Progress in OTM Loop Antennas

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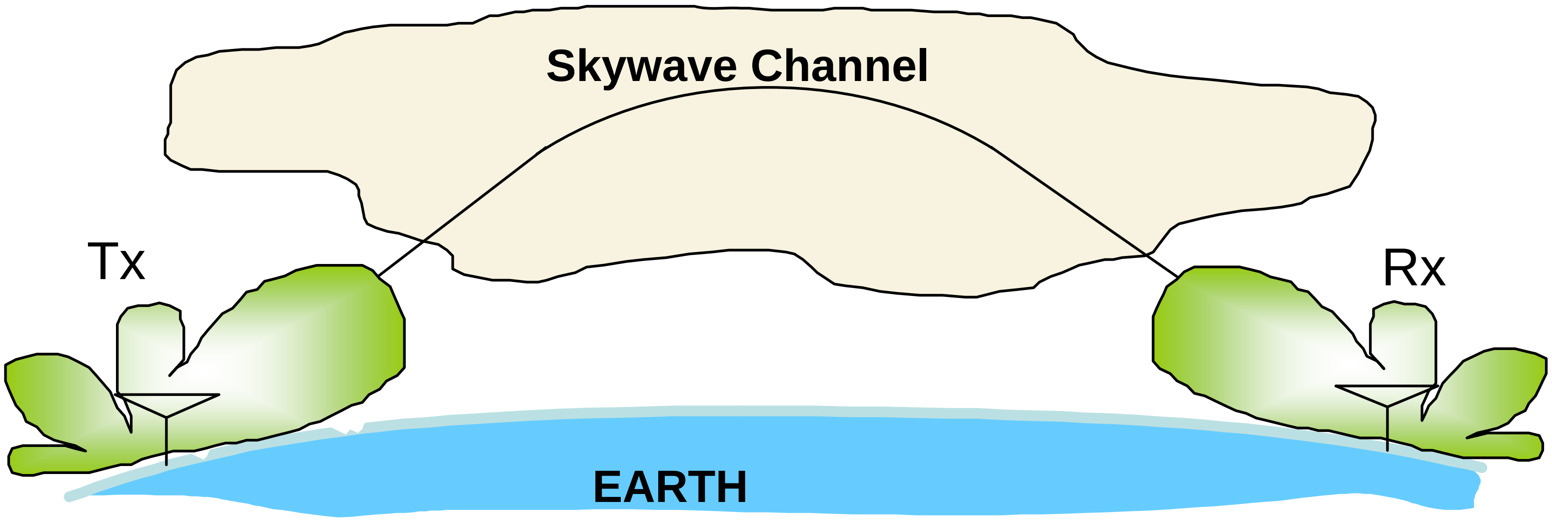
Agenda

- Background/History
- Benefits/Issues
- Numerical Treatment
- On-Air-Measurements
- Summary and Conclusions

Background

- Continuous Search for the Better OTM HF Antenna
- Today’s Communication Environment
  – Dry Deserts to Rugged Mountains limits LOS
  – Limited Satellite Bandwidth
  – Users Want to Own & Control Hardware
  – Repeaters are Vulnerable
- Users Perception – Small Cellular Phone talks around the world

HF Propagation



- Refraction from Ionosphere
- Ionosphere Thickness and Density is Variable
- Variability - Man can not Control but can Predict
    - Diurnal Variation (24 hour cycle)
    - Seasonal Variation (365 day cycle)
    - Solar Variation (11 year cycle)

History

- General Loop History
  - 1913 Farrand, two triangular loops for direction finding
  - 1915 Kolster, multi turns loop
  - 1930 Loops went out of favor for long wires
  - 1938 Loops started to appear again
  - 1940 Russian Military adapted Vehicular Loops
  - 1970 Ferrite Rod loops
  - 1970 Active loops commercially available
- Harris Progress
  - 1994 Experimented with Digital Tuned Loops
  - 2004 Half-loop Interfaced to Harris Radios
    - Operation in both 2G ALE
    - Issues – Mounting, Complexity, Cost
  - 2009 Full Loop Seamless Interface with Harris Coupler/Radios

Loop Antennas Benefits

- Basic Theory: For a Given Volume, a Magnetic Antenna is more efficiency than an Electric Antenna
- Ideal Radiation Pattern for NVIS Comm with Limited Real Estate.
- Omni-direction at High to Medium TOA
- Figure-8 at Low TOA
  - Potential Elimination of Undesired Signals and Noise
- Full loop does not Require a Gnd Plane

Loop Antenna Tribulations

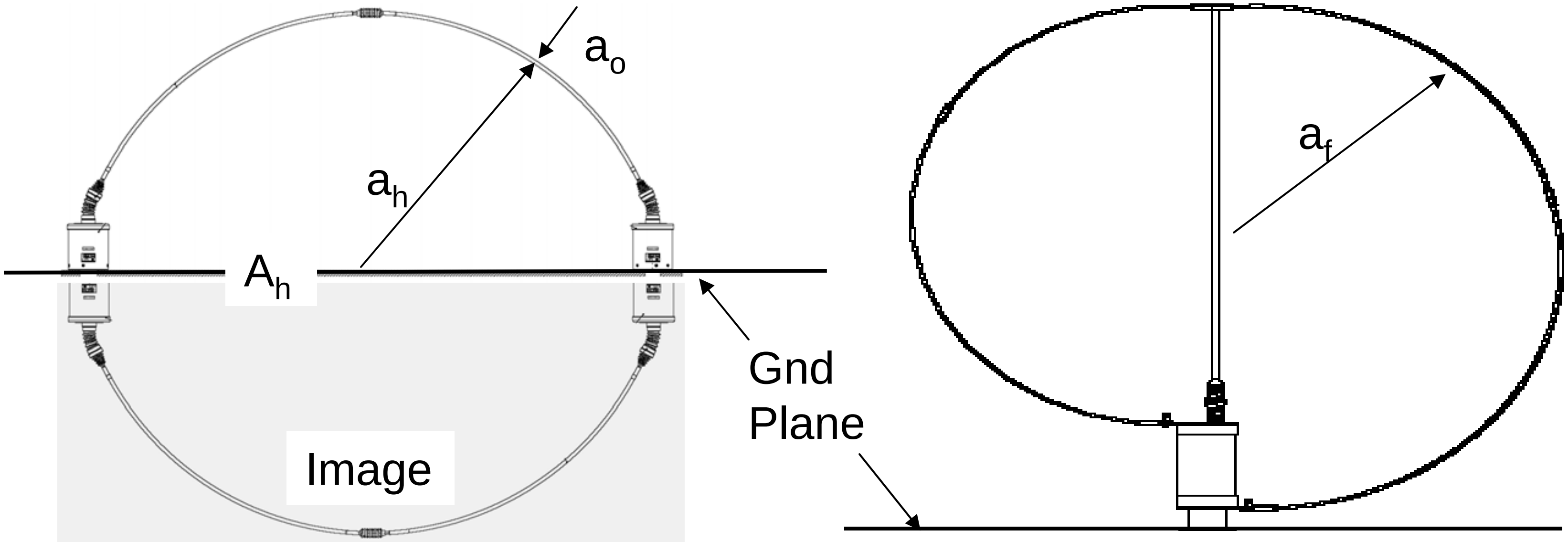
- Why Are They Not Everywhere?
- Mounting Complex Relative to Whip
- Radiation Resistance Very Small
- Inductance Very High
- Fixed Capacitor – Single Freq. Solution
- Digitally Tuning Difficult without Inherent Losses
- High Current Flow

