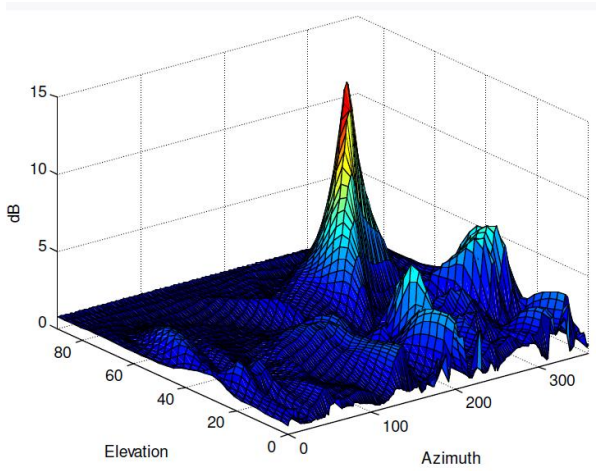




- Interferometry first used in radio astronomy
- Measures angle of incident wavefront at multiple elements
- Relies on digital signal processing for sensor array processing
- Electrically small active or passive elements, wideband performance
- Number of elements in CI antenna varies (5-9 typical)

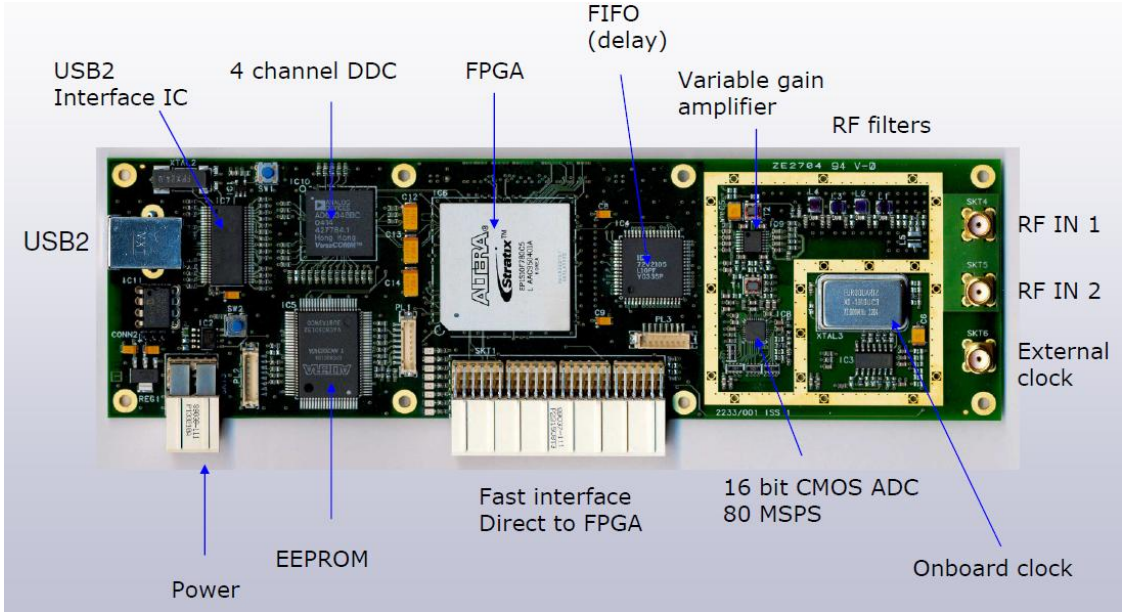
TDOA / Super-resolution / SRDF





- Taking advantage of software - digital signal processing techniques
  - Since 1990's, order of magnitude increase in resolution
  - Increased DF accuracy
  - Azimuth and elevation DF
  - Simultaneous DF of multiple co-channel signals
  - Operation with very few data samples (MUSIC, Capon, ESPRIT algorithms)
  - Adaptive beam forming for signal separation (null steering)
  - Not fixed to a particular array geometry (array manfold from stored calibration function)

