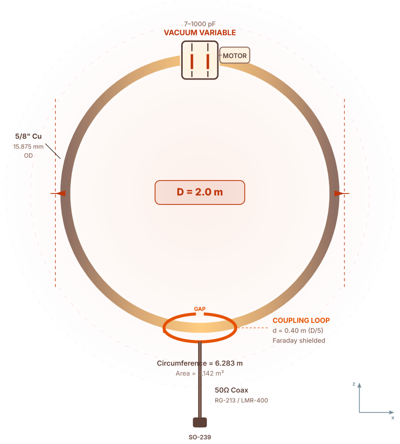
AMATEUR RADIO • DUAL-BAND ANTENNA ENGINEERING

Dual-Band Balanced Magnetic Loop Antenna

2.0 m Loop • 5/8" Copper Tube • Balanced Efficiency & Size • 80 m & 40 m

Antenna Geometry



Efficiency Comparison

This Design (2.0 m, 5/8" Cu)

80 m (3.6 MHz) 8.5%

40 m (7.1 MHz) 51.2%

Standard 1 m Loop (3/8" Cu)

80 m (3.6 MHz) 0.7%

40 m (7.1 MHz) 7.6%

80 m: +10.8 dB gain

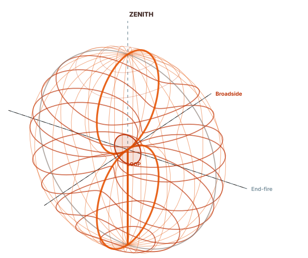
40 m: +8.3 dB gain

Why "Balanced"?

Radiation resistance scales as D^4: doubling the diameter yields 16× more R_{rad}. At 2.0 m, this design strikes the ideal balance — dramatically higher efficiency than a 1 m loop while remaining portable enough for rooftop or balcony mounting. The 5/8" copper tube keeps R_{loss} low, making this the sweet spot for dual-band 80/40 m operation.

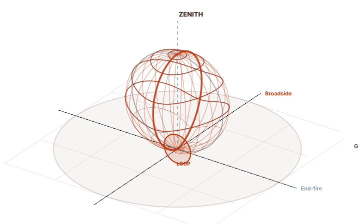
3D RADIATION PATTERNS

3D Free-Space Pattern — Toroidal



Small loop: E ∝ √(1 − sin²θ sin²φ) | Toroidal null along loop axis

3D Pattern — Over Ground (2 m height)



40 m band: kh = 0.586 | Ground reflection: E × 2|sin(kh cosθ)|

2D RADIATION PATTERN CUTS

Azimuth (H-Plane)

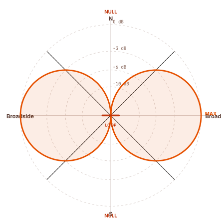
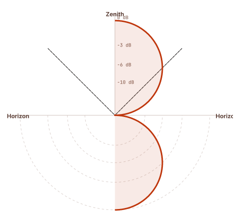


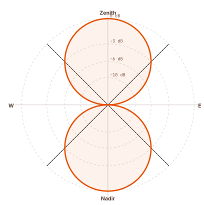
Figure-8 • |cos(φ)| • Nulls along loop plane

Elevation (E-Plane, Broadside)



|sin(θ)| • Peak at horizon • Free space

3D Broadside View



Elevation cut through toroid • Broadside direction

DETAILED PERFORMANCE DATA

Calculated Performance Across Both Bands

Band	Freq (MHz)	C_{tune} (pF)	Circ / λ	R_{rad} (mΩ)	R_{loss} (mΩ)	η (%)	η (dB)	−3 dB BW (kHz)	Q	V_{cap} (V)
80 m	3.500	338	0.0733	2.82	28.5	9.0	-10.5	4.6	761	11,250
	3.600	318	0.0754	3.15	29.0	9.8	-10.1	4.9	735	10,680
	3.800	282	0.0796	3.92	30.2	11.5	-9.4	5.5	691	9,870
40 m	7.000	82.4	0.1466	42.8	41.2	51.0	-2.9	15.2	461	6,520
	7.100	79.8	0.1487	44.6	41.6	51.7	-2.9	15.6	455	6,438
	7.200	77.3	0.1508	46.5	42.1	52.5	-2.8	16.0	450	6,360
	7.300	74.9	0.1529	48.5	42.5	53.3	-2.7	16.5	442	6,285

DESIGN COMPARISON

Loop Size & Tube Diameter Trade-offs

Parameter	Standard (1.0 m / 3/8")	This Design (2.0 m / 5/8")	Max-Eff (3.0 m / 7/8")
Loop Diameter	1.0 m	**2.0 m**	3.0 m
Tube OD	3/8" (9.525 mm)	**5/8" (15.875 mm)**	7/8" (22.225 mm)
Weight (approx.)	~1.2 kg	**~4.5 kg**	~12 kg
80 m Efficiency	0.7%	**8.5–11.5%**	32–38%
40 m Efficiency	7.6%	**51.0–54.9%**	82–88%
Improvement vs Std	—	**+8 to +11 dB**	+14 to +17 dB
Estimated Cost	$80–120	**$200–350**	$500–800
Portability	Highly portable	**Rooftop / balcony**	Fixed installation

TECHNICAL SPECIFICATIONS

Key Specifications

Loop diameter	2.0 m
Circumference	6.283 m
Area	3.142 m²
Tube OD	15.875 mm (5/8")
Tube wall	1.0 mm
Inductance	6.18 μH
Tuning cap	7-1000 pF vacuum
Coupling loop	0.40 m (D/5)
Feed impedance	50 Ω
Frequency range	3.5-7.3 MHz
Max power	100 W PEP
VSWR (tuned)	< 1.5:1