Vehicular Loop Antennas

2005 Half-Loop

2009 Full-Loop

Half-loop to Full Loop



$A=\pi a^2$

$R=10\beta^4 A^2 I_o^2$

$P=1/2 I_o^2 R$

$Q=6\ln(a/a_o)/\pi\beta^3$

$A_h=3.14*0.9^2=2.54m^2$

$A_f=3.14*0.73^2=1.68m^2$

Seems the Half-loop is a better Antenna

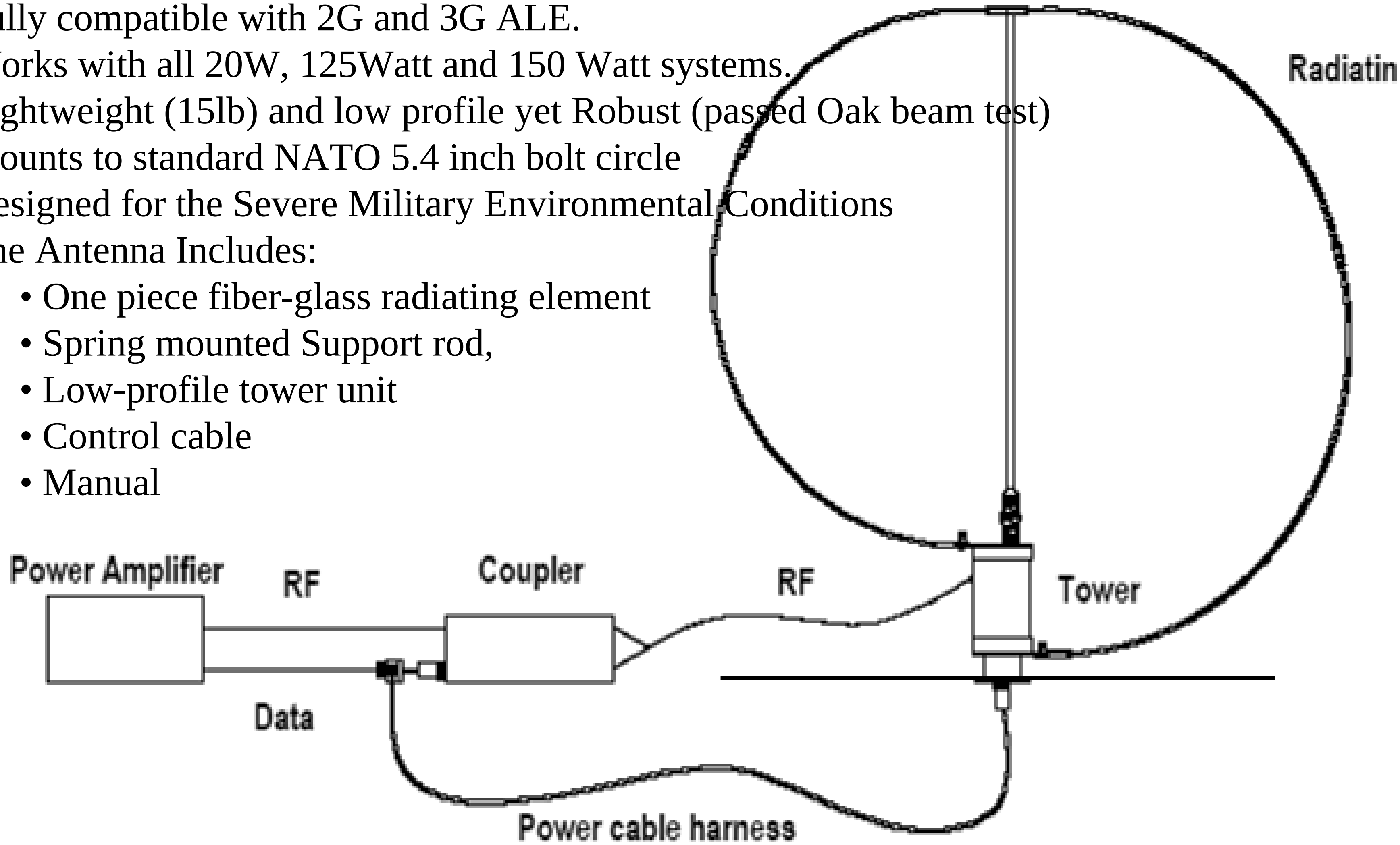
Only true if gnd plane is infinite

So, half-loop has Area = $A_h/2$

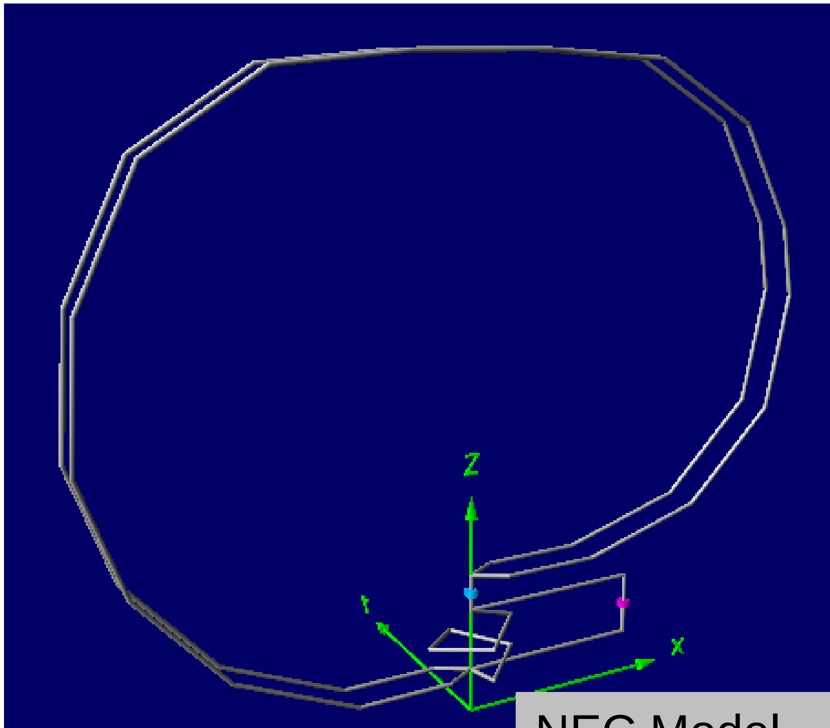
Therefore $A_h=1.27m^2$

Loop Components

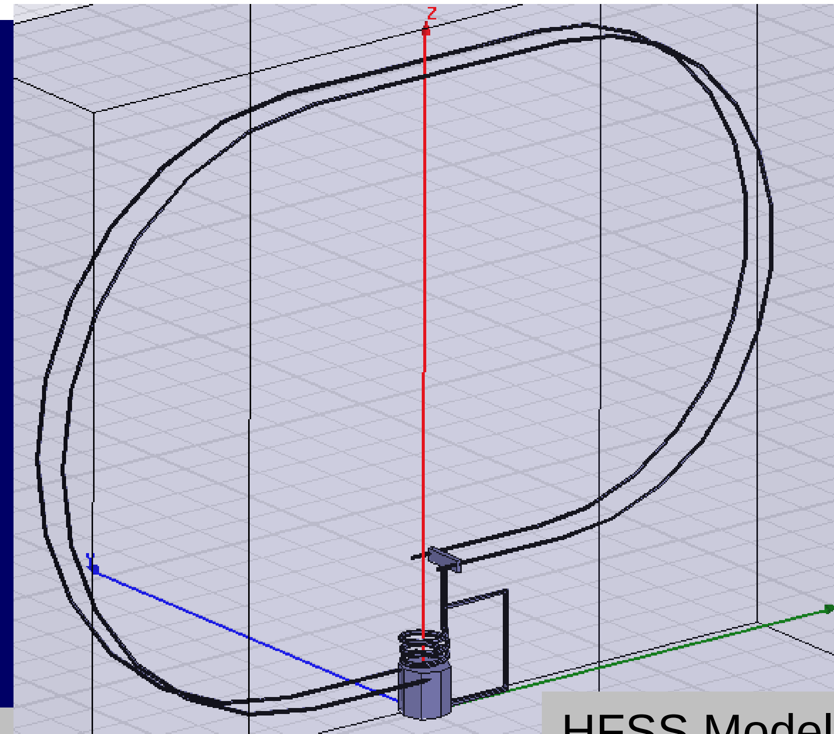
- Interfaces Directly to Harris Couplers (RF-382 and RF-5382)
- Fully compatible with 2G and 3G ALE.
- Works with all 20W, 125Watt and 150 Watt systems.
- Lightweight (15lb) and low profile yet Robust (passed Oak beam test)
- Mounts to standard NATO 5.4 inch bolt circle
- Designed for the Severe Military Environmental Conditions
- The Antenna Includes:
    - One piece fiber-glass radiating element
    - Spring mounted Support rod,
    - Low-profile tower unit
    - Control cable
    - Manual



Numerical Meshed Models



NEC Model

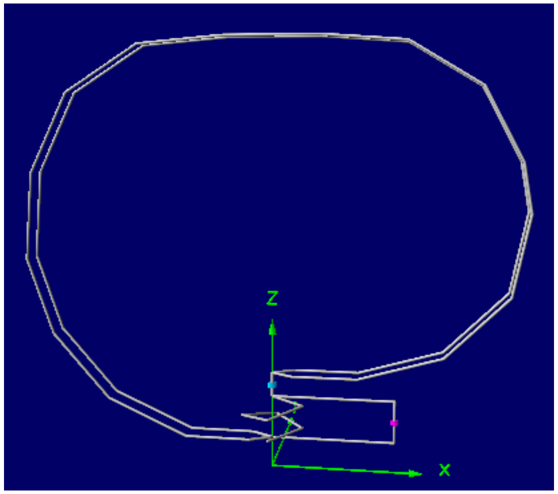


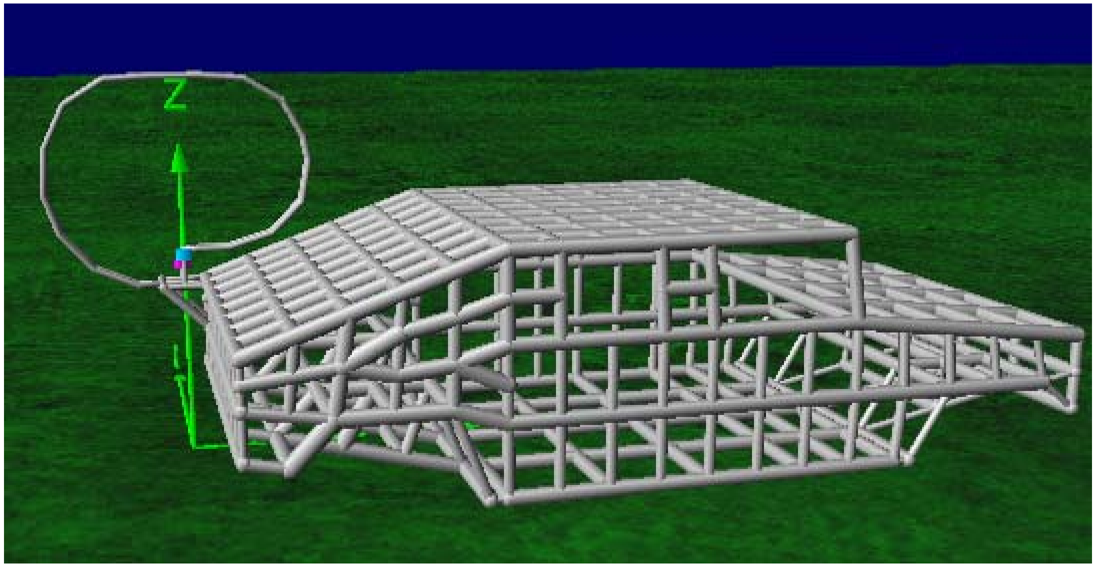
HFSS Model

- Loop Simple | Better Feed System
- NEC: 103 segments | HFSS: 22,098 tetrahedra
- NEC: < 1min | HFSS: 12 minutes on 3.2 GHz PC

