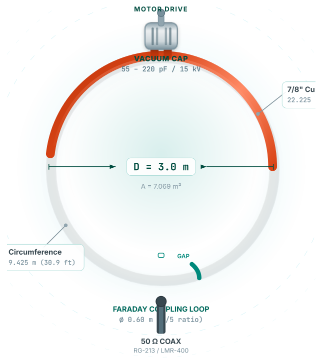
AMATEUR RADIO • NVIS ANTENNA ENGINEERING

NVIS High-Angle Magnetic Loop Antenna

3.0 m Vertical Loop at 5 m Height • Peak Radiation at Zenith • 0–500 km Regional Coverage

3.0 m	**9.397** μH	**90°**	**5.0** m
LOOP DIAMETER	INDUCTANCE	PEAK TAKE-OFF (ZENITH)	CENTRE HEIGHT

ANTENNA GEOMETRY



EFFICIENCY — THIS DESIGN VS STANDARD

THIS DESIGN (3.0 M / 7/8" TUBE)

80 m Band (3.5 MHz) — 30.5%

30.5%

vs Standard 1m loop: 0.7% → **+16.2 dB improvement**

40 m Band (7.0 MHz) — 83.3%

83.3%

vs Standard 1m loop: 7.6% → **+10.4 dB improvement**

STANDARD REFERENCE (1.0 M / 3/8" TUBE)

80 m — 0.7%

40 m — 7.6%

▲ 80 m: +16.2 dB ▲ 40 m: +10.4 dB

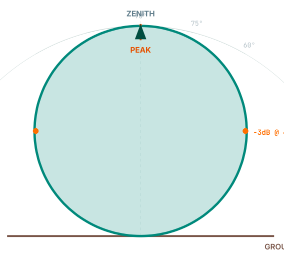
Why so much better?

Radiation resistance scales as D^4. A 3× larger diameter yields 81× more R_{rad}, while conductor loss only increases 1.3×. Thicker tube cuts loss a further 2.3×.

