Space Limited Antennas- work the World with Digital Modes

Wires, loops and low power

Station: K3GO (EM90)

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Thank you – k3go@bellsouth.net John

FT8 and FT4: Theory, Transmission, and WSPR (Weak Signal Propagation Reporter)

Station: K3GO (EM90)

Introduction to FT8, FT4 & WSPR

- FT8 and FT4 are digital communication modes designed for efficient, reliable QSOs under weak-signal and noisy propagation conditions.

- All modes are part of the WSJT-X suite developed by Joe Taylor (K1JT) and his team, building upon the success of earlier weak-signal modes such as JT65 and WSPR. WSPR is part of the WSJT-X which may be selected in your configuration.

WSPR-Weak Signal Protocols

- WSPR, or "Weak Signal Propagation Reporter," is a radio protocol and software application for amateur radio operators that uses low-power, Weak Signal Digital communications to test and monitor radio propagation paths. Developed by Joe Taylor, K1JT, the software encodes a station's callsign, location, and power into slow, 2-minute transmissions that can be decoded by other WSPR stations even with signal-to-noise ratios well below the threshold of audibility.

WSPR Features

(Weak Signal Propogation Reporter)

- **Low power**: WSPR is designed for ultra-low-power transmission, often using just 5 watts or less. It is highly effective even with milliwatt power levels, allowing signals to be received across oceans.
- **Highly sensitive**: The WSPR protocol is extremely sensitive and can decode signals with a signal-to-noise ratio as low as -28 dB. This means it can pick up transmissions that are well below the threshold of human hearing.
- **Automated reporting**: WSPR stations automatically upload their reception reports to a central database called *WSPRnet.org*, creating a global, real-time map of propagation paths.
- **Narrow bandwidth**: A WSPR transmission occupies a very narrow bandwidth of only about 6 Hz. This allows many stations to operate within a small 200 Hz segment of an amateur radio band without interfering with each other.
- **Digital protocol**: WSPR uses a digital signal processing technique with strong forward error correction (FEC) to ensure messages can be successfully decoded even when signals are extremely weak

Brief History

– FT8 introduced in 2017 by K1JT, K9AN, and G4WJS.
– FT4 released in 2019 as a faster contest-friendly version.
– Evolved from JT65/JT9 and WSPR for practical weak-signal two-way communication.
– FT stands for 'Franke–Taylor', honoring Steve Franke (K9AN) and Joe Taylor (K1JT).

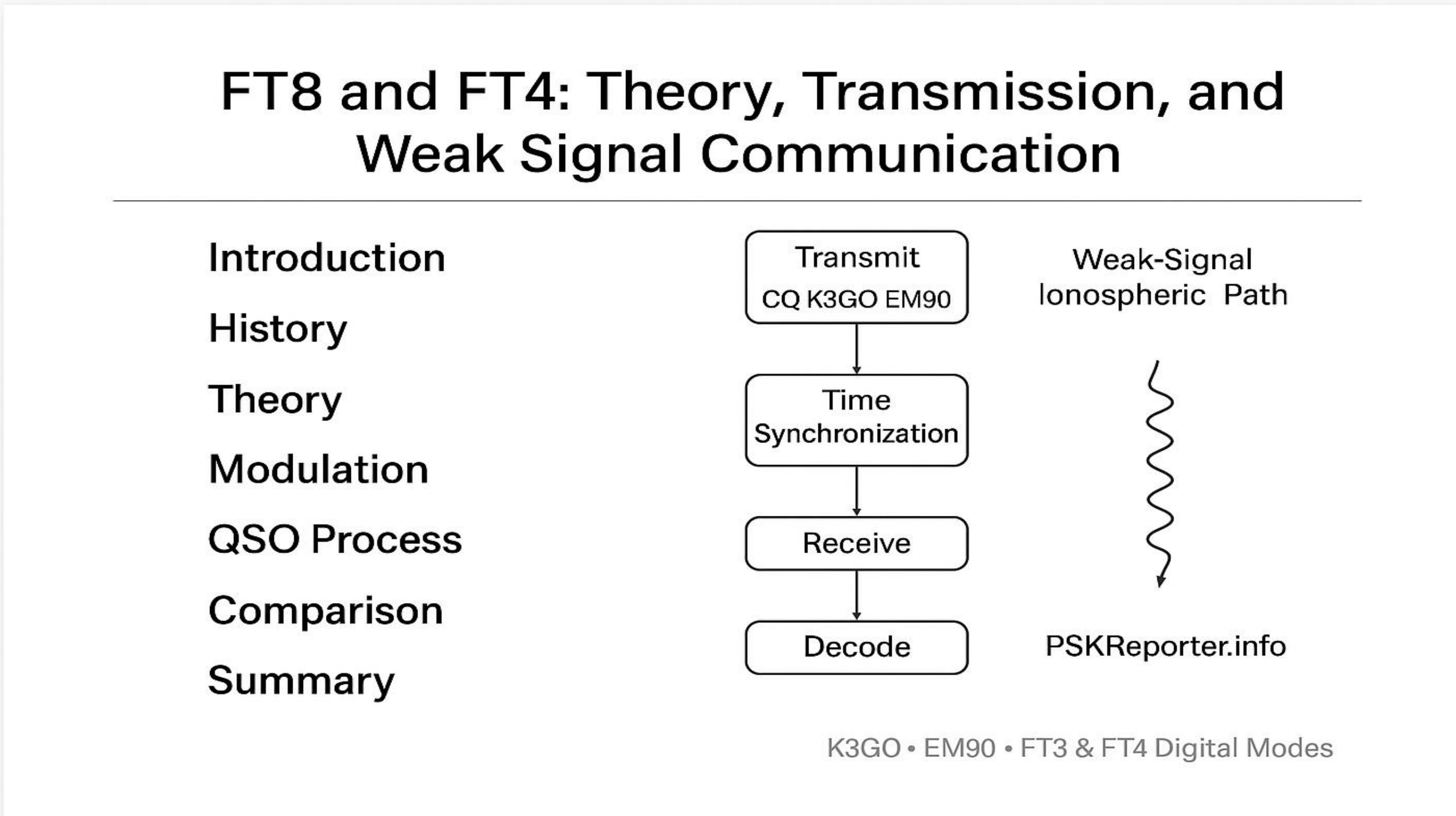
Theory of Operation

– Operates near the theoretical Shannon limit for low SNR communication.
– Employs strong Forward Error Correction (LDPC) to recover data below the noise floor.
– Precise synchronization to UTC ensures time-slotted transmissions and decodes.
– 8-FSK modulation with 6.25 Hz tone spacing and ~50–90 Hz bandwidth.
– Optimized for automated, structured QSOs with minimal operator intervention.