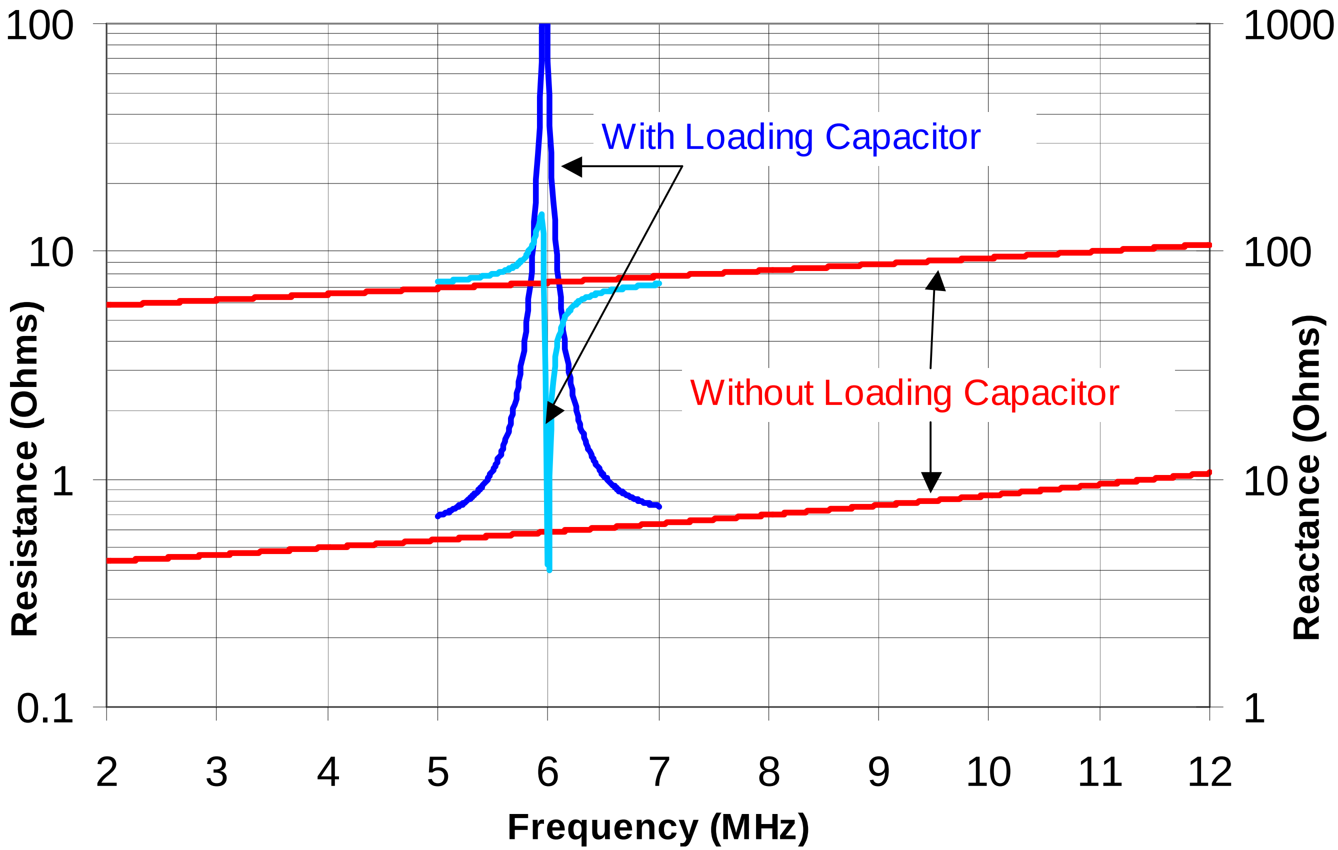
Numerical Modeling

- Twin Loop Elements
- Feed System Coil
- Loading Capacitor
  - Binominal Switched Capacitors modeled by one Capacitor
  - Feed Lines to Coupler
- Free Space
- With Ground Plane
- On HMMWV
- Over Real Ground



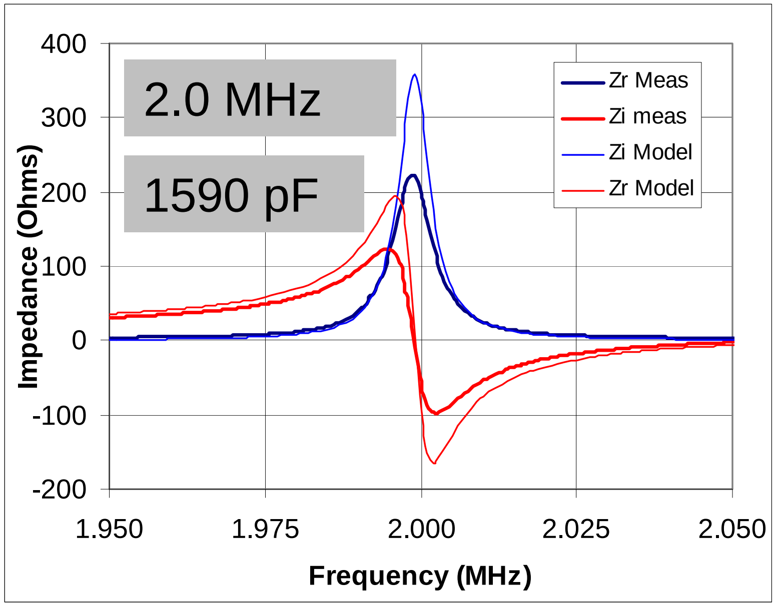


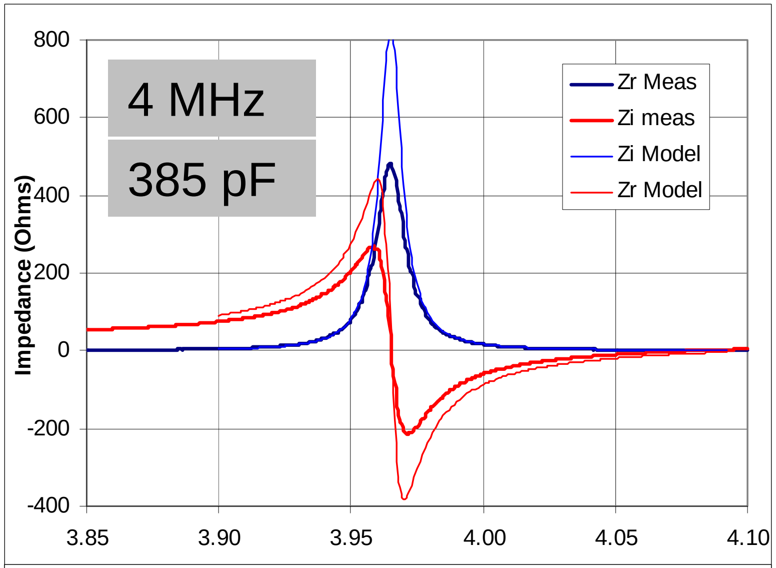
Capacitor Loading

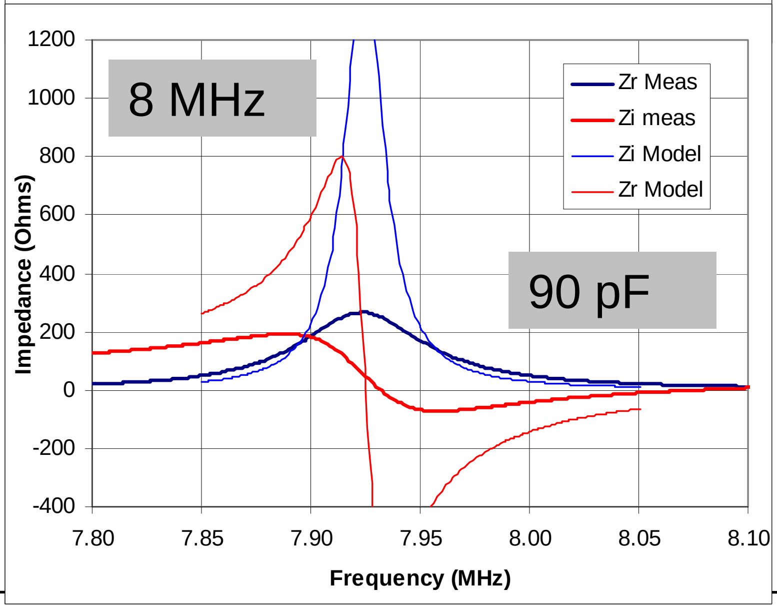


- Loading with a Capacitor to Tune Loop to 6 MHz
- Increases Resistance 600mΩ to 100Ω
- Reactance Resonance

Capacitor Tuning

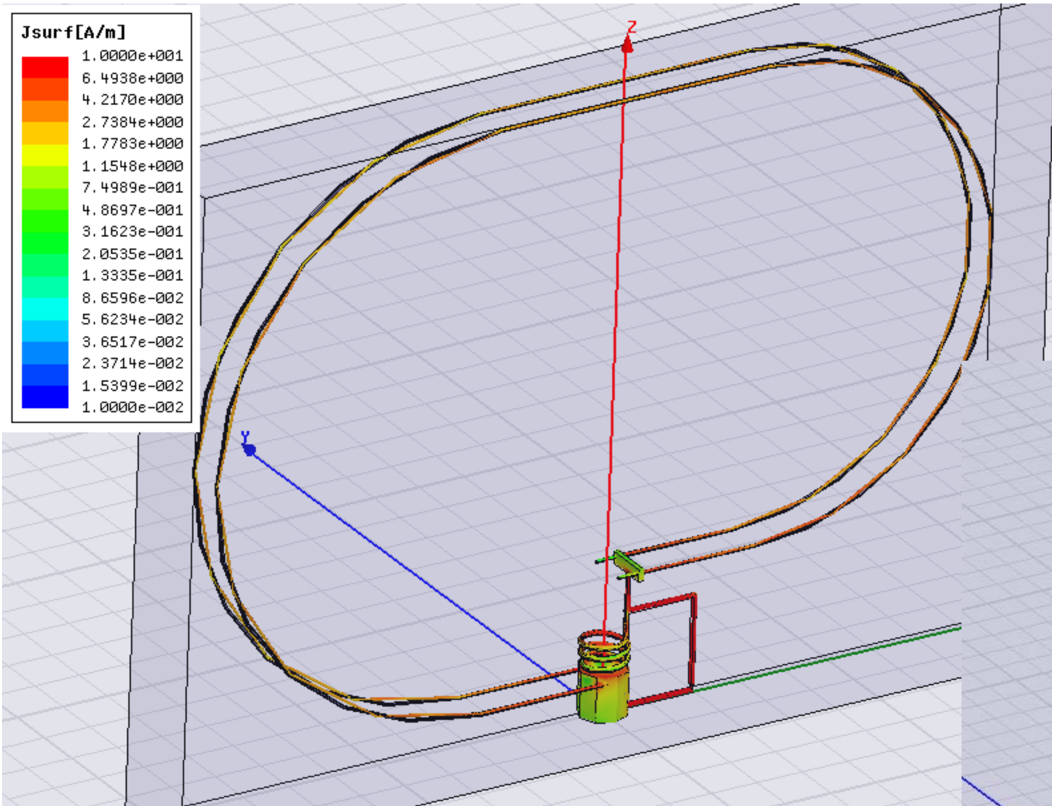


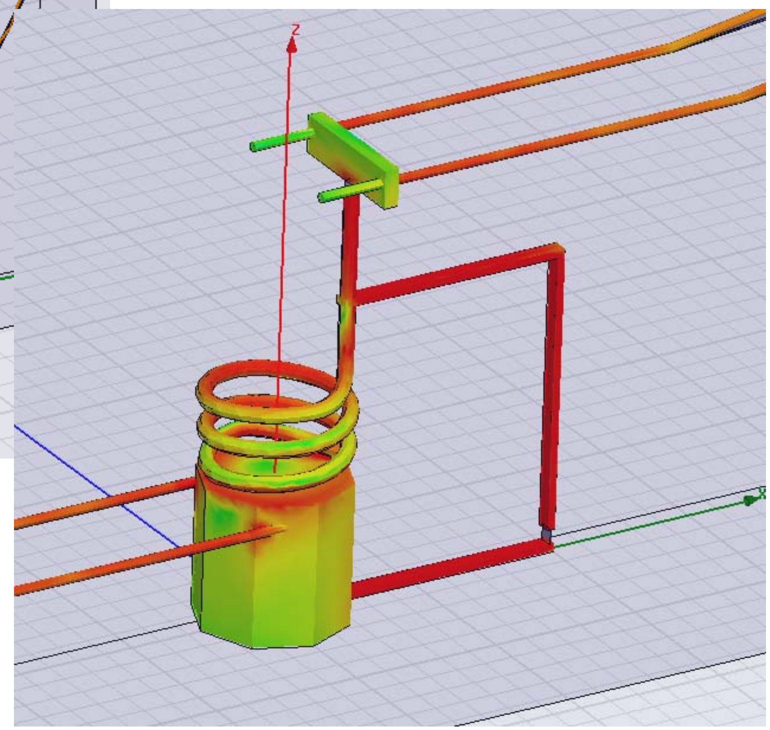




- 2, 4, and 8 MHz
- Measurements and Modeling
- Results match Well on BW
- Measurements have higher Values