NVIS RADIATION PATTERN — OVER GROUND

ELEVATION — 80 M

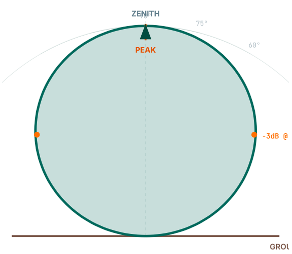
3.5 MHZ • H = 5 M • KH = 0.37



Peak at zenith • Null at horizon • NVIS cone 45°–90°

ELEVATION — 40 M

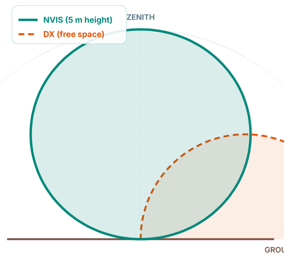
7.0 MHZ • H = 5 M • KH = 0.73



Peak at zenith • Null at horizon • NVIS cone 44°–90°

NVIS VS DX OVERLAY

40 M — NVIS (TEAL) VS DX (ORANGE)

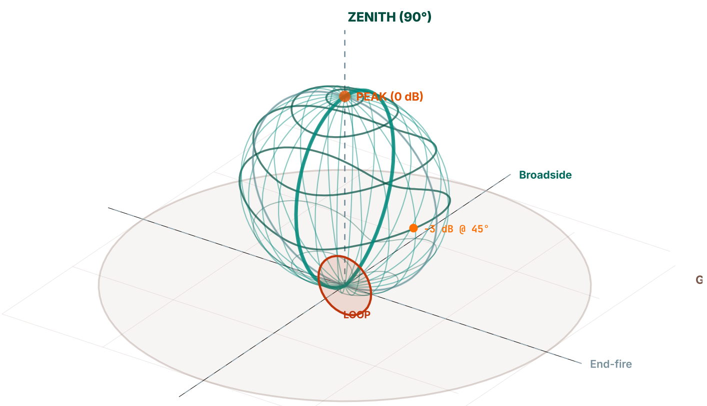


NVIS peaks UP • DX peaks sideways • Inverted patterns

3D RADIATION PATTERN — WIREFRAME VIEW

3D NVIS PATTERN — 40 M OVER GROUND

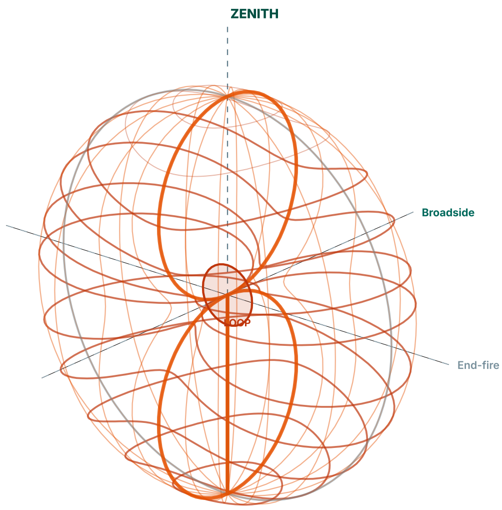
KH = 0.73 • HEIGHT 5 M • UPWARD LOBE



Radiation concentrated upward • Ground suppresses horizon • Ideal NVIS shape

3D FREE-SPACE PATTERN — REFERENCE

NO GROUND • TOROIDAL (DONUT) • DX MODE



Classic donut around magnetic moment axis • No zenith null • Horizon maximum broadside

ELEVATION PATTERN DATA (BROADSIDE, PEC GROUND)

ELEVATION	80 M (3.5 MHZ, KH=0.37)		40 M (7.0 MHZ, KH=0.73)	
	NORMALISED	DB	NORMALISED	DB
90° (zenith)	1.000	0.0	1.000	0.0
80°	0.985	-0.1	0.989	-0.1
70°	0.941	-0.5	0.951	-0.4
60°	0.870	-1.2	0.888	-1.0
50°	0.774	-2.2	0.794	-2.0
45° (−3 dB)	0.716	-2.9	0.742	-2.6
30°	0.509	-5.9	0.537	-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

$AF(\alpha) = 2|\sin(kh \cdot \sin\alpha)|$ — −3 dB beamwidth covers **45°–90°** (NVIS cone). Low-angle radiation suppressed >15 dB below 10°.

NVIS COVERAGE VS ELEVATION (F2 @ 300 KM)

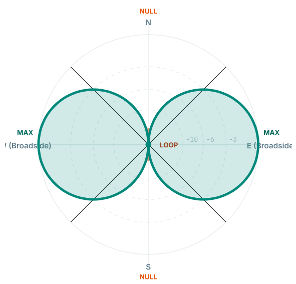
ELEVATION	GROUND RADIUS	ROUND-TRIP	APPLICATION
90°	0 km	600 km	Directly overhead
80°	53 km	606 km	Local (city-wide)
70°	109 km	624 km	Regional
60°	173 km	660 km	Inter-city
45°	300 km	735 km	Extended regional
30°	520 km	866 km	NVIS limit

$R = H_{iono} \times \tan(90° - \alpha)$ — The −3 dB cone (45°–90°) provides strong coverage from **0 to 300 km**. Signals >500 km are suppressed by the pattern null at the horizon.

Typical Link Budget (40 m, 100 W, 300 km)
EIRP +54 dBm → Path −125 dB → Iono −10 dB → Rx +4.8 dBi
Received: **−76 dBm** • Noise floor: −100 dBm • **SNR = +24 dB**

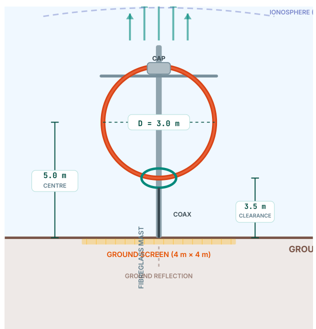
AZIMUTH PATTERN (HORIZONTAL PLANE)

FIGURE-8 • COS(Φ) • BROADSIDE E–W



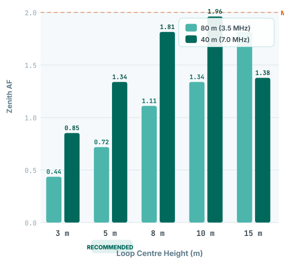
Nulls off loop ends • Max broadside • Orient N–S for E–W coverage

NVIS MOUNTING — SIDE VIEW



ZENITH SIGNAL VS HEIGHT

ARRAY FACTOR AT ZENITH • AF(90°) = 2|SIN(KH)|



5 m = good compromise • λ/4 = optimum per band

NVIS ARRAY FACTOR — KEY FORMULA

$$E(\alpha) = 2\,|\sin(k \cdot h \cdot \sin(\alpha))|$$

where α = elevation angle, $k = 2\pi/\lambda$, h = loop centre height

Zenith signal: $AF(90°) = 2\,|\sin(kh)|$

Optimal height: $h_{opt} = \lambda/4 \rightarrow AF = 2.0$ (maximum)