Transmission Timing and Cycles

- FT8: 12.64 seconds transmission within a 15-second cycle.
- FT4: 4.48 seconds transmission within a 6-second cycle.
- All transmissions start on even UTC seconds (synchronized time slots).
- Decoding occurs in the final few seconds of each cycle before next transmit slot.
- Tight time accuracy (±1 second) is critical for successful decodes. (use GPS clocking for timing)

FT8 and FT4 Transmission Flow Overview



Example FT8 QSO Exchange

- Typical automated FT8 QSO sequence:
  - CQ K3GO EM90
  - W1ABC K3GO EM90
  - K3GO W1ABC –10
  - W1ABC K3GO R–12
  - K3GO W1ABC RR73
  - W1ABC K3GO 73

FT8 vs. FT4 Comparison

- FT8: General QSOs, DXing, and low SNR operation (~–21 dB).
- FT4: Optimized for faster contest exchanges (~–17 dB SNR).
- FT8: 15-second cycles; FT4: 6-second cycles.
- FT8 bandwidth ≈ 50 Hz; FT4 ≈ 90 Hz.
- FT4 enables roughly 2.5× more QSOs per minute than FT8.

Applications and Use Cases

- Weak-signal HF DXing with low power (QRP and QRP+).
- Real-time band condition monitoring using PSKReporter.
- Contesting (FT4) and automated digital operation (FT8).
- Propagation and antenna performance analysis.
- Experimentation and digital signal processing education.

Summary

- FT8 and FT4 are efficient, standardized weak-signal communication modes.
- They use digital synchronization, LDPC(low density parity check) FEC (forward error correction), and narrow bandwidth to achieve contacts near the noise floor.
- FT8 is ideal for DXing and QRP work; FT4 is optimized for speed and contesting.
- Together, they define the modern standard of weak-signal amateur communication.

Introduction

- Both magnetic loop antennas (MLAs) and wire antennas (dipoles, end-fed, etc.) are popular in amateur radio for HF operation. They share similar goals but differ fundamentally in radiation mechanism, efficiency, and installation requirements.
- Many argue about MLA’s vs wire but I say it’s just another tool in our kit to have fun!

Magnetic Loop Antenna (MLA) Overview

- Operates as a resonant LC circuit — a conductive loop with a variable capacitor.
- Radiates primarily via magnetic (H-field) coupling.
- Compact (typically 0.1λ or smaller), suitable for restricted-space installations.
- Advantages: small size, low noise reception, directional nulls, no counterpoise, plug and pray and not very high- couple meters off ground.
- Limitations: narrow bandwidth, high voltage on capacitor, tuning sensitivity.

Wire Antenna Overview

– Operates as a resonant radiator (dipole, end-fed, or long wire).
– Radiates primarily via electric (E-field) coupling.
– Requires length proportional to wavelength ($\lambda/2$ or more).
– Advantages: broadband response, higher efficiency, simplicity.
– Limitations: requires space, more noise susceptibility, installation height critical.

Performance Comparison

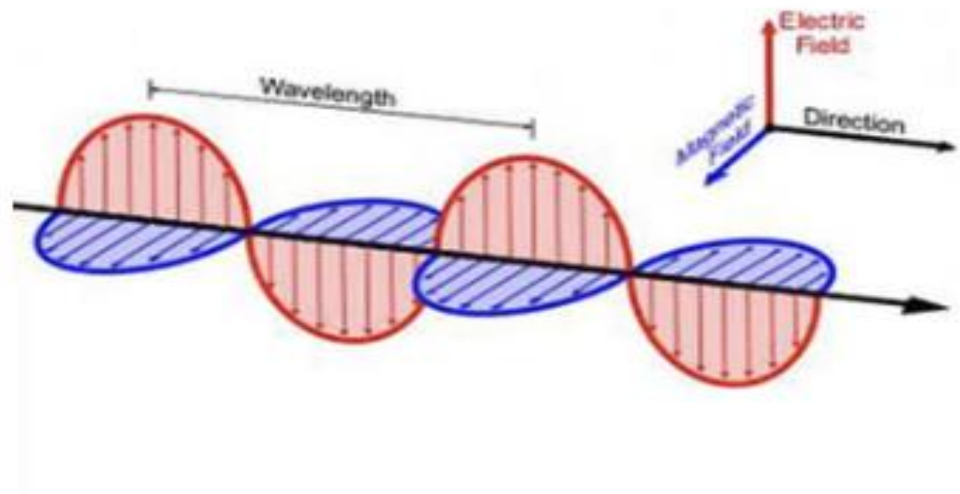
- Size: MLA compact ($<0.1\lambda$) vs. full-size wire.
- Efficiency: MLA 60–90% (HF); wire 85–98%.
- Noise pickup: MLA low (H-field), wire high (E-field).
- Bandwidth: MLA narrow (high-Q), wire broader.
- Directivity: MLA nulls for noise rejection; wire broadside pattern.
- Power handling: MLA limited by capacitor; wire higher tolerance.

Magnetic Loop vs Wire Antenna Radiation Fields

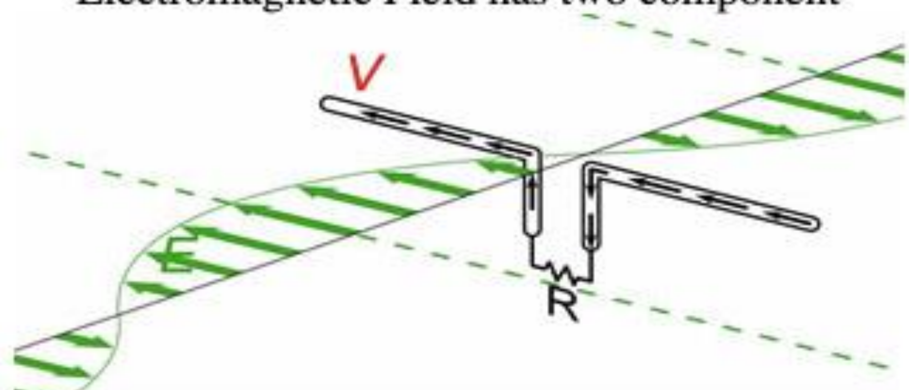
Diagram: Magnetic Loop (H-field) vs Wire Antenna (E-field) radiation pattern

Loop: Circular magnetic field lines, low noise coupling.

Wire: Broadside electric field radiation, stronger far-field power.