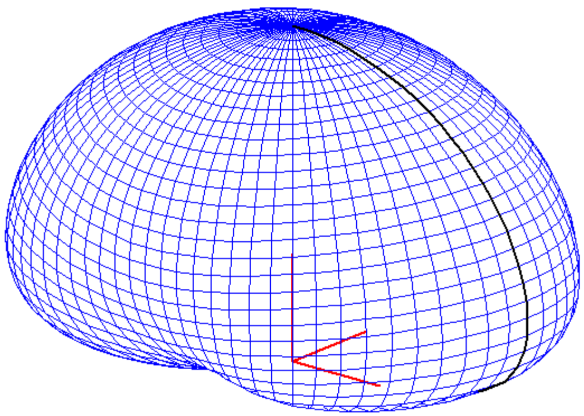
Surface Current Magnitude



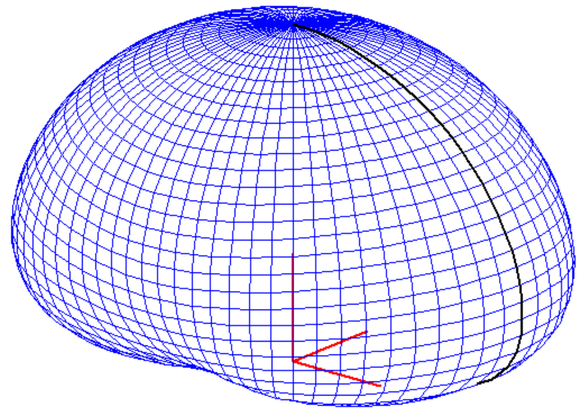


- Surface Current (A/m)
- Uniform Current Density over Loop
- Feed Loop higher Current Density

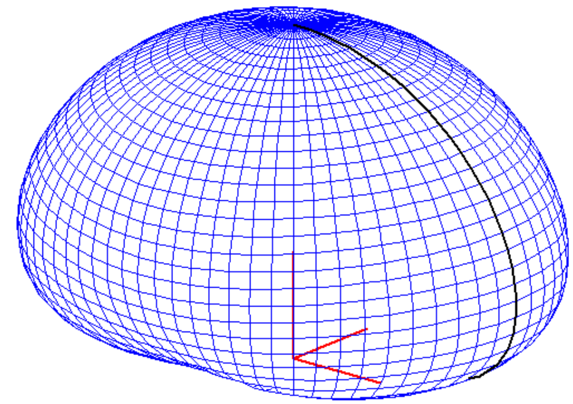
3D Radiation Patterns



2 MHz

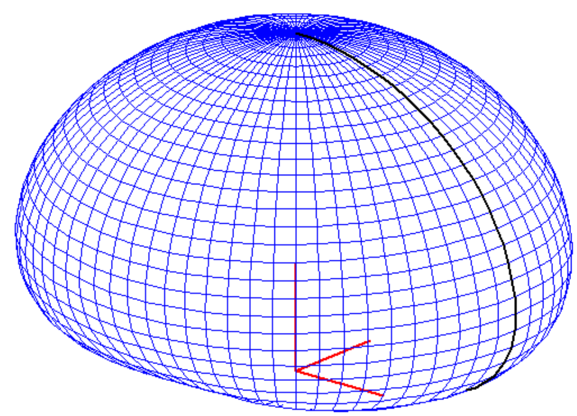


4 MHz



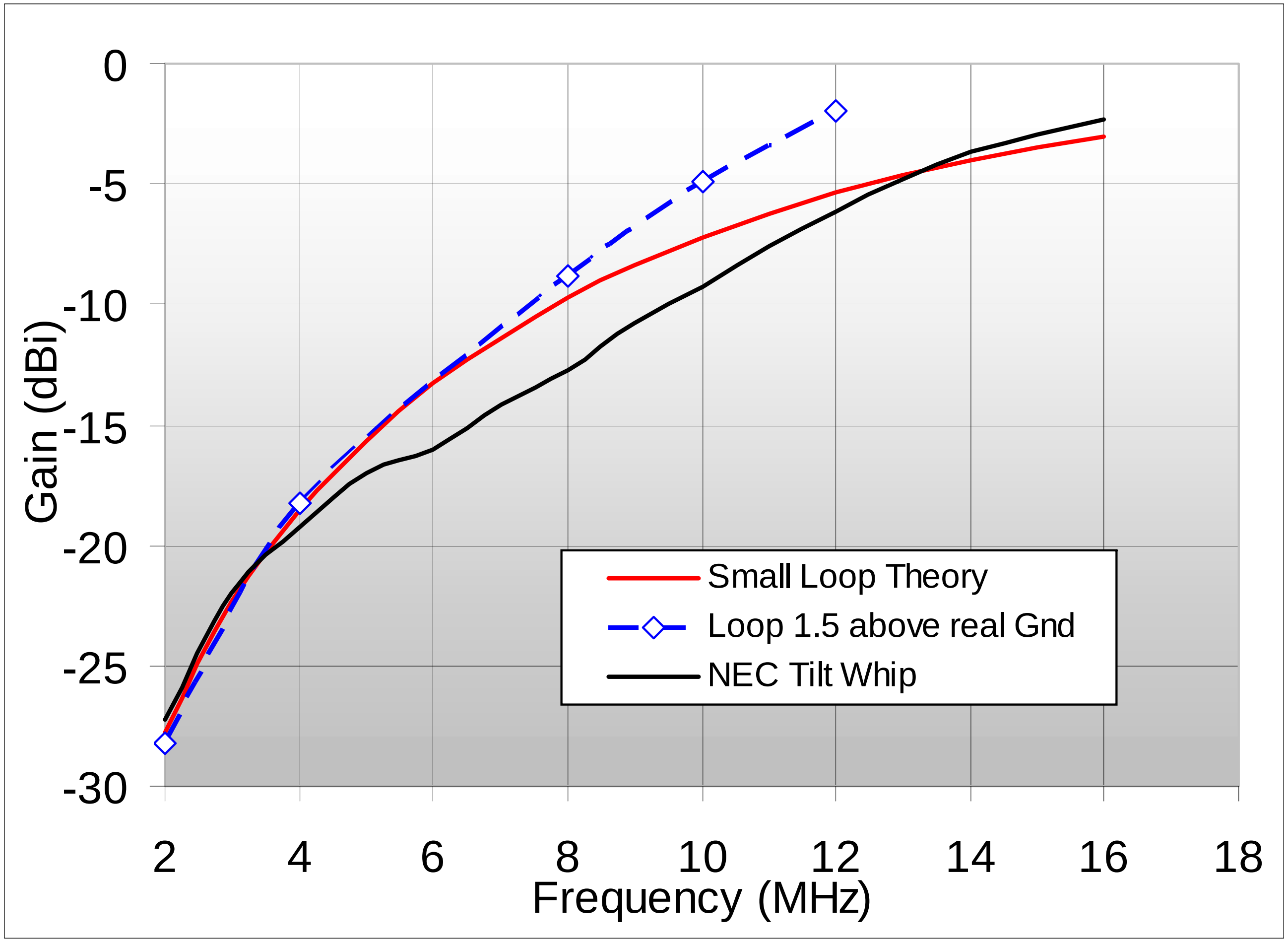
8 MHz

- Loop 1.5m above Real Earth (12/.005)
- Peak Gain towards Zenith
- Omni Pattern at High Elevation
- Figure-8 Pattern at low Elevation