At $h = 5$ m: $AF(80m) = 0.72$ • $AF(40m) = 1.34$

WHY VERTICAL LOOP = NVIS

A vertically-mounted small magnetic loop has its **magnetic moment horizontal**. The free-space pattern is a torus (donut) around this axis. The **zenith direction is perpendicular to the magnetic moment** — so the loop radiates at **full strength straight up**. There is no zenith null.

When placed over ground at height $h < \lambda/4$:

- Direct + reflected waves **add constructively** at high elevation
- At the horizon, they **cancel** (destructive interference)
- Result: **peak at zenith, null at horizon** — pure NVIS

This is the opposite of a horizontal dipole at low height, which has a zenith null and radiates at low angles.

DETAILED PERFORMANCE DATA

COMPLETE PERFORMANCE TABLE

BAND	FREQ (MHZ)	C_{TUNE} (PF)	CIRC / λ	R_{RAD} (Ω)	R_{LOSS} (Ω)	EFFICIENCY	H (DB)	−3 DB BW	Q	V_{CAP} @100W
80 m	3.500	220.0	0.110	0.0289	0.0659	**30.5 %**	-5.16	1.61 kHz	2 176	6 712 V
80 m	3.650	202.3	0.115	0.0342	0.0673	**33.7 %**	-4.72	1.76 kHz	2 068	6 762 V
80 m	3.800	186.6	0.119	0.0402	0.0687	**36.9 %**	-4.33	1.94 kHz	1 963	6 799 V
40 m	7.000	55.0	0.220	0.4631	0.0932	**83.3 %**	-0.79	9.42 kHz	743	5 544 V
40 m	7.100	53.5	0.223	0.4903	0.0939	**83.9 %**	-0.76	9.73 kHz	730	5 483 V
40 m	7.200	52.0	0.226	0.5185	0.0945	**84.6 %**	-0.72	10.39 kHz	693	5 427 V
40 m	7.300	50.6	0.230	0.5478	0.0952	**85.2 %**	-0.70	10.78 kHz	677	5 375 V

DESIGN SPECS

Loop Diameter	3.000 m
Circumference	9.425 m
Area	7.069 m²
Tube OD	22.225 mm
Inductance	9.397 μH
Cap Range	50 – 220 pF
Cap Type	Vacuum Var.
Voltage	≥ 15 kV
Coupling	0.60 m Faraday
Feed Z	50 Ω
Weight	~12 kg
Cost	$455 – $900

ENGINEERING FORMULAE

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

$$C = 1 / (\omega^2 \cdot L)$$

$$R_r = 320\pi^4 (A / \lambda^2)^2$$

$$\delta = 1 / \sqrt{\pi f \mu_0 \sigma}$$

$$R_{loss} = C_{loop} / (\pi d \sigma \delta)$$

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

$$Q = \omega L / (R_r + R_{loss})$$

$$V_{cap} = \sqrt{P/R_{tot}} \cdot \omega L$$

MATERIALS & BOM

Radiator	7/8" Cu Type L
Cu Tube Length	12 m
Conductivity	5.8×10^7 S/m
Skin Depth (3.5)	35.3 μm
Skin Depth (7.0)	25.0 μm
Joints	Silver Solder
Mast	Fibreglass 4 m
Coax Feed	RG-213 / LMR-400
Connector	N-type / SO-239
Capacitor	Jennings CSVF
Motor	12V DC Gear
Est. Total	$455 – $900

HIGH VOLTAGE WARNING: At 100 W, capacitor voltages exceed **6 700 V** on 80 m and **5 500 V** on 40 m. Mount the antenna ≥ 2.5 m above ground. Use motor-driven tuning only. **Never touch the loop or capacitor during transmission.** These voltages are lethal.

NVIS Magnetic Loop Antenna — 80 m & 40 m High-Angle Regional Coverage

Based on small-loop theory and ground-reflection array factor (Kraus, *Antennas*; Straw, *ARRL Antenna Book*).

All values are theoretical — actual performance depends on construction quality, ground conductivity and environment.

github.com/Asteriskman2020/Magnetic-Loop-Antennas