Digital receivers



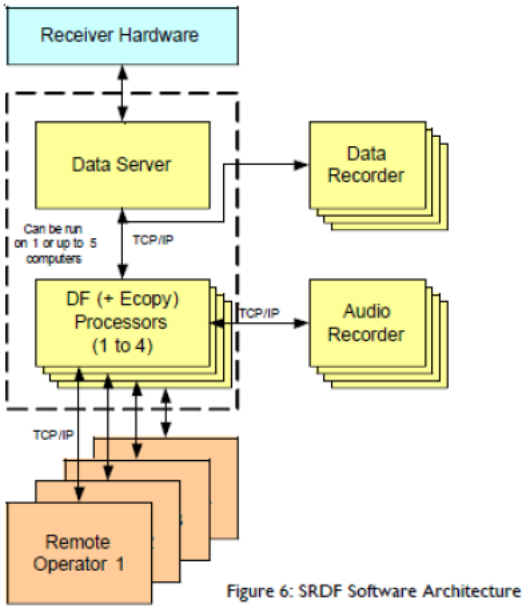
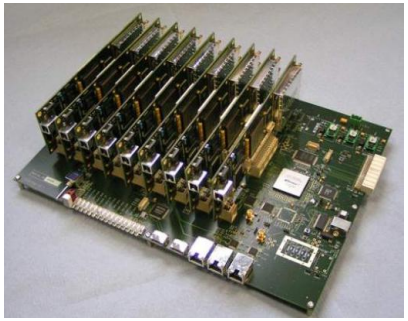


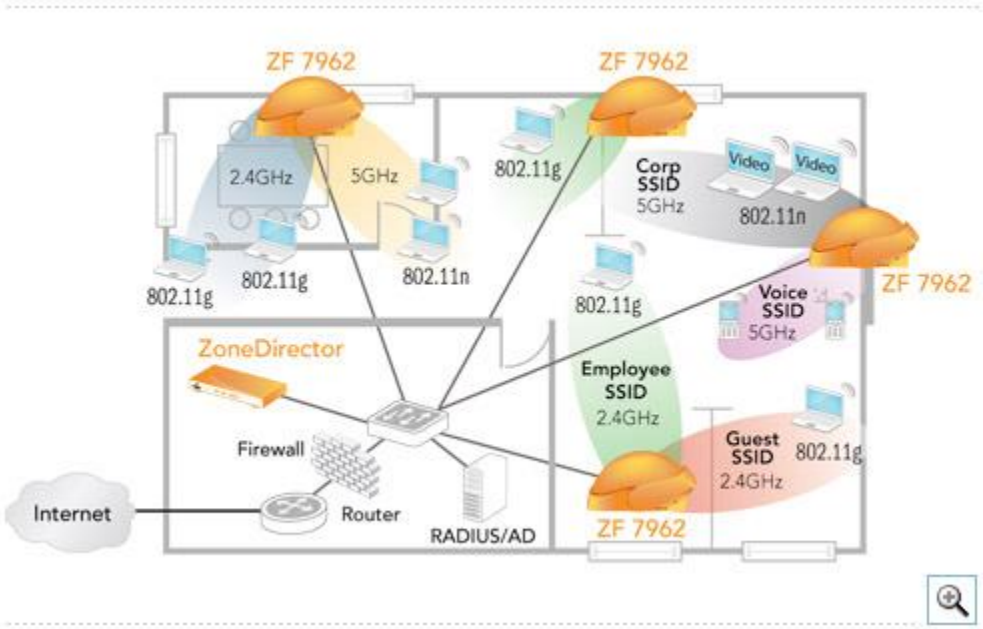
Figure 6: SRDF Software Architecture

- Near instantaneous signal acquisition
- No calibration required
- No need for multiple coherent local oscillators
- Supports DF on short duration / frequency hopping signals
- Supports reconstruction of frequency hoppers
- Broadband beam forming without need for large coaxial cable delay lines
- N channels provides 10logN dynamic range enhancement



Ref: http://www.g4axx.com/HF_Radio_Direction_Finding.pdf

Digital Beam forming

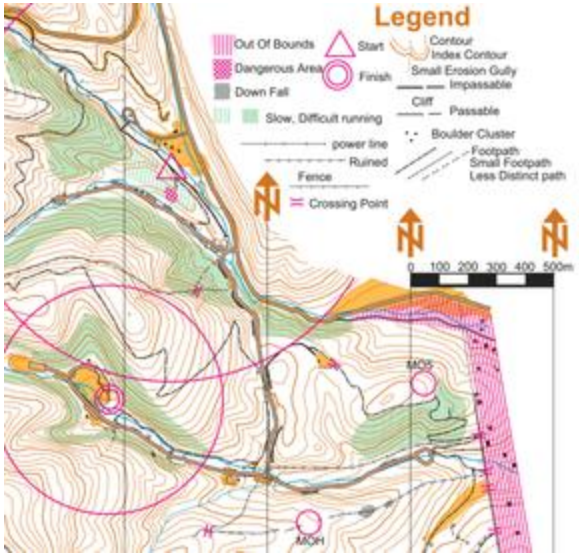


- You might have digital beam forming equipment in your home or office right now!
- 802.11n WI-FI since 2009 (e.g. Cisco Aironet, Ruckus 7962)
  - Adaptive antenna technology
  - Null steering for automatic interference mitigation