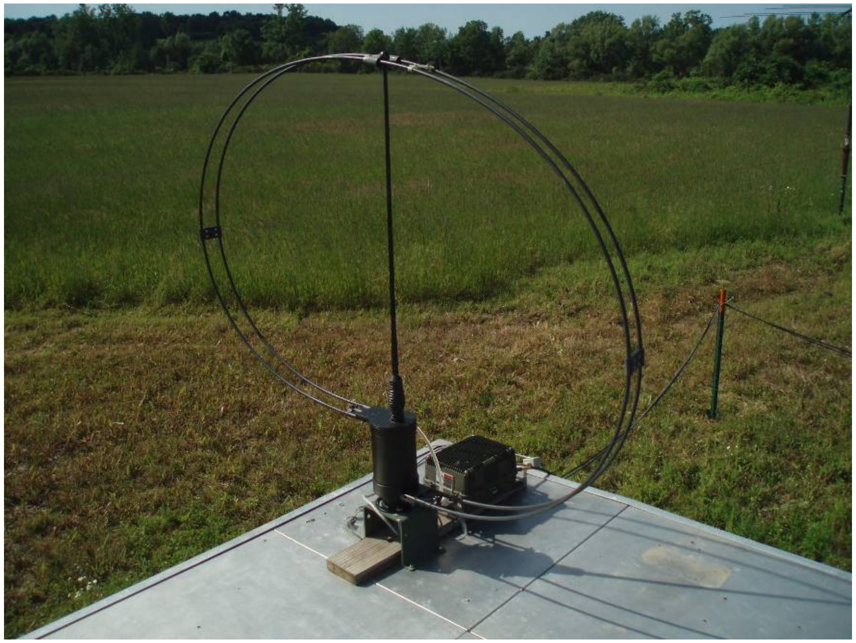


16 MHz

Gain - Theory and Numerical



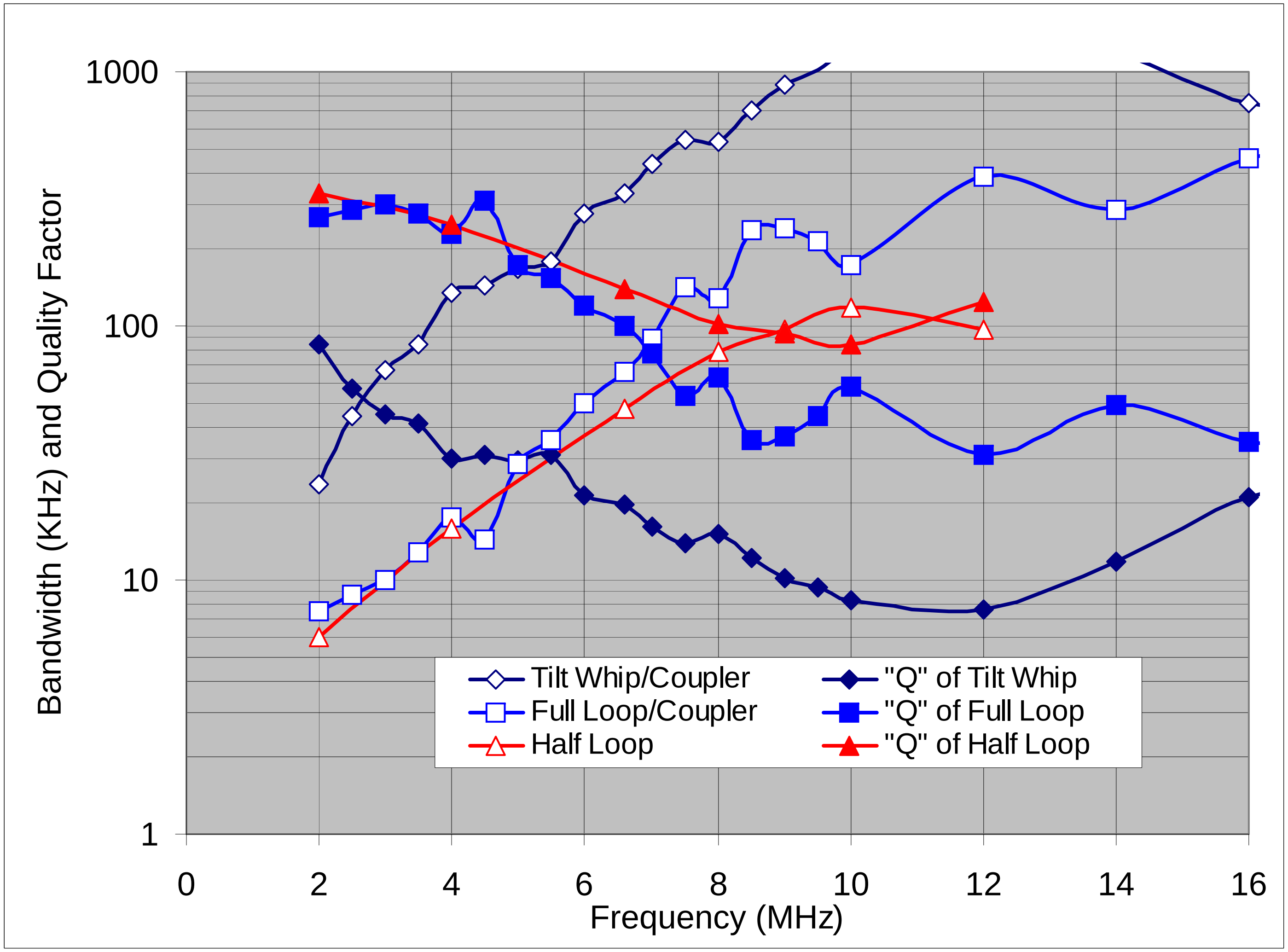
Field Testing



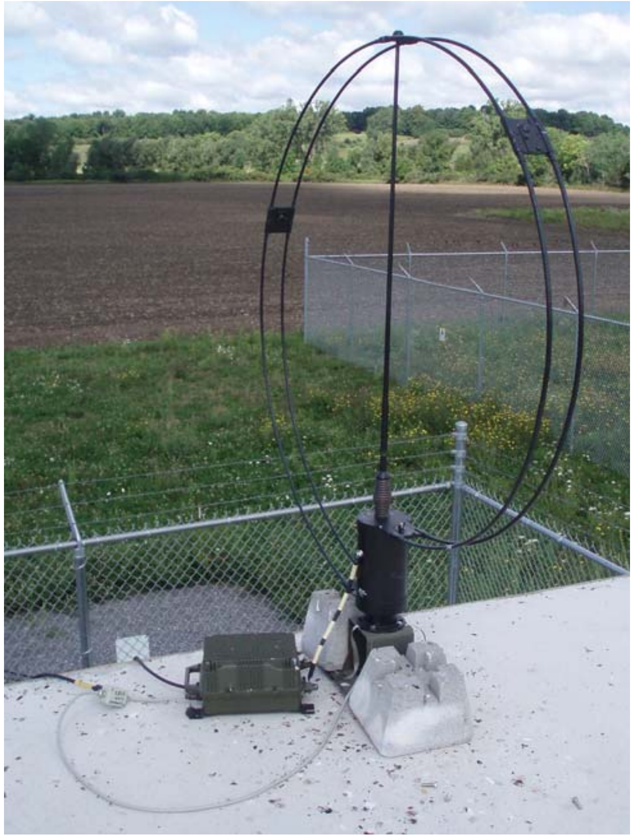
Loop on 10x10-ft²
Ground Plane

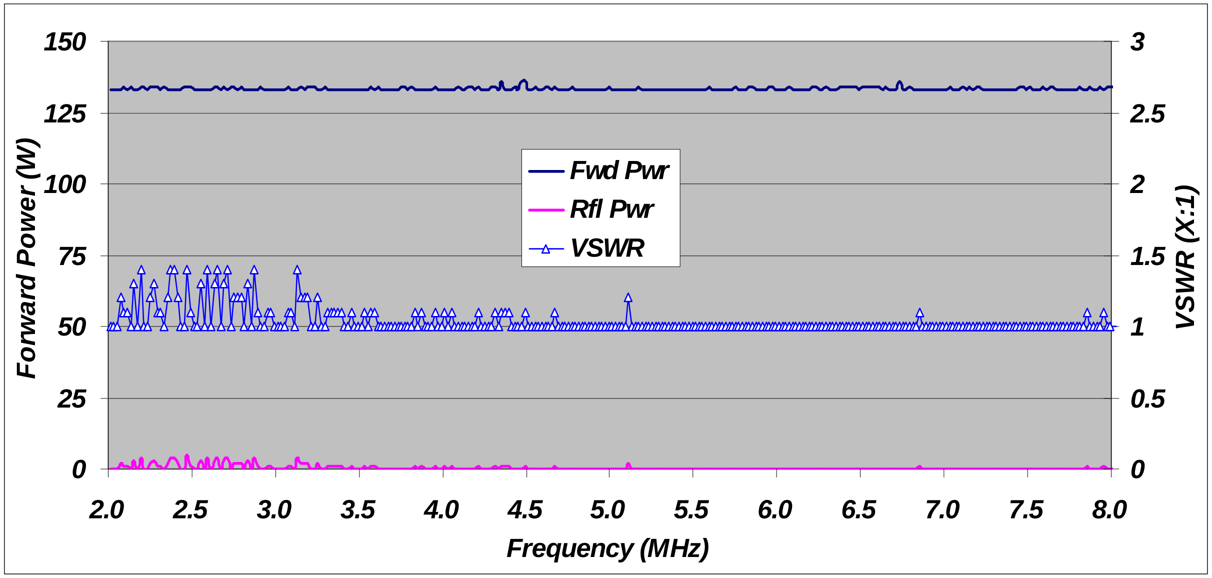
Loop w/o Gnd Plane

Measured Bandwidth and “Q”



Tune Script Results



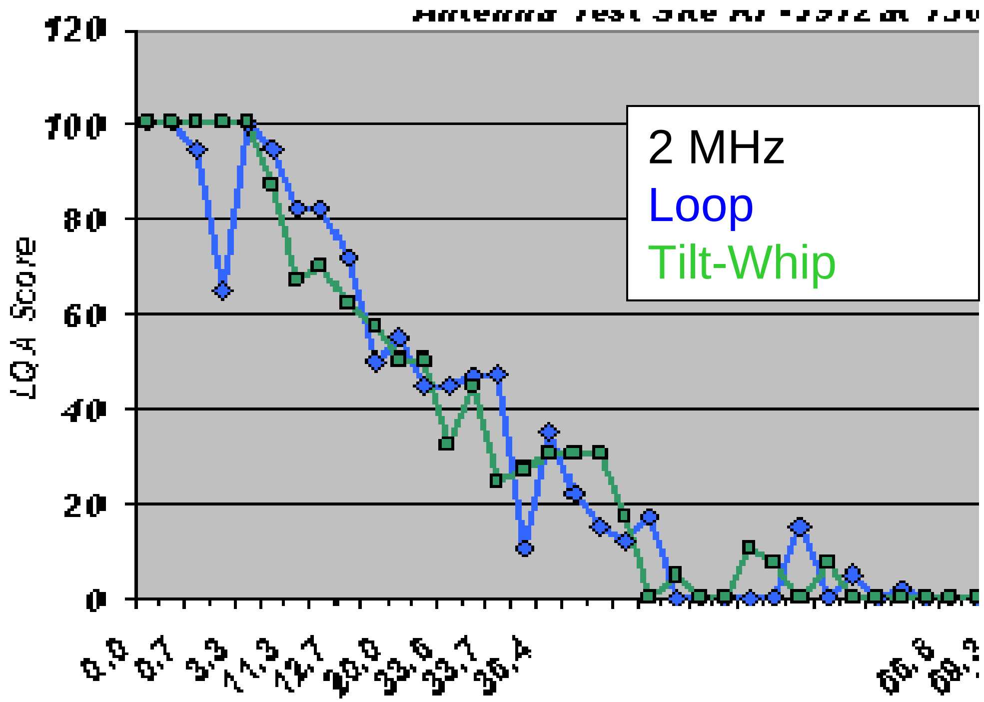


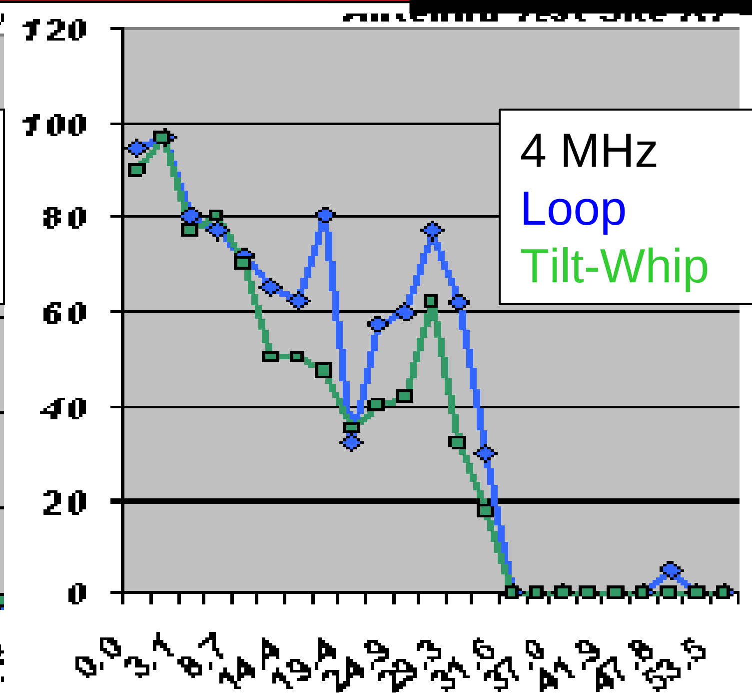
- Step every 10KHz, Tune for VSWR
- Only NVIS band shown
- Tunes from 2 to 30 MHz
- Without Ground Plane