Electromagnetic Field has two component

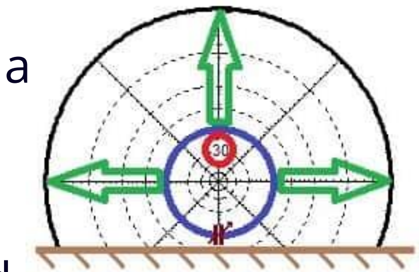


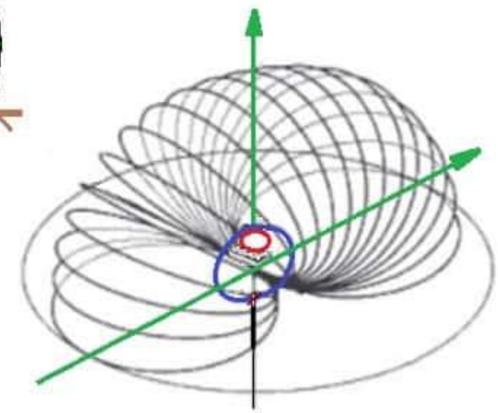
Dipole antenna is an E-field antenna

Courtesy Alpha Antennas

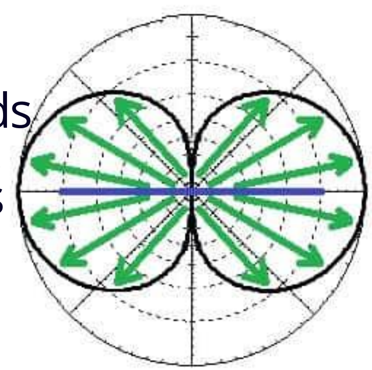
What MLA radiation looks like-

Far Field Patterns in the image show a MagLoop antenna with the small Feed Loop represented in Red. This loop couples with the BLUE outer loop to form the inductive characteristics of the MagLoop antenna. As a result, turning the variable air capacitor shown in Maroon tunes the loop.





Directionality of the MagLoop
The signal pattern of a loop include; Ground-Wave, NVIS (Near Vertical Incident Skywave), and DX (Long Range). A MagLoop antenna has a signal pattern that looks like a giant and ever-expanding donut. This is similar to the shape as the ionosphere for propagating DX. NVIS uses a take-off pattern above the antenna. DX uses a low take-off angle towards the horizon for greater distances. As a result, a MagLoop provides all of the signal patterns that are used.



Courtesy Alpha Antennas

Theoretical Background

- MLA radiation resistance proportional to $(A/\lambda^2)^2$ — efficiency improves with larger loop and low-loss capacitor.
- Wire antenna radiation resistance ≈ 73Ω for half-wave dipole — inherently efficient radiator.
- Magnetic loops dominated by H-field; wire antennas dominated by E-field radiation.
- High-Q MLA stores energy in its near field, producing sharp resonance and narrow bandwidth.

Real-World WSPR Test Results (17 m Band)

- K3GO EM90 – 17 m band comparative analysis:
  - Test setup: 200 mW and 2 W transmissions using MLA and EFLW antennas.
  - MLA reached 7,544 km at 200 mW; EFLW extended to 9,573 km at 2 W.
  - Mean distance: MLA 2,045 km vs EFLW 2,488 km (22% longer paths).
  - MLA provided cleaner SNR due to reduced E-field noise coupling.
  - Conclusion: MLA ~1–2 S-units lower ERP but superior SNR stability.

Applications

– Portable or stealth operation — Magnetic Loop.
– Base station or multiband fixed use — Wire antenna.
– Urban QRM environments — Magnetic Loop (lower noise).
– High power HF stations — Wire antenna (better efficiency).
– QRP portable or balcony use — Magnetic Loop with motorized tuning.

Summary: Antenna metrics (spots, avg SNR, avg distance)

Antenna	Spots	Unique Callers	Avg SNR	Min SNR	Max SNR	Avg Dist (km)	Max Dist (km)	Reporter Points (with lat/lon)
ChaLoop NS	356	19	-15.39	-30.0	3.0	2628.21	15698.0	355
EFLW72Feet	512	33	-13.3	-31.0	10.0	4483.18	12039.0	512
MLA EW (200mw)	313	1	-20.35	-34.0	-3.0	1298.47	3070.0	313
MLA NS (200mw)	174	1	-21.1	-33.0	-2.0	1281.79	3047.0	174
MLA-NE-SW (200mw)	248	1	-20.68	-32.0	-8.0	1251.18	3070.0	248
MLP1" 17M	606	9	-14.8	-32.0	6.0	2347.89	8098.0	606
MLP1" 20M	458	46	-14.06	-30.0	3.0	1305.8	11893.0	458
PreciseRF NESW102Loop	155	9	-15.35	-29.0	2.0	3541.45	9573.0	155
PreciseRF NS102"Loop	218	11	-13.98	-32.0	6.0	2818.72	12039.0	218
PreciseRF 140"Loop	658	--	-15.76	--	-5.0	2492.65	10340.0	502

Summary

- Magnetic Loops excel in compact and noisy environments with strong magnetic-field coupling.
- Wire antennas excel where space and height allow efficient full-size operation.
- Both can achieve impressive WSPR and FT8 performance when matched properly.
- MLA tuning quality and loop design are critical to achieving wire-like efficiency.
- Choice depends on installation constraints, operating goals, and noise conditions.

WSPR 200 mW Antenna Performance Analysis

Station: K3GO (EM90)