Amateur RDF

- Locating sources of Interference
  - Unintentional
  - Malicious
- Help in Emergencies
  - Radiolocation, search and rescue
- Radiosport!
  - Amateur Radio Direction Finding (IARU)
  - T-Hunting

ARDF - On-Foot Hunt



- Amateur Radio Direction Finding (ARDF)
- On-foot, several KM, running through the woods to finish in lowest time
- Combines orienteering (compass/map) skills, with radio DF skills
- International rules, national and international competitions
- Great web site for ARDF: www.homingin.com

- Just want to see what Orienteering is about? Is great Fun for the Fall!
  The best, and local: Delaware Valley Orienteering Association
  - Walking beginner courses: http://www.dvoa.org/

Mobile T-Hunt

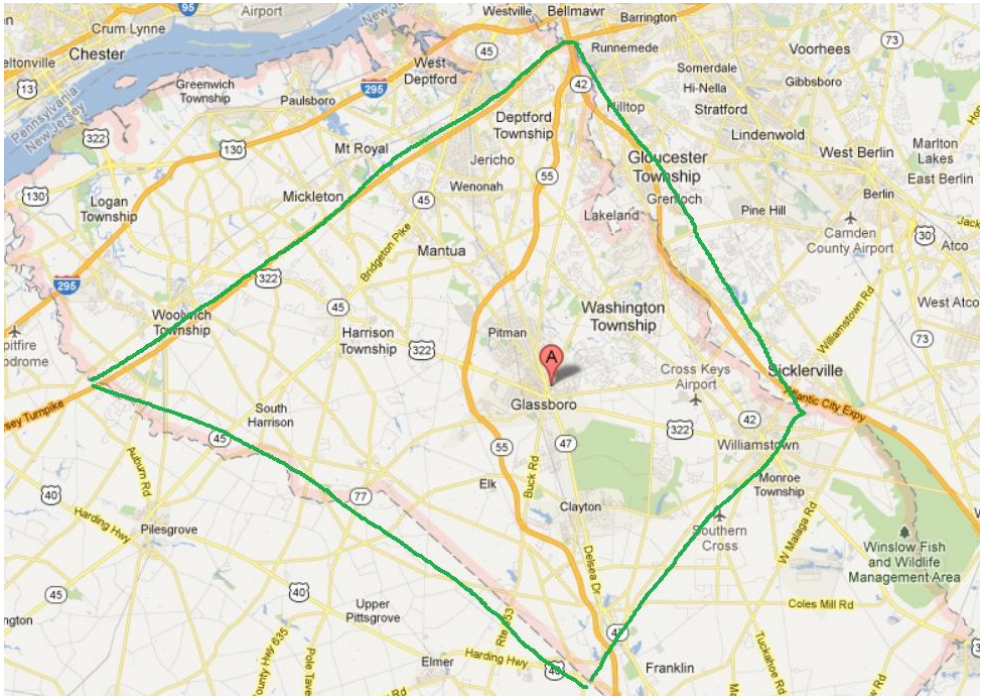
- Transmitter Hunting (T-Hunt, fox hunt)
  - Take place in larger geographic area than ARDF events
- Southern California variants
  - Shortest time or lowest mileage
  - Individual or cooperative team
  - Fixed or mobile transmitter

Let's Have Some Fun!

Practice RDF skills while having fun!