Measurement System

- Use Radio Link Testing to Compare Antenna Performance
- PC Controls Two Radios Systems in Mobile Platform
- Each System Runs 3G LQA Sequentially Every Minute
- Systems Runs Autonomously Until Stopped
- Saves Radio Raw Data and GPS data as Platform is Traveling

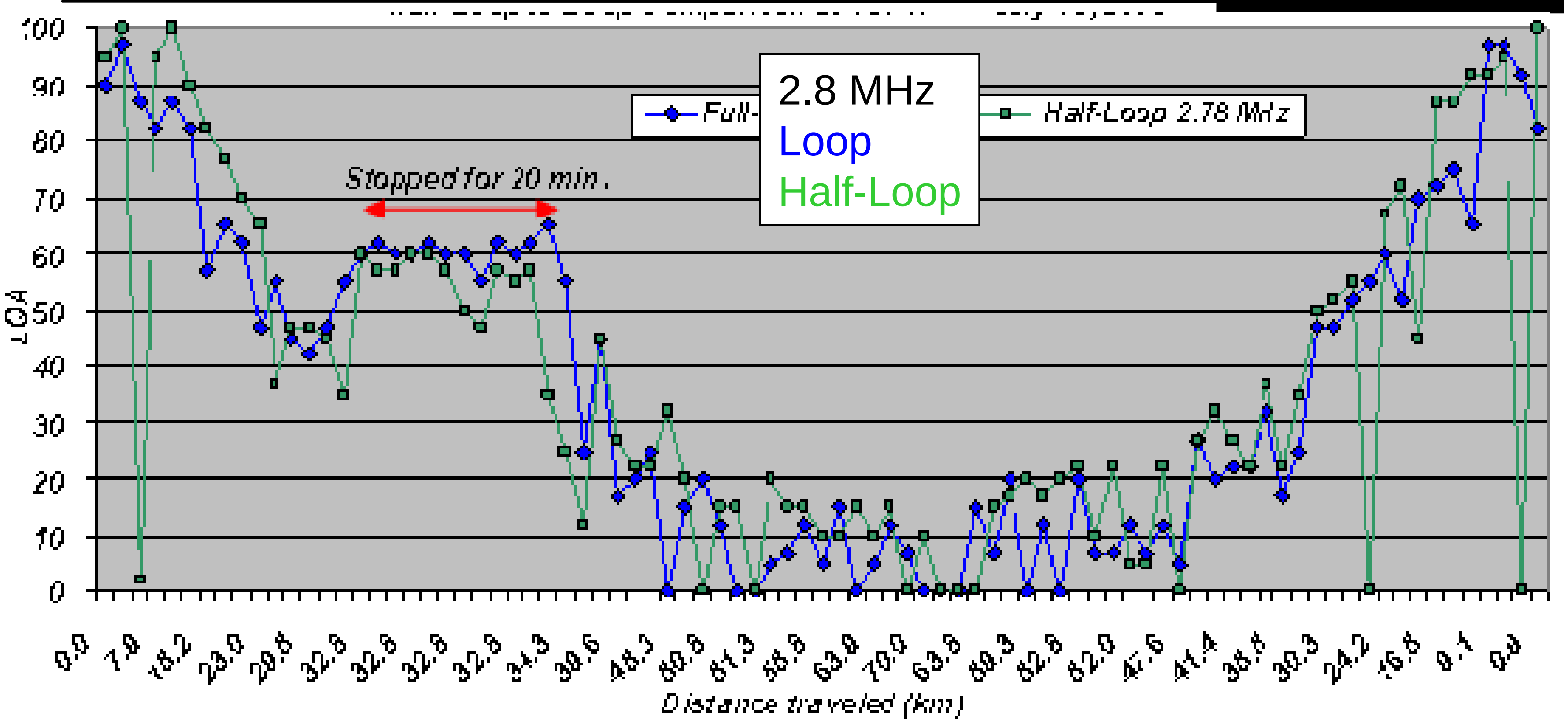
Mobile Testing Ground Wave





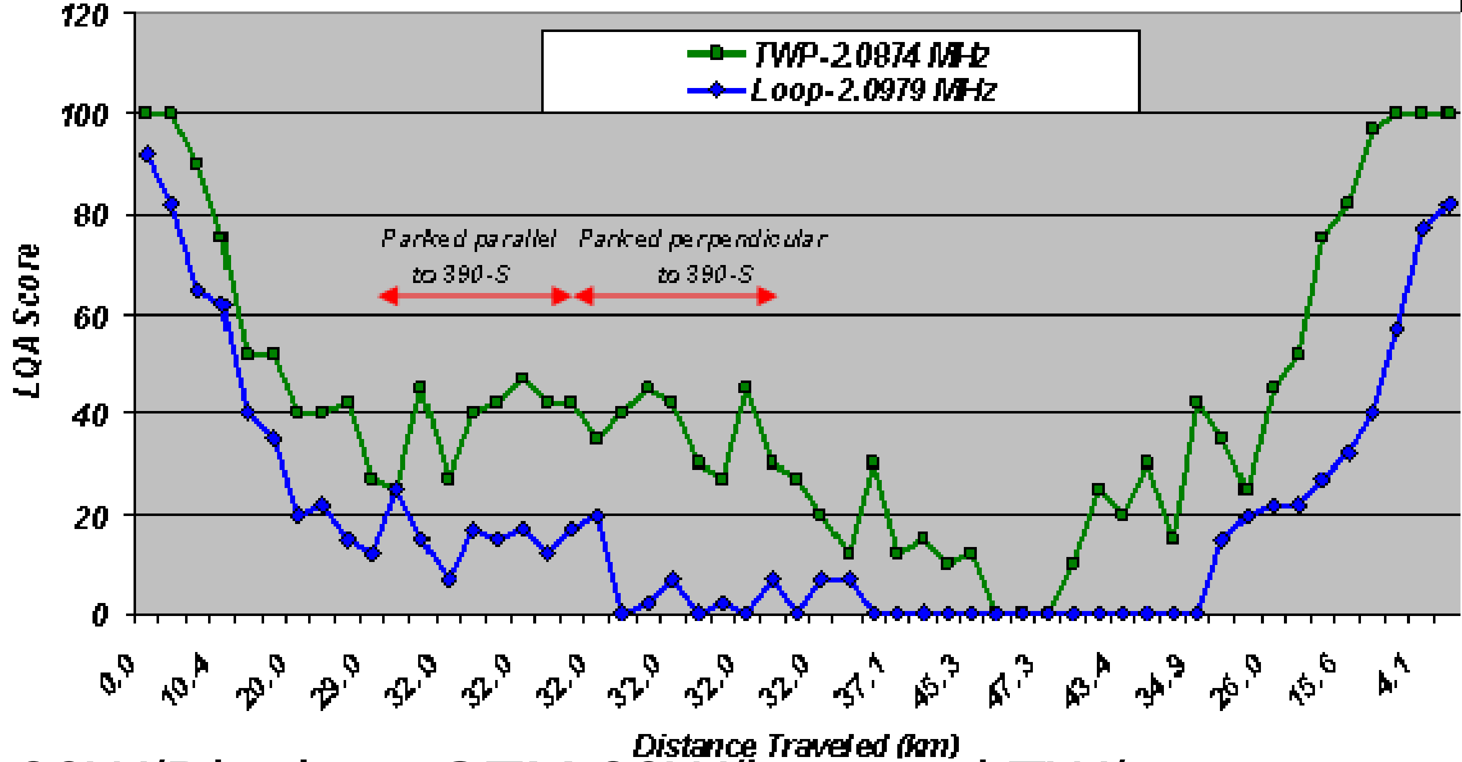
- 150W/Dipole to OTM 150W/loop & TW at 2/4MHz
- LQA scores in 3G
- Platform drove from 0 to 70km and then back
- All Ground Wave – some NVIS hits - Early Afternoon
- Loop and Tilt-whip have Equivalent Performance

Loop and Half-loop Comparison



- 150W/1912 to OTM 150W/loop and HL/van
- LQA scores in 3G
- Van drove from 0 to 70km and then back
- At 2.8 MHz, Many NVIS events
- Performance Increase when Vehicle Stops