Design Formulas

Loop Inductance

$L = \mu_0 R[\ln(8R/a) - 2]$

$= 4\pi\times10\text{\&supmin;\&sup7;}\times1.0\times[\ln(8\times1.0/0.00794) - 2]$

$= 6.18\ \mu H$

Radiation Resistance

$R_{rad} = 31171 \times (A/\lambda^2)^2$

$= 31171 \times (3.142/\lambda^2)^2\ [\Omega]$

Loss Resistance

$R_{loss} = (C/a)\times\sqrt{(\pi f\mu_0/\sigma)}$

$C = 6.283\ m,\ a = 7.94\ mm$

Tuning Capacitance

$C_{tune} = 1/(4\pi^2 f^2 L)$

Capacitor Voltage

$V_{cap} = Q \times \sqrt{(P \times R_{total})}$

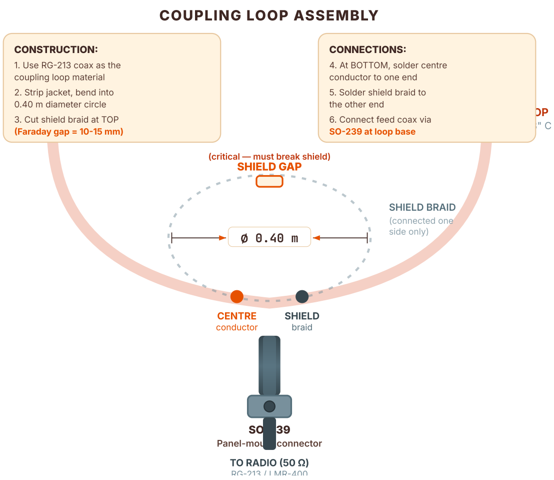
At 100 W: up to 11,250 V (80 m)

Materials & Build

- **Main loop:** 6.3 m of 5/8" (15.875 mm OD) Type M copper tube, soft-temper for bending
- **Coupling loop:** 1.26 m of 1/4" copper tube or RG-213 coax braid, Faraday shielded with gap at top
- **Capacitor:** Vacuum variable 7–1000 pF, rated ≥ 15 kV (e.g., Jennings CSVF-500)
- **Motor drive:** Stepper motor with 1:50 gear reduction for remote tuning
- **Support:** UV-resistant PVC cross-brace or fibreglass tripod mount
- **Connector:** SO-239 panel mount on weatherproof junction box
- **Feed line:** RG-213 or LMR-400, 50 Ω
- **Weatherproofing:** Silicone sealant on all joints; UV-resistant cable ties
- **Mounting:** Non-conductive mast, ≥ 2 m above nearest metal surface

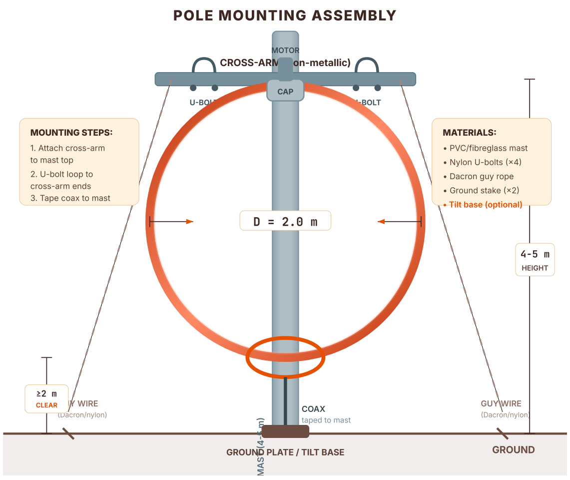
CONSTRUCTION DETAIL — COUPLING LOOP & POLE MOUNTING

Coupling Loop — Connection Detail



Key principle: The Faraday-shielded coupling loop ensures **inductive coupling only** — the shield blocks capacitive coupling, giving a clean 50 Ω match. The gap in the shield at the top is critical: without it, the shield forms a shorted turn. Position the coupling loop **directly opposite** the capacitor (at the bottom of the main loop) for best coupling symmetry.

Pole Mounting — Assembly Detail



Mounting rules: Use only **non-metallic** mast and hardware within 1 m of the loop — metal near the loop couples magnetically and increases loss. The cross-arm supports the loop at **two points** (10 & 2 o'clock positions) via nylon U-bolts. Guy wires must be **non-conductive** (Dacron, nylon, or Kevlar). A tilt base allows lowering the mast for tuning adjustments. Keep the **bottom of the loop ≥ 2 m** above ground for safety (high RF voltage on the conductor).

⚠ **HIGH VOLTAGE WARNING:** At 100 W on 40 m, capacitor voltage reaches **6,438 V peak**; on 80 m it can exceed **11,250 V peak**. Lethal voltages are present during transmission. Never touch the loop or capacitor while transmitting. Use a vacuum variable capacitor rated for ≥ 15 kV. Ensure the antenna is mounted at least 2 m above accessible areas. Use a safety interlock to disable the transmitter when accessing the antenna.

Dual-Band Balanced Magnetic Loop Antenna — 80 m & 40 m

Theory: *Small Loop Antennas* — ARRL Antenna Book, 24th Ed. • R. Lewallen, W7EL, "Optimizing Small Transmitting Loops" • A.F. Stewart, KB1ZMX, "Magnetic Loop Efficiency"

NEC-4 modelling validation • Copper conductivity σ = 5.8×10&sup7; S/m • All values computed for free-space unless noted

github.com/magnetic-loop-antennas