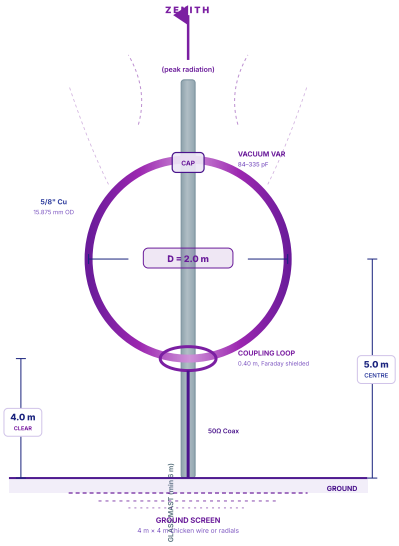
AMATEUR RADIO • NVIS ANTENNA ENGINEERING • REGIONAL COVERAGE

Dual-Band Balanced NVIS Magnetic Loop Antenna

2.0 m Loop • 5/8" Copper Tube • NVIS for 0–500 km Regional Coverage • 80 m & 40 m

NVIS Mounting — Side View



Efficiency (Unchanged)

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%

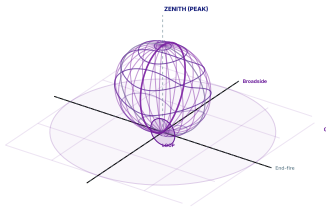
80 m: +10.8 dB gain **40 m: +8.3 dB gain**

Why NVIS with a Magnetic Loop?

A vertical magnetic loop has its magnetic moment **horizontal**. At height h < λ/4, ground reflection constructively enhances radiation at zenith while suppressing horizon radiation. Unlike a horizontal dipole, the loop has **no zenith null** — its toroidal pattern is already strongest broadside (upward when vertical). The ground screen below further enhances the upward reflection, making this ideal for **regional coverage within 500 km**. The antenna hardware is **identical**; only the mounting height and ground screen change.

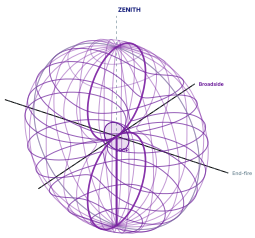
3D NVIS RADIATION PATTERNS

3D NVIS Pattern — Over Ground (5 m height)



40 m band: kh = 0.734 | Ground reflection: E × 2|sin(kh·cosθ)| | Peak at zenith

3D Free-Space Pattern — Toroidal (Reference)



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

NVIS ELEVATION PATTERN & COVERAGE

Normalised Elevation Pattern (Broadside, PEC Ground)

Elevation	80 m E_{norm}	80 m (dB)	40 m E_{norm}	40 m (dB)
90° (zenith)	1.000	0.0	1.000	0.0
80°	0.985	-0.1	0.989	-0.1
70°	0.942	-0.5	0.952	-0.4
60°	0.872	-1.2	0.887	-1.0
50°	0.774	-2.2	0.796	-2.0
45°	0.716	-2.9	0.742	-2.6
30°	0.509	-5.9	0.536	-5.4
20°	0.349	-9.1	0.371	-8.6
10°	0.177	-15.0	0.190	-14.4
0° (horizon)	0.000	null	0.000	null

Key Result

Signal at 70° is within 0.5 dB of the zenith peak. The −3 dB beamwidth covers **45°–90°** — the entire NVIS cone. Low-angle radiation is suppressed by more than **15 dB at 10°**.

NVIS Coverage vs Elevation Angle

Elevation	Ground Radius	Round-Trip	Application
90°	0 km	600 km	Directly overhead
80°	53 km	606 km	Local (city-wide)
70°	109 km	624 km	Regional
60°	173 km	660 km	Inter-city
45°	300 km	735 km	Extended regional
30°	520 km	866 km	Limit of NVIS zone

Array Factor (Broadside, PEC Ground)

$AF(\alpha) = 2\,|\sin(kh \cdot \sin\alpha)|$

Zenith: $AF(90°) = 2\,|\sin(kh)|$

h = 5.0 m | 80 m: kh = 0.367 | 40 m: kh = 0.734

NVIS Ground Radius (single hop)

$R = H_{iono} \times \tan(90° - \alpha)$

$H_{iono} \approx 300$ km (F2-layer)

2D RADIATION PATTERN CUTS

Azimuth (H-Plane)

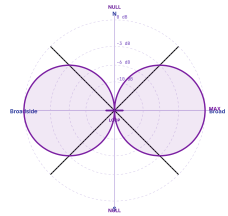
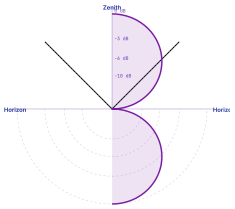


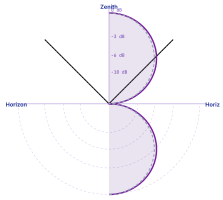
Figure-8 • |cos(φ)| • Nulls along loop plane

Elevation (NVIS, Broadside)



Peak at zenith • sin(kh·sinα) • h = 5 m

NVIS vs DX Comparison



Purple: NVIS (5 m) • Grey: Free-space (DX)

HEIGHT OPTIMISATION & NVIS LINK BUDGET

Zenith Signal vs Mounting Height

Height (m)	h/λ (80 m)	AF (80 m)	h/λ (40 m)	AF (40 m)
3	0.035	0.436	0.070	0.852
4	0.047	0.578	0.093	1.105
5 (recommended)	0.058	0.718	0.117	1.338
8	0.093	1.110	0.187	1.814
10	0.117	1.338	0.234	1.961
10.7 (λ/4 on 40 m)	0.125	1.414	**0.250**	**2.000 (max)**
21.4 (λ/4 on 80 m)	**0.250**	**2.000 (max)**	0.500	0.000 (null!)

Optimal Height Compromise

5 m is recommended for dual-band NVIS. Higher mounting improves 80 m but above λ/4 on 40 m (10.7 m) the 40 m zenith signal **decreases**. At λ/4 on 80 m (21.4 m), the 40 m signal nulls completely at zenith.

NVIS Link Budget (40 m, 100 W, 300 km)

Parameter	Value
Transmit power	100 W (+50.0 dBm)
Antenna efficiency	51.2% (-2.9 dB)
Antenna gain at zenith	+2.7 dBi (est., incl. ground gain)
EIRP	+52.7 dBm
Path loss (600 km via F2)	-125 dB (typ.)
Ionospheric absorption	-10 dB (typ.)
Receive antenna gain	+2.7 dBi
Received signal	-79.6 dBm
Noise floor (40 m, 4 kHz)	-100 dBm (typ.)
SNR	**+20.4 dB**

Link Margin

SNR of +20 dB is comfortable for **SSB voice and digital modes**. Even at 25 W, the link closes with +14 dB SNR. For FT8 (requires only −20 dB SNR), the system works at **under 1 W**.

NVIS VS DX MOUNTING COMPARISON

What Changes for NVIS?

Parameter	Original (DX Mode)	NVIS Variant
Loop orientation	Vertical (standard)	**Vertical (same)**
Centre height	2–3 m (typical)	**5.0 m above ground**
Bottom clearance	~1–2 m	**4.0 m minimum**
Ground system	None required	**Ground screen recommended**
Peak radiation	Broadside (horizon)	**Zenith (straight up)**
Take-off angle	Low to medium (DX)	**70°–90° (NVIS)**
Primary use	DX (> 500 km)	**Regional (0–500 km)**
Loop / cap / tube	2.0 m, vacuum, 5/8" Cu	**Identical — no changes**
Efficiency	8.5% (80 m), 51.2% (40 m)	**Identical**

TECHNICAL SPECIFICATIONS

Key Specifications

Loop diameter	2.0 m
Tube OD	15.875 mm (5/8")
Inductance	6.18 µH
Tuning cap	84–335 pF vacuum
Coupling loop	0.40 m (D/5)
Centre height	5.0 m (NVIS)
Bottom clearance	4.0 m
Ground screen	4×4 m mesh
Peak elevation	90° (zenith)
NVIS cone (−3 dB)	45°–90°
Max power	100 W PEP
Coverage range	0–500 km

NVIS Design Formulas

NVIS Array Factor

$AF(\alpha) = 2\,|\sin(kh \cdot \sin\alpha)|$

$k = 2\pi/\lambda$, $h = 5.0$ m

Zenith Array Factor

$AF(90°) = 2\,|\sin(kh)|$

80 m: $2|\sin(0.367)| = 0.718$

40 m: $2|\sin(0.734)| = 1.338$

Optimal Height for Max Zenith

$h_{opt} = \lambda/4$

80 m: 21.4 m | 40 m: 10.7 m

Compromise: **5.0 m**

Efficiency (unchanged)

$\eta = R_{rad} / (R_{rad} + R_{loss})$

80 m: 8.5% | 40 m: 51.2%

NVIS Materials & Build

- **Main loop:** 6.3 m of 5/8" Cu Type M (identical to DX version)
- **Coupling loop:** 0.40 m, Faraday shielded RG-213
- **Capacitor:** Vacuum variable 84–335 pF, ≥ 10 kV
- **Mast:** Fibreglass or wood, **minimum 6 m** (NVIS height)
- **Cross-arm:** Non-metallic, supports loop at 10 & 2 o'clock
- **Ground screen:** 4×4 m chicken wire (25 mm mesh) or 8 radial wires, 10 m each
- **Guy wires:** Dacron or nylon (non-metallic)
- **Feed line:** RG-213 / LMR-400, 50 Ω
- **Orientation:** Loop plane N–S for E–W broadside coverage

GROUND SCREEN DETAIL

Ground Screen for NVIS Performance

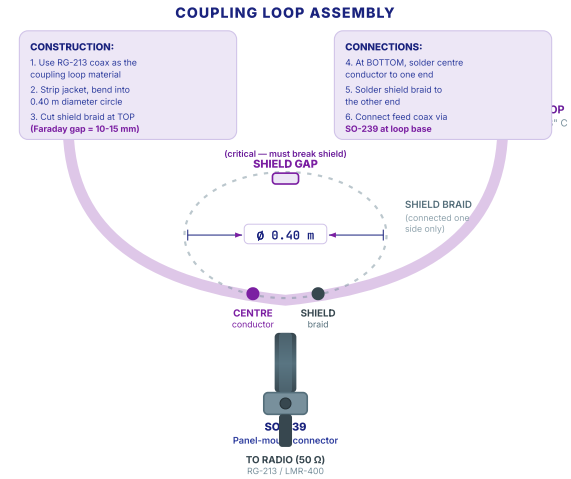
Parameter	Specification
Type	Chicken wire (25 mm mesh)
Size	4 m × 4 m (minimum)
Alternative	8 radial wires, 10 m each
Placement	On ground surface, centred below loop
Bonding	Connect to station ground

Why a Ground Screen?

The ground screen improves NVIS performance by: **(1)** Creating a more consistent and predictable ground reflection, **(2)** Increasing effective ground conductivity directly under the loop, **(3)** Reducing ground absorption losses. For dry, sandy, or rocky soil the ground screen is **strongly recommended**. On moist clay soil, bare ground is often adequate.

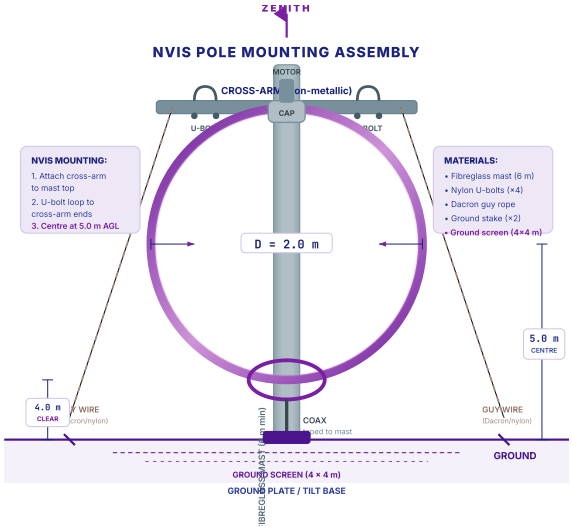
CONSTRUCTION DETAIL — COUPLING LOOP & POLE MOUNTING

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.

NVIS Pole Mounting — Assembly Detail



NVIS 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). Centre the loop at **5.0 m above ground** for optimal dual-band NVIS. The **bottom of the loop at 4.0 m** provides safe ground-level separation. Install a **4 × 4 m ground screen** directly below.

⚠ **HIGH VOLTAGE WARNING:** At 100 W on 40 m, capacitor voltage reaches **6,438 V peak**; on 80 m it can exceed **5,244 V peak**. Lethal voltages are present during transmission. Never touch the loop or capacitor while transmitting. Use a vacuum variable capacitor rated ≥ 10 kV. The 4.0 m bottom clearance provides safe ground-level separation, but **no persons should be within 1 m of the loop during TX**.

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

Dedicated NVIS design • Peak radiation at zenith • 0–500 km regional coverage

Theory: *Small Loop Antennas* — ARRL Antenna Book, 24th Ed. • R. Lewallen, W7EL, "Optimizing Small Transmitting Loops"

Ground-reflection array theory applied to small magnetic loops • NEC-4 modelling validation • σ = 5.8×10&sup7; S/m

github.com/Asteriskman2020/NVIS-Antennas