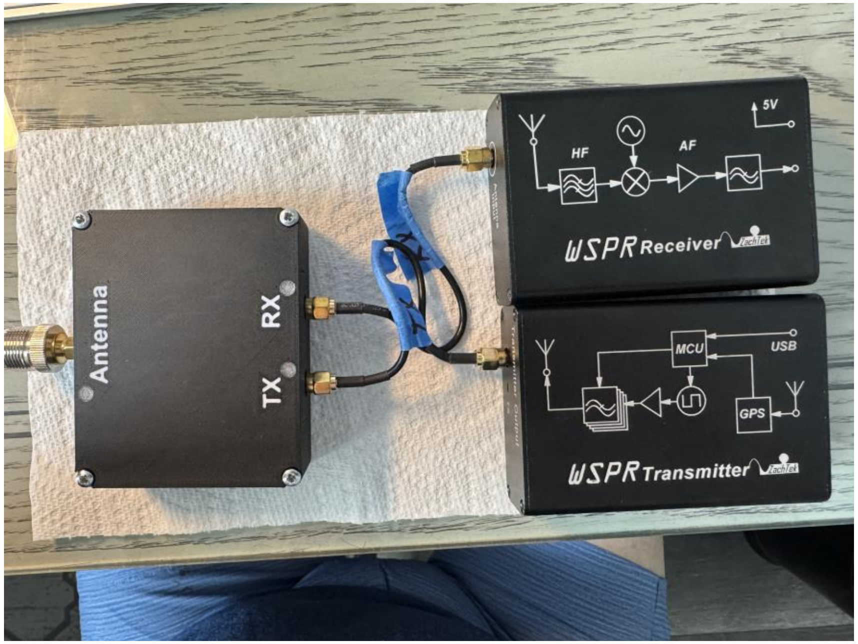
MLA 200 mW LMR400 • 20 m Band

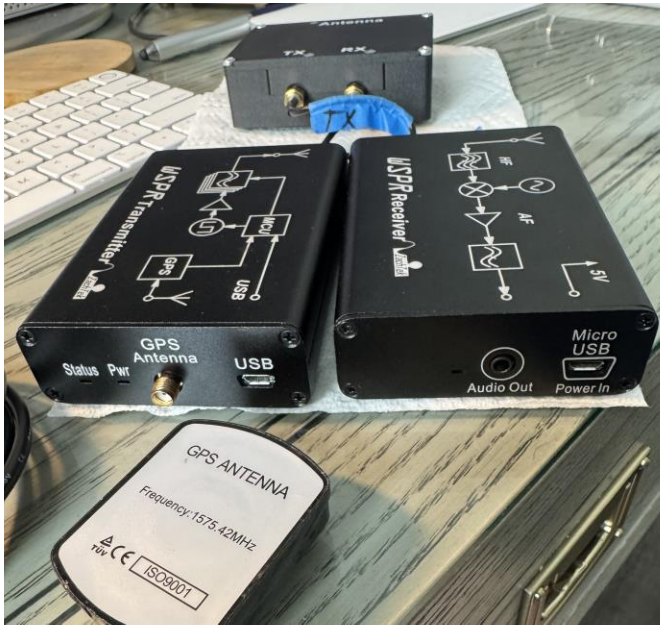
Executive Summary

– EW loop achieved the greatest mean distance (~1298 km) and maximum reach (~3070 km).
– NS and NE–SW orientations showed balanced coverage across directions.
– All loops reached ~3000 km, suggesting band propagation limits, not antenna limits.
– Polar and heatmap plots show distinct lobes consistent with MLA directionality.
– Strong propagation efficiency at 200 mW demonstrates excellent low-power performance.

200mW Distance Performance
20 meter Summary

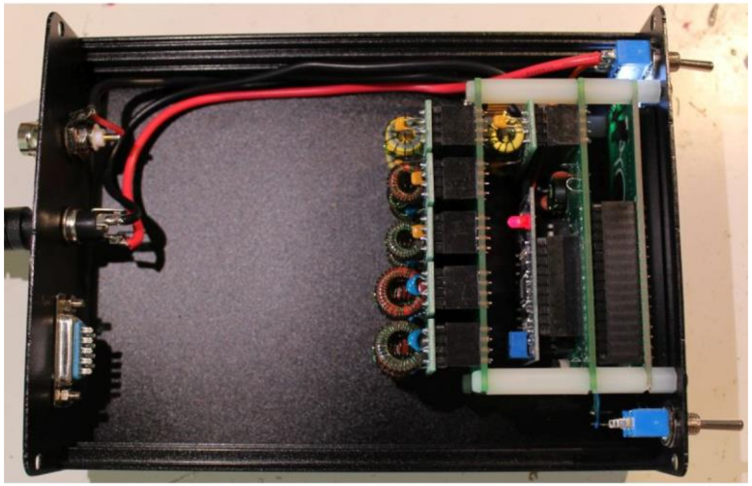
Antenna	Spots	Mean_km	Median_km	Max_km	Avg_SNR_dB
MLA EW	313	1298.5	1383.0	3070	nan
MLA NS	174	1281.8	1358.0	3047	nan
MLA-NE-SW	248	1251.2	1358.0	3070	nan





https://www.zachtek.com/product-page/wspr-desktop-transmitter

Additional WSPR Kits



https://qrp-labs.com/

Very reasonable priced kits. They work well and you can range from milliwatts to 5, 10 or 50 watts

Conclusions

– EW loop orientation offers the best long-range propagation performance.
– NS and NE–SW loops maintain stable, omnidirectional coverage.
– All configurations perform well under 200 mW, showing high system efficiency.
– Ideal for propagation studies and QRP (low-power) experimentation.

WSPR 17 m Antenna Performance Analysis

Station: K3GO (EM90)

MLA & EFLW Configurations • 17 m Band

Conclusions

- EFLW72Feet configuration provides the strongest average long-distance coverage on 17 m.
- ChaLoop17 NS achieved the longest single DX distance (~15,698 km).
- MLA and EFLW antennas show robust low-power performance even under 200 mW.
- 17 m propagation yielded excellent DX conditions, with all antennas exceeding 8,000 km median reach in some sessions.

Distance Performance Summary (17 m)

Sheet	Spots	Mean_km	Median_km	Max_km	Avg_SNR_dB
CHaLoop17 EW	161	2510.6	1593.0	8098.0	nan
ChaLoop17 NS	355	2628.2	1718.0	15698.0	nan
PreciseNS102" Loop	218	2818.7	1718.0	12039.0	nan
PreciseEW102 Loop	155	3541.4	2430.0	9573.0	nan
EFLW72Feet	512	4483.2	3847.0	12039.0	nan

17 m WSPR Power Comparison (Aggregated) — K3GO

Station: K3GO (EM90)

Power Levels: 200 mW vs 2 W

Distance Performance Summary (Aggregated)

power_bin	Spots	Mean_km	Median_km	Max_km
200mW	458	2044.6	1463.0	7544.0
2W	1029	2487.5	1506.0	9573.0

Executive Summary

- All WSPR spots aggregated by power level across configurations.
- 200mW: mean 2045 km, median 1463 km, max 7544 km (n=458).
- 2W: mean 2488 km, median 1506 km, max 9573 km (n=1029).
- Polar and density maps reveal directional coverage differences between 200 mW and 2 W.