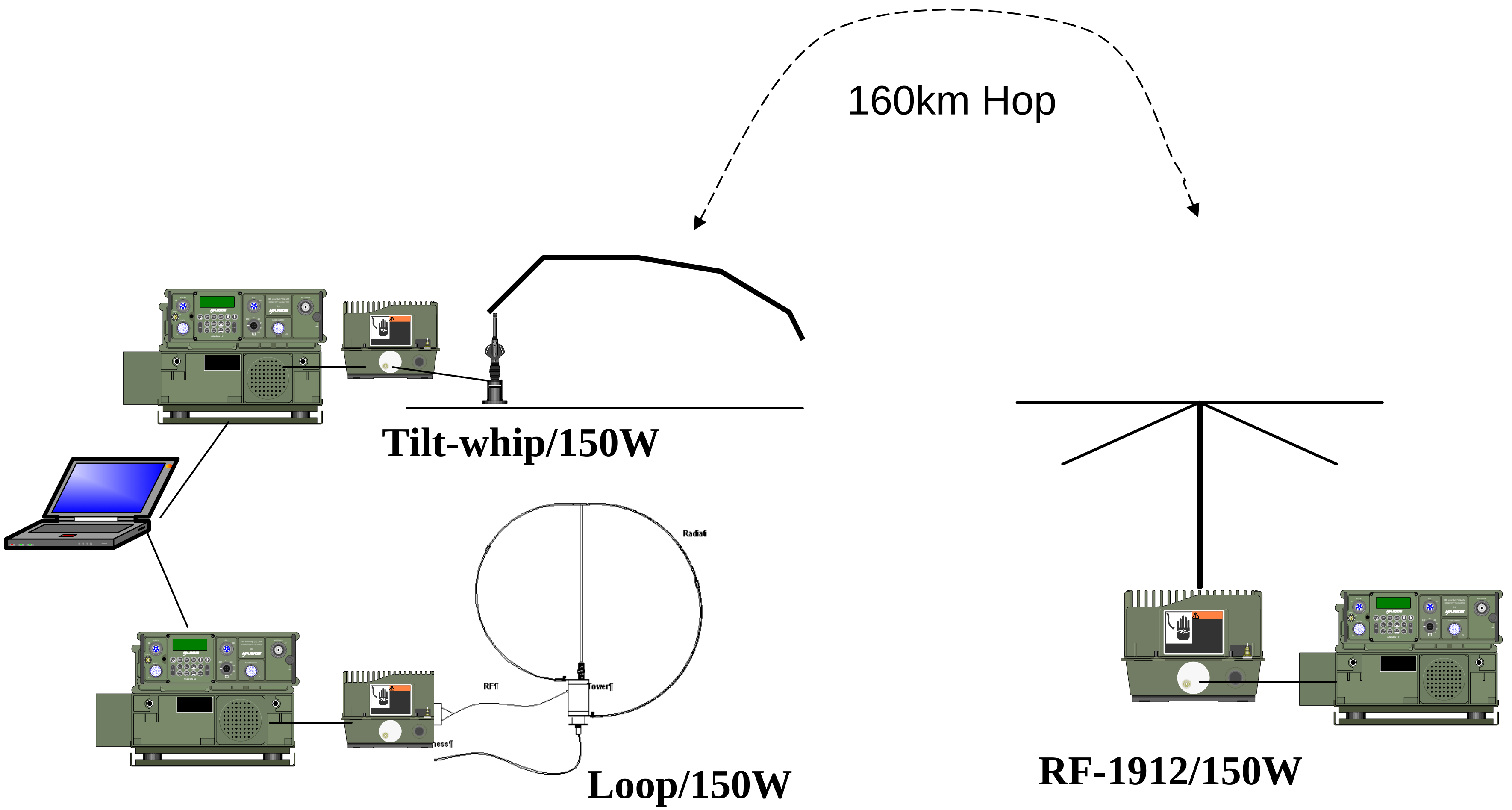
0-50 km LQA Comparisons 20W/2MHz



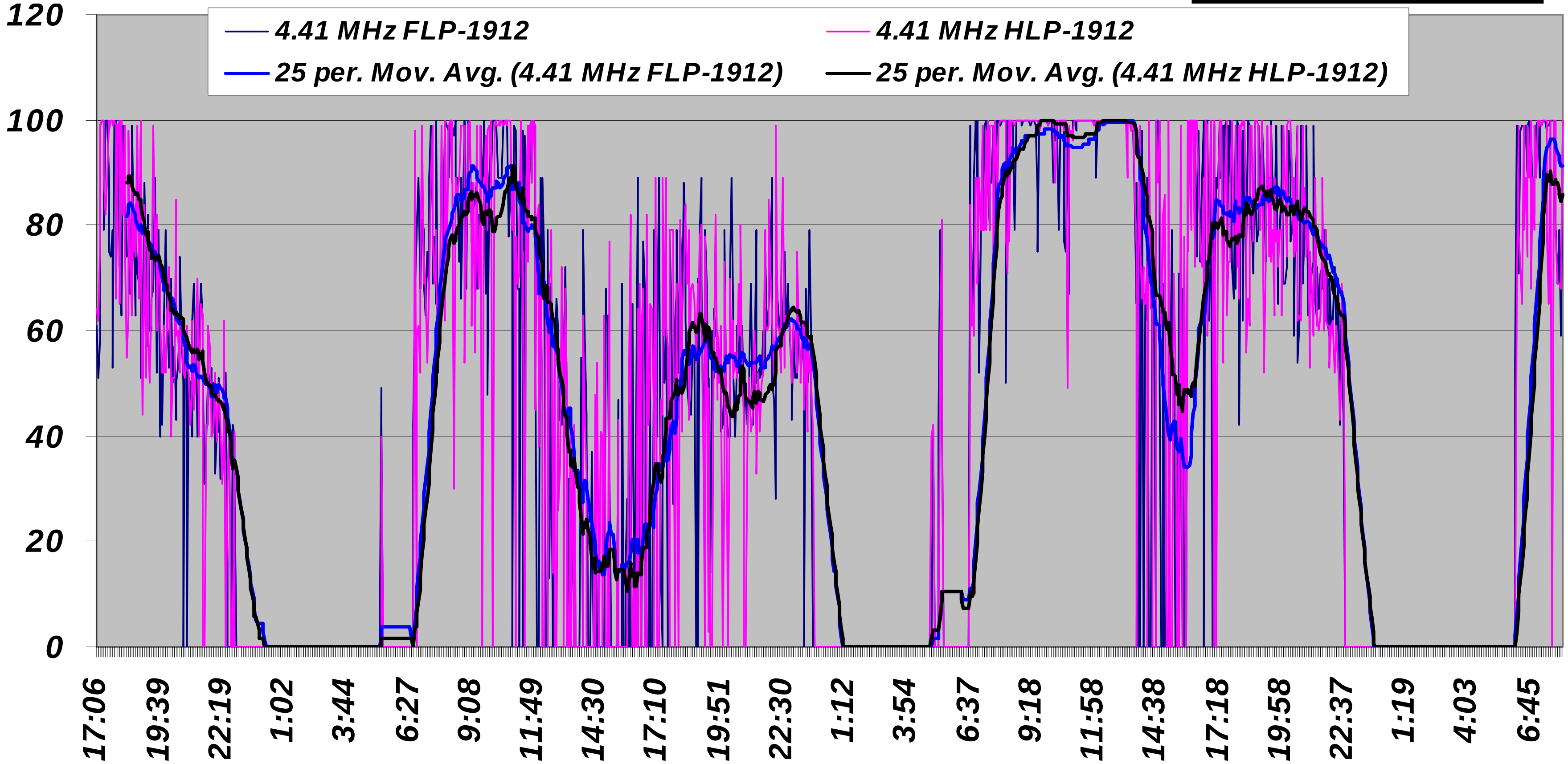
- 20W/Dipole to OTM 20W/loop and TW/van
- LQA scores in 3G
- Van drove from 0 to 50km and then back
- Difference in Parallel versus Perpendicular GW performance of Loop