- GCARC Mobile T-hunt!
  - Driving, Navigating, RDF activity, all in one
  - This Sunday Aug 5, 1-3pm
  - Team check-in on our 2M repeater (147.180+, PL 131.8)
  - Fox ID, then he'll QSY to simplex (147.54 vs. 146.565)
- Meet-up after for socializing: Whitman Diner

Boundaries



- Central Gloucester County
  - Fox will park in publicly accessible place (no private property)
  - Twice per minute transmissions (minimum), on simplex frequency using his own ID, clearly identifying self as the “hidden transmitter”
  - Hunters leave simplex frequency open for Fox transmissions coordinate with each other during hunt on our 2M repeater frequency
  - Fox will give better clues if any teams still searching after an hour (2pm)
    - Will talk-in any teams still searching after an hour and a half (2:30pm)

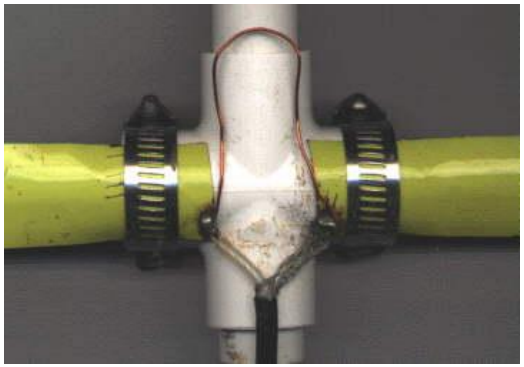
T-hunt Techniques

- Homing-in
  - Directional antenna or technique (e.g. body fade)
  - S-meter, signal strength indication (peak or null)
    - The stronger the signal, the closer you are!
  - Map of area, with plastic cover can write-on
    - And marker, straight edge, and maybe a compass
  - Recommend driver independent from navigator, radio operator (less driving distraction)
    - Fun with partners
    - Don’t all have to be hams!
  - Maybe copy of your ham license (just in case)
- Practice ahead of time
  - Talk with other club members
  - Can triangulate on W2MMD, other known repeaters

Body Fade

- Simple technique, using your hand-held (2M HT)
- Hold HT close to your chest or waist and use your body to block (attenuate) the signal
- Slowly turn around, and listen to signal (or observe your S-meter)
- When signal sounds the weakest, the transmitter is behind you (180 degrees from direction you are facing)
- As you get closer to transmitter, you may not detect any changes in signal strength.
  - Lower HT into cardboard box or tube shielded in aluminum foil until hear noticeable change in signal strength. Try body fade again.
  - Tune off frequency +/-5-10 kHz to reduce receiver's sensitivity (thereby signal strength). Try body fade again.
  - Tune to 3rd harmonic (if multi-band HT), and listen for lower strength signal there
    - (147.54 x 3 => 442.62 MHz, 146.565 x 3 => 439.695 MHz)
  - Remove the antenna and perform body fade technique again (remember RX only – don't TX!)

Build a Simple Directional Antenna



- Tape Measure Beam Optimized for Radio Direction Hunting
  - Joe Leggio, WB2HOL: http://theleggios.net/wb2hol/projects/rdf/tape_bm.htm
- Flexible steel “tape measure” elements
  - Self-supporting, yet fold easy to get in-and-out of car
- Great front-to-back ratio (> 50 db) for hidden transmitter hunts
- Build using only simple hand tools (no machine shop needed)

Hunt Techniques

- Starting
  - Consider start on higher ground
  - Check-in with hunt coordinator on 2M repeater before start (1PM)
  - Get initial bearing line on target, once Fox revealed
  - Agree on plan of attack
  - Navigate for triangulation
- Close-in
  - Stop often to get updated bearings to Fox transmissions
  - Narrow target area through triangulation
  - Front-end overload, use attenuation
    - Off-frequency tuning (+/- 5-10kHz)
    - 3rd harmonics (147.54 MHz x 3)
    - Foil cardboard tube wrap (don't short out battery terminals!)
    - Remove the antenna + all the above
  - Body-fade for null
- Find the transmitter, and you've found the Fox!

Techniques

- Finish
  - "Amazing race" style in-person finish
    - face-to-face with Fox operator
    - get handshake and your finish order confirmation
  - Clear area for other hunters
  - If teams still hunting after first hour, Fox gives better and better clues as approach hard stop time (3pm)
  - Fox declares hunt over when all teams have checked-in at finish
    (or given up, with confirmation from the Fox)

Foxhunt

- Too easy, too fast a finish?
  - If first team to fox in under 30 minutes, drive out to become 2nd Fox (146.565)
- Future T-hunts/foxhunts?
  - Let's see how this one goes first!

  Possibilities…..
    - Portable ARDF transmitters (CW ID, up to 5, in-order)?
    - Coordinated event with other area clubs?
- Sources for additional information
  - ARRL, QST Magazine (online links http://www.arrl.org/direction-finding)
  - CQ Magazine
- Questions?

Radio Direction Finding

- Thank you! See you Sunday!