Exploiting NVIS Propogation for RAYNET Operations

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The author plans to provide more detail concerning aerial design referred to here in a follow-up article.

Near-Vertical Incident Sky-wave (NVIS) fills the gap between line-of-sight ‘ground-wave’ and long-distance ‘skip’ sky-wave communications. In *Fig 1*, station C is within ground-wave range whilst station B is not, but is contactable via sky-wave B-B. All stations between the ground-wave limit and B do not receive the transmissions as they are within the Skip Zone.

NVIS is a combination of radio hardