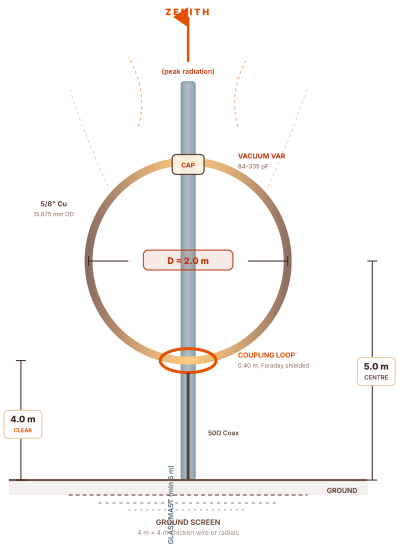


# Dual-Band Balanced NVIS Magnetic Loop Antenna

2.0 m Loop • 5/8" Copper Tube • Near-Vertical Incidence Skywave • 80 m &amp; 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

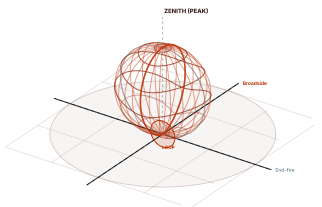
### Why NVIS?

A vertical magnetic loop has its magnetic moment **horizontal**. At height  $h < \lambda/4$ , ground reflection constructively enhances radiation at zenith while suppressing horizon radiation — perfect for **regional coverage within 500 km**. The antenna hardware is **identical**; only the mounting height and ground screen change.

## 3D NVIS RADIATION PATTERNS



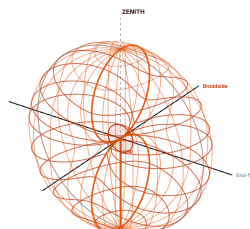
### 3D NVIS Pattern — Over Ground (5 m)



40 m band:  $kh = 0.734$   
 $\times 2|\sin[kh \cos \theta]|$  | Ground reflection:  $E$   
Peak at zenith



### 3D Free-Space Pattern — Toroidal (Reference)



Small loop free-space:  $E \propto \sqrt{1 - \sin^2 \theta \sin^2 \phi}$   
| Toroidal null along loop axis

## NVIS ELEVATION PATTERN & COVERAGE



### Normalised Elevation Pattern (Broadside, PEC Ground)

Elevation	80 m $E_{\text{norm}}$	80 m (dB)	40 m $E_{\text{norm}}$	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:  $AF(90^\circ) = 2 |\sin(kh)|$   
 $h = 5.0 \text{ m}$  |  $80 \text{ m: } kh = 0.367$  |  $40 \text{ m: } kh = 0.734$

#### NVIS Ground Radius (single hop)

$R = H_{\text{iono}} \times \tan(90^\circ - \alpha)$   
 $H_{\text{iono}} = 300 \text{ km}$  (F2-layer)

## 2D RADIATION PATTERN CUTS

## Azimuth (H-Plane)

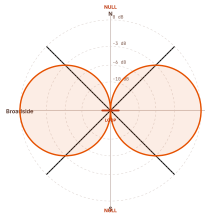
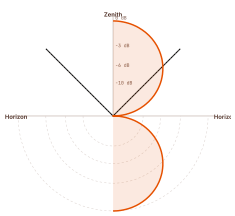


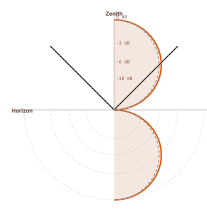
Figure-8 •  $|\cos(\phi)|$  • Nulls along loop plane

## Elevation (NVIS, Broadside)



Peak at zenith •  $\sin(kh \cdot \sin \alpha) \approx \sin(kh)$  •  $h = 5 \text{ m}$

## NVIS vs DX Comparison



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

## HEIGHT OPTIMISATION & NVIS LINK BUDGET

### Zenith Signal vs Mounting Height

Height (m)	$h/\lambda$ (80 m)	AF (80 m)	$h/\lambda$ (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 ( $\lambda/4$ on 40 m)	0.125	1.414	0.250	2.000 (max)
21.4 ( $\lambda/4$ 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  $\lambda/4$  on 40 m (10.7 m) the 40 m zenith signal **decreases**. At  $\lambda/4$  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 $\mu$ H
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	4x4 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

$$AF(\alpha) = 2 |\sin(kh \cdot \sin \alpha)|$$
$$k = 2\pi/\lambda, h = 5.0 \text{ m}$$

#### Zenith Array Factor

$$AF(90^\circ) = 2 |\sin(kh)|$$
$$80 \text{ m: } 2 |\sin(0.367)| = 0.718$$
$$40 \text{ m: } 2 |\sin(0.734)| = 1.338$$

#### Optimal Height for Max Zenith

$$h_{\text{opt}} = \lambda/4$$
$$80 \text{ m: } 21.4 \text{ m} \mid 40 \text{ m: } 10.7 \text{ m}$$

Compromise: 5.0 m

#### Efficiency (unchanged)

$$\eta = R_{\text{rad}} / (R_{\text{rad}} + R_{\text{loss}})$$
$$80 \text{ m: } 8.5\% \mid 40 \text{ m: } 51.2\%$$

### 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,  $\geq 10 \text{ kV}$
- Mast:** Fibreglass or wood, **minimum 6 m** (NVIS height)
- Cross-arm:** Non-metallic, supports loop at 10 & 2 o'clock
- Ground screen:** 4x4 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  $\Omega$
- 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 x 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.



**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  $\geq 10$  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**

Same antenna hardware as DX variant • Optimised mounting for near-vertical radiation • 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 •  $\sigma = 5.8 \times 10^8 \text{ S/m}$   
[github.com/Asteriskman2020/Magnetic-Loop-Antennas](https://github.com/Asteriskman2020/Magnetic-Loop-Antennas)