Measurement System

- Same System as Before – Now at Fixed Sites

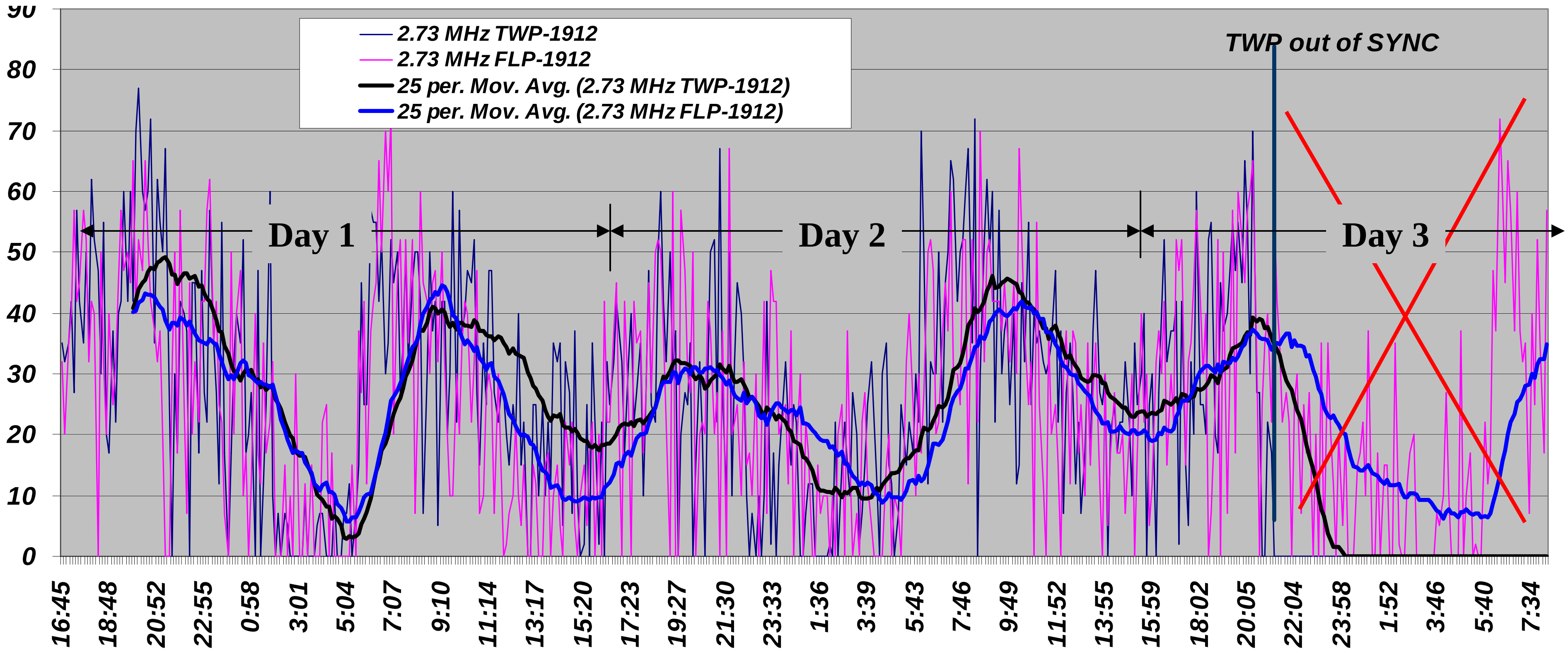


160 km Link in 2G - Loop and HLp



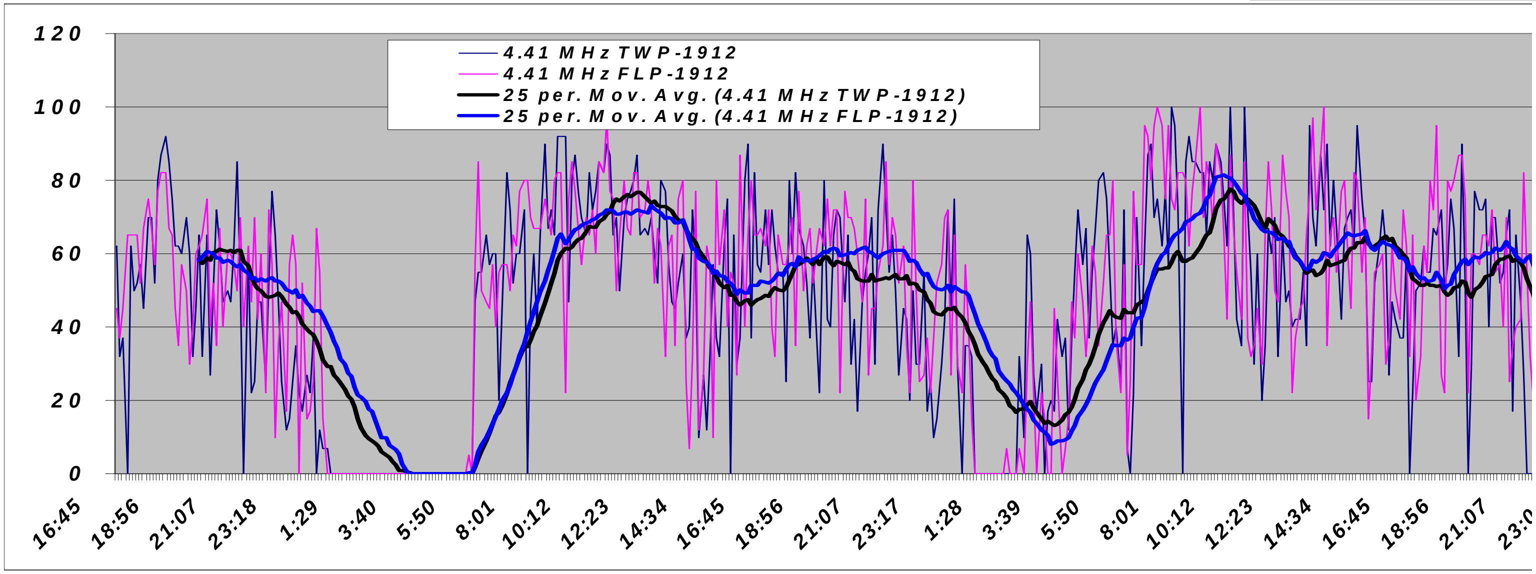
- Loop and Half-loop to 150W Fan Dipole
- Very Limited scores at 2.7 and 6 MHz
- Diurnal Variations Noticeable

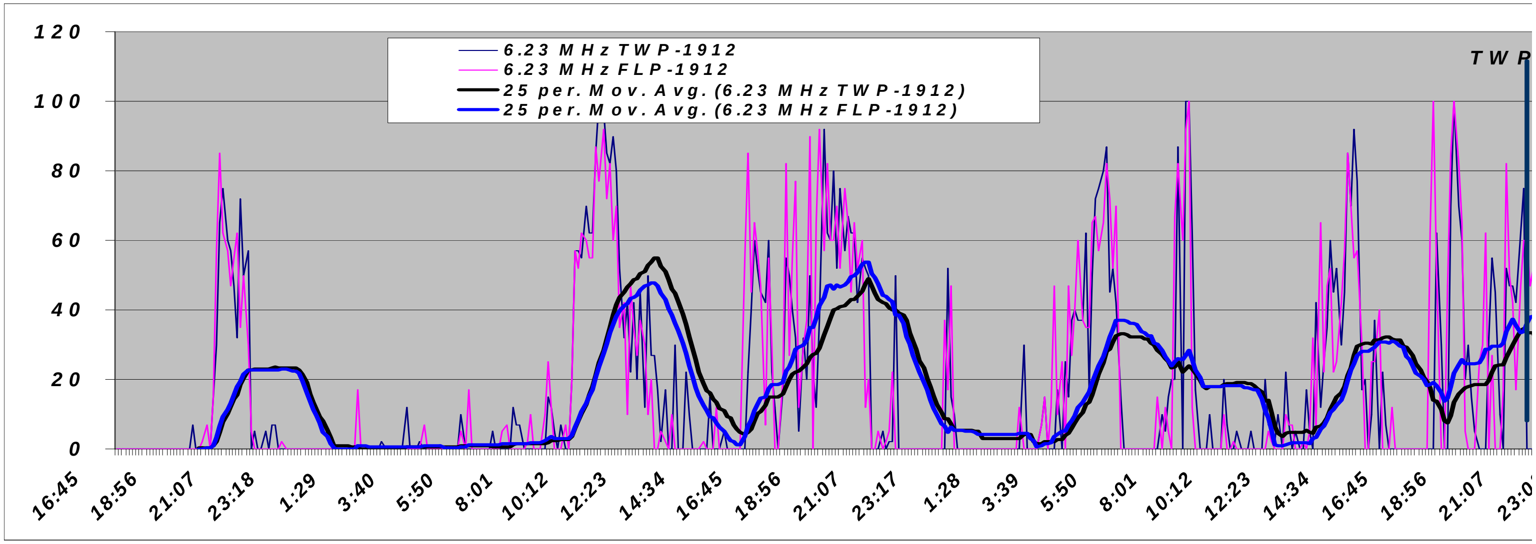
160 km Link in 3G - Loop and TWP



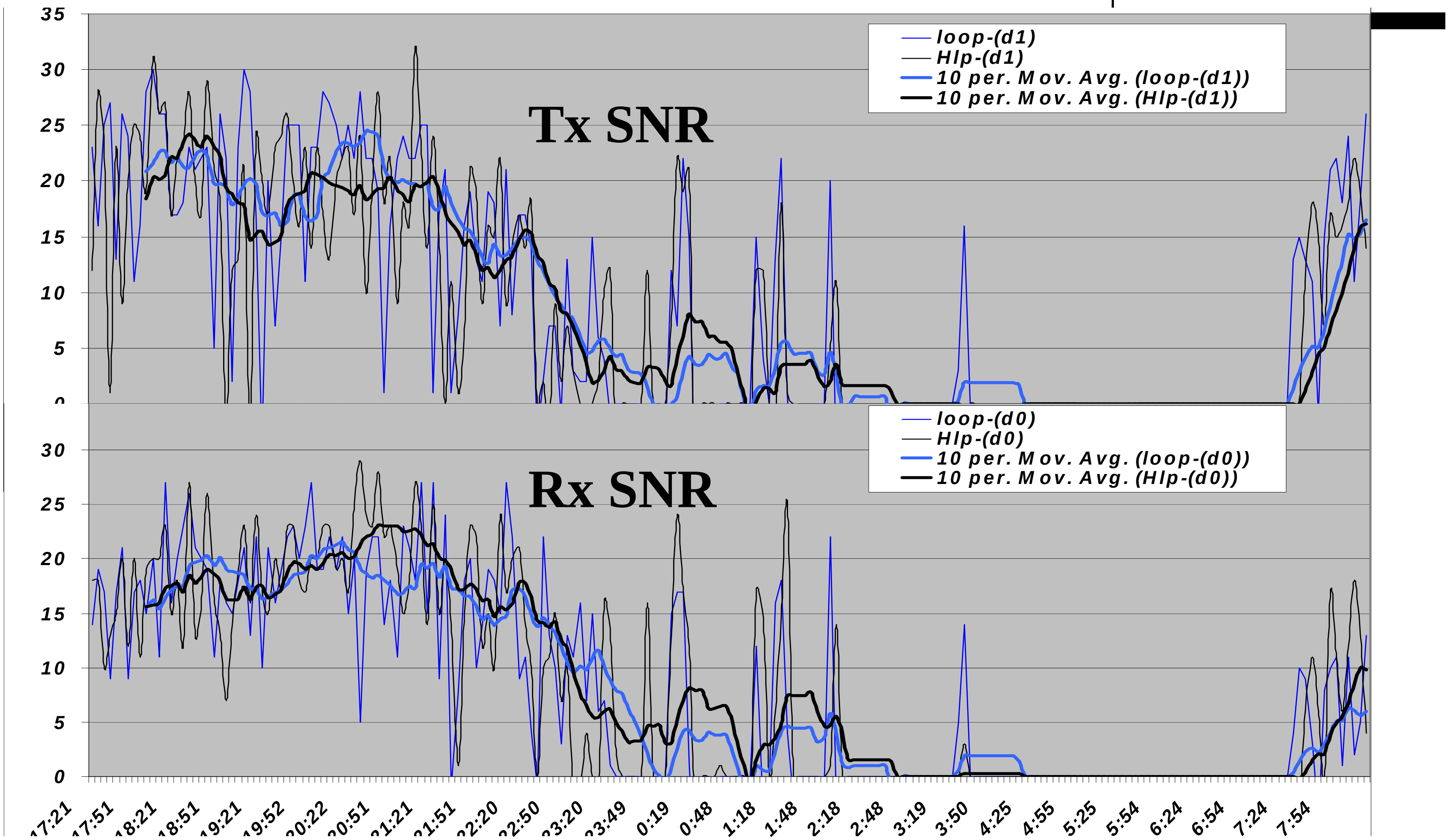
- Loop (w/o GP) and Tilt-whip Linking with 150W Fan Dipole at 2.7 MHz
- Single Hop HF Link Available 24 hours a day
- During Day 3 Initiator Lost Sync
- Real LQA data highly variable – bold lines are 25 pt moving averages

Same Link at 4.4 & 6.2 MHz





SNR 3G Performance at 4.4 MHz



- Tx SNR Perform comparison of Transmit (Rx SNR at the Dipole End)
- Rx SNR Performance Comparison of Receive
- Overall: Loop and Half-loop have equal SNR performance

Conclusions/Summary

- Numerical Modeling Provides Loop Parameters which are difficult to Measure
  - Includes Ground Losses/ vehicular/ comparison of Ground Planes
- Testing:
  - 0 to 70km Mobile Ground Wave
  - NVIS 160km fixed testing
- Tilt-whip, Half-loop, Full-loop all Provide HF Link Closure
- Loops are Omni-Directional for High TOA & Directional for Low TOA
- Full Loop
  - Less Complex than Half-Loop
  - Simple Mounting
  - No need for Extensive Ground Plane
  - Allows User to Swap Between Loop and Whip in the Field
  - Allows use of Standard HF Coupler for Larger Tactical HF antenna to Fulfill At-The-Pause HF Requirements