WSPR Antenna Analysis

Station: K3GO (EM90)

Summary: Antenna metrics (spots, avg SNR, avg distance)

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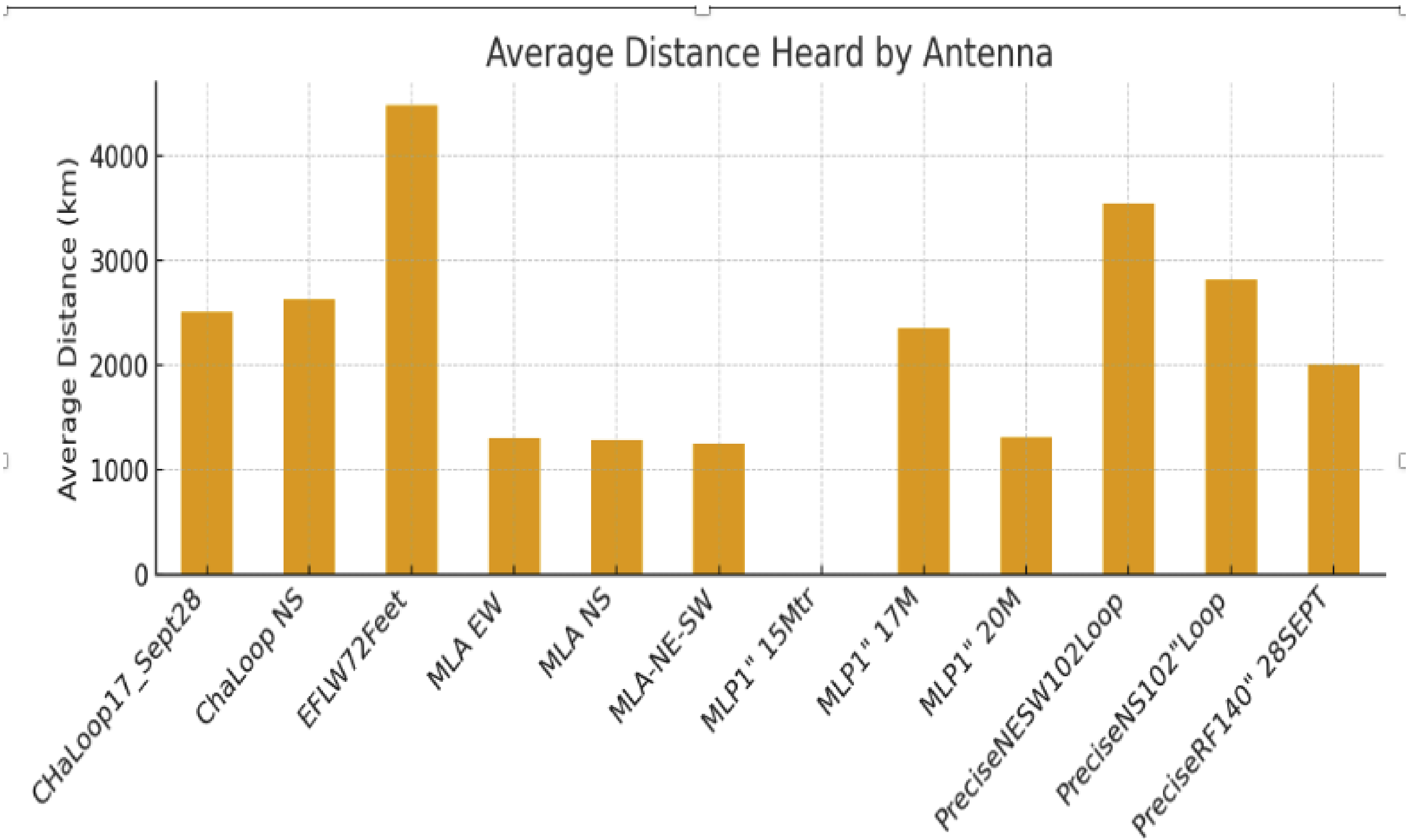
Distance by Antenna



WSPR 20mtr 1” vs LMR400 Analysis Report

Station: K3GO (EM90)

Source: Balcony second story

Raw data

Balcony Summary Statistics (20 m)

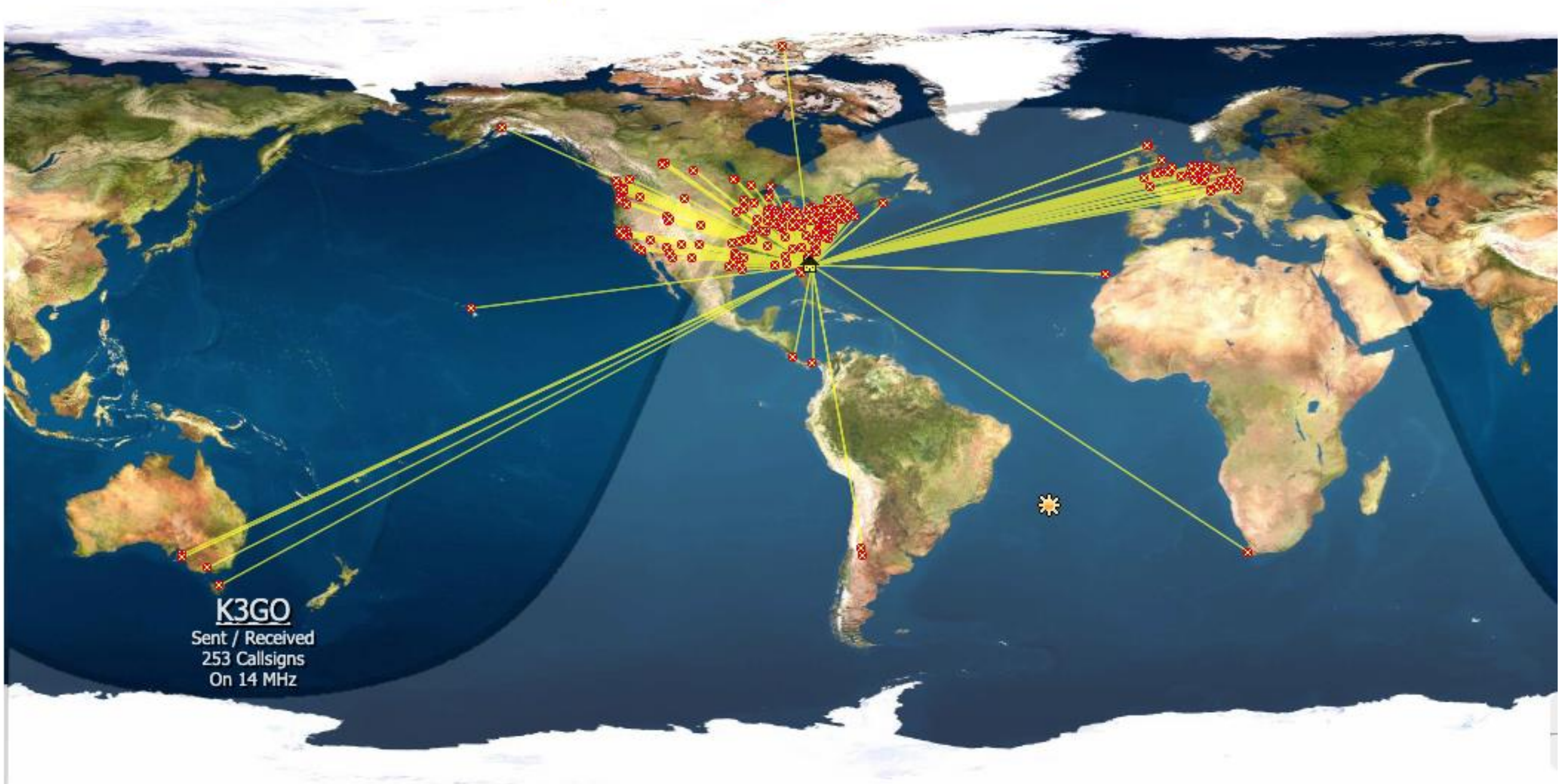
Spots	Unique Reporters	Mean Distance (km)	Median Distance (km)	Max Distance (km)	Mean SNR (dB)	Median SNR (dB)
1206	202	2600.9	1556.0	16257.0	-14.4	-16.0

	AL 1"	LMR400	KM	AZ	Delta
K1RA-4	-	-24	1018	18	-14
K9DZT	-9	-10	1556	339	1
K9IMM	1	-12	1611	335	13
KB8VUC	-	-16	1458	346	9
KB9AMG	7	-9	1565	338	16
KC8COM	-24	-10	816	2	-14
KD2OM	-12	-12	1478	13	0
KF4EAG	-13	-18	657	21	5
KF5QDQ	-21	-23	1479	286	2
KFS	-11	-20	3847	293	13
KFS/G	-13	-21	3847	293	8
KK6PR	-15	-15	3830	306	0
KM3T	-7	-8	1662	29	1
KM3T-3	-2	-4	1662	29	2
KX4AZ/T	8	-1	1602	348	26
KX4O	-	-16	1009	18	-3
LU7MT	-21	-26	7319	168	5
ND7M	-15	-22	3281	291	7
TI4JWC	-13	-21	2242	188	8
VA3RYV	-23	-	1489	3	-6
VE3CWM	0	-	1763	14	10
VE6JY	-3	-	3644	325	15
VK5ARG	-22	-19	16244	252	-3
W9RAN	-13	-	1548	334	8
	-9.20833	-12.7916667			
		3.58			

About 3.5 dB or almost double the signal reported at 4 watts on 20 meters for the 1” solid aluminum loop vs LMR400 loop

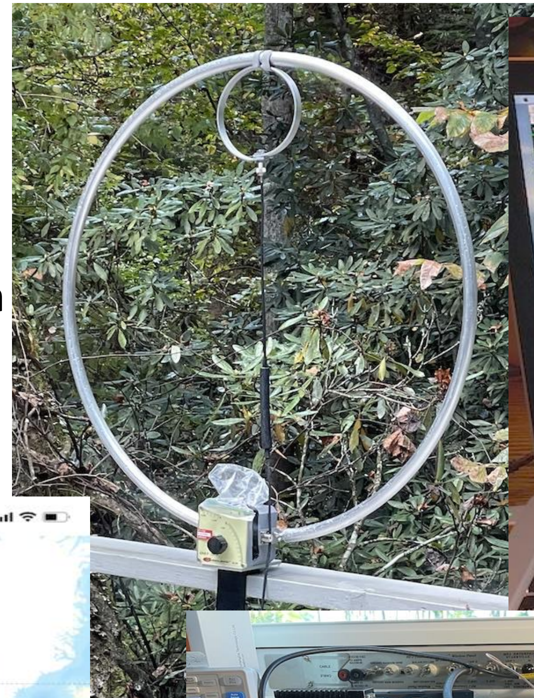
Spotters on 20 Meter Test for 1” loop vs LMR400 loop

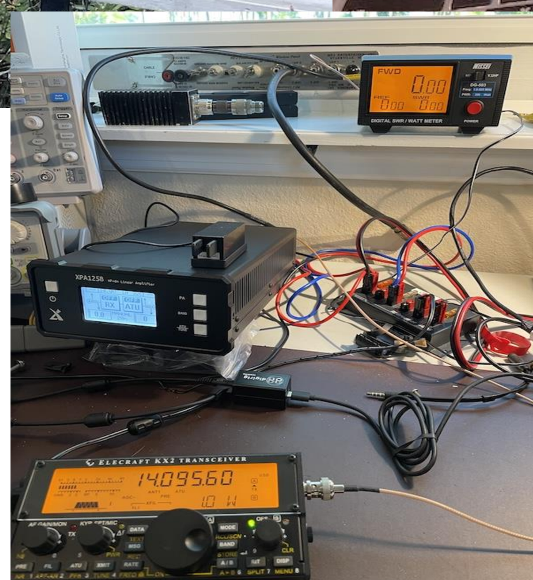
Map shows K3GO and his 253 spoters on 14 MHz. From Dec-23 20:50z to 22:56z 2h.



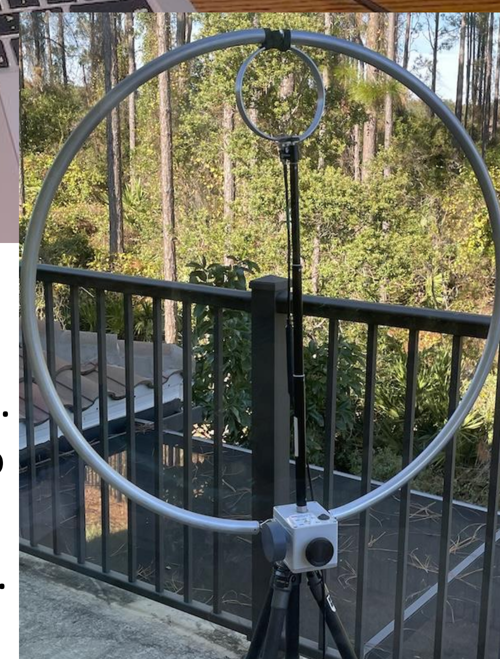
2 Different Balcony Setups

ICOM 705 @3 Watts on30 meters mounted on balcony in mountain vacation house





KX2 at 150 mW, MLA w 1” dia tubing. Using amp to drive 4 watts into antenna.



WSPR Multi-Band Performance Analysis Setup & Photos

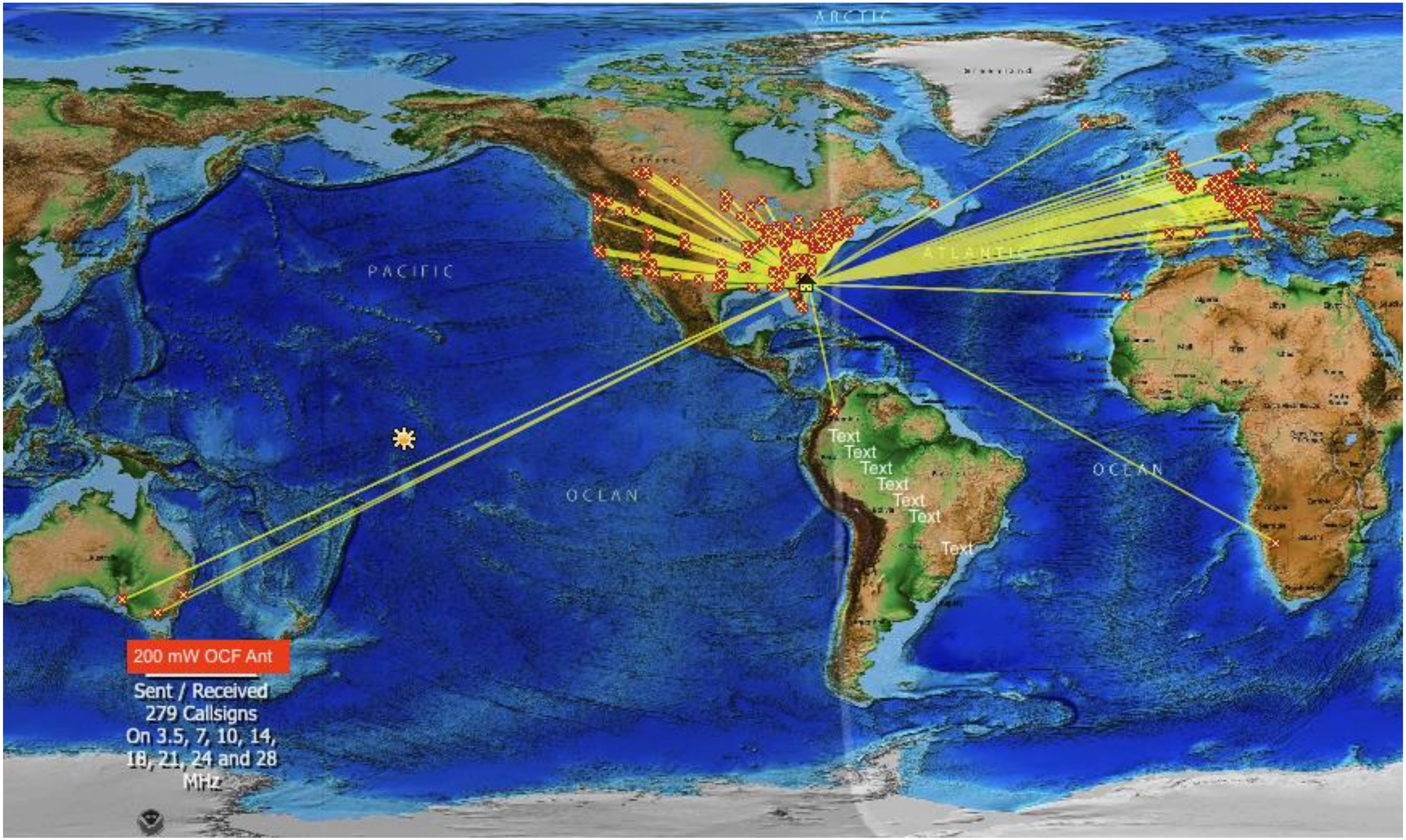
Station: K3GO (EM90)

Bands: 20 m, 17 m • Power: 2 W

Executive Summary

- Analysis covers 20 m and 17 m WSPR bands using 200mW and 2 W transmit power.
- 17 m achieved the highest average and median DX ranges (~3,326 km median 2,236 km).
- 20 m showed consistent short-to-mid-range coverage (~1,300 km mean- daytime operation).
- Propagation and antenna efficiency at 2 W demonstrate strong low-power reach.
- All loops are on tripos on my driveway

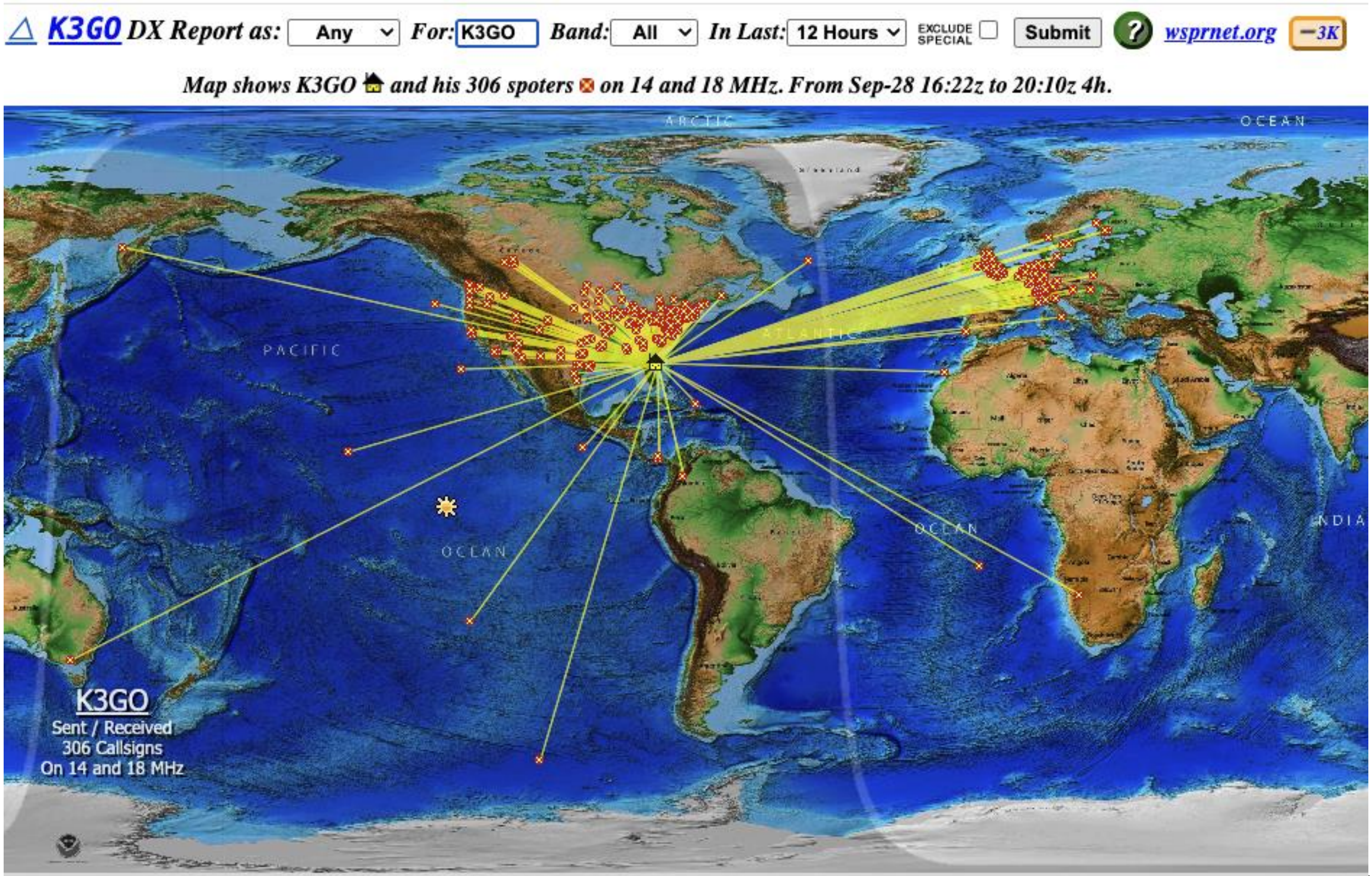
200mW on Zacks Xmit on OCF ant



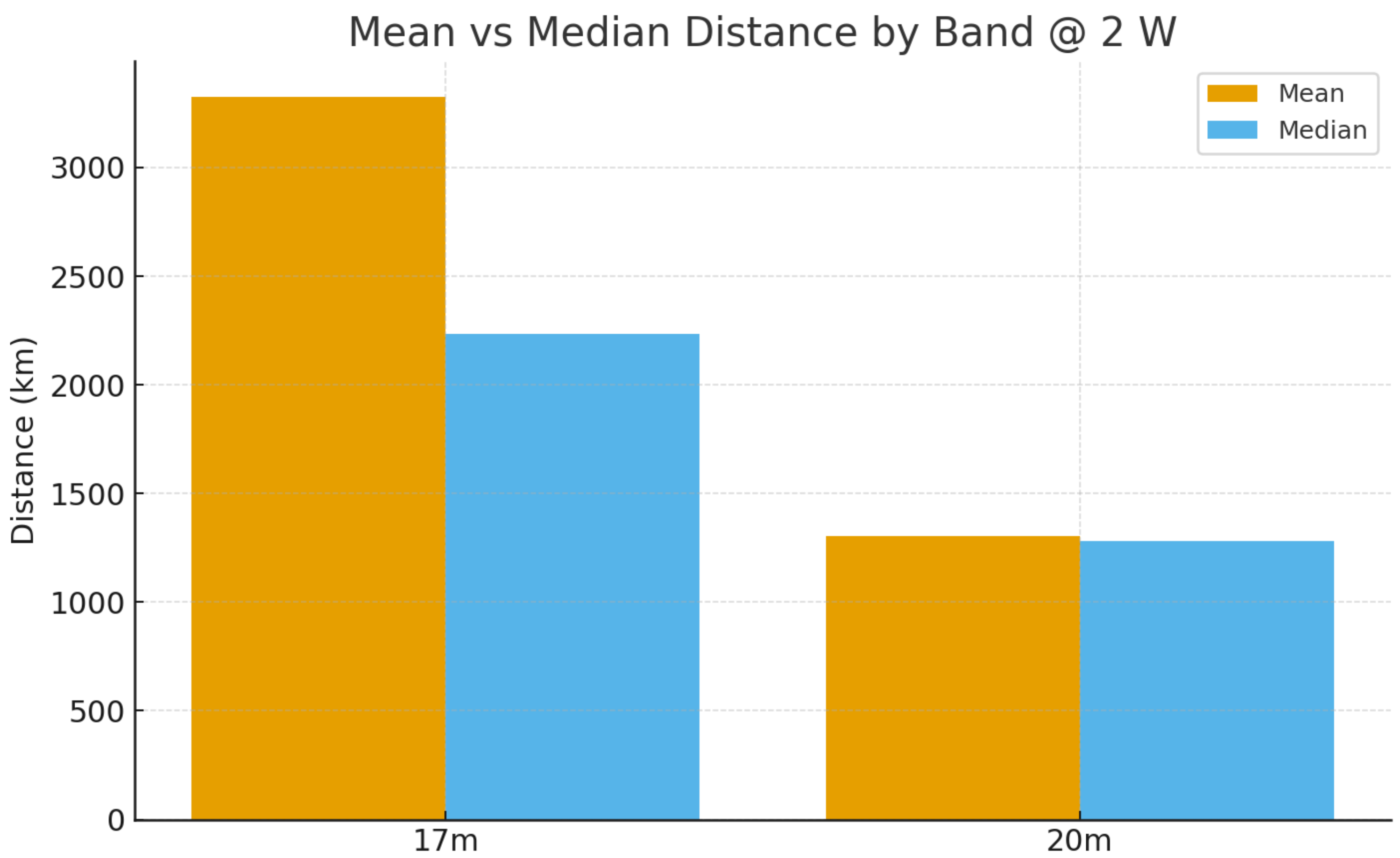
Equipment Setup on Driveway/Garage

Distance Performance Summary

band	Spots	Mean_km	Median_km	Max_km
17m	1118	3325.8	2236.5	12039.0
20m	458	1305.8	1283.0	11893.0



Mean vs Median Distance by Band



Conclusions

- 17 m band provides the most consistent long-distance DX performance in this dataset.
- 20 m delivers steady regional and mid-range coverage typical of *daytime* F-layer propagation.
- Multi-band results confirm robust 2 W station performance (QRP+ efficiency).
- HOA and condo's can achieve world wide digital communications via MLA and Short EFLW. I have done so with multiple sites traveling on the road and at my home QTH.

Best regards and thanks for your attention.

You can have fun with these modes

John K3GO – k3go@bellsouth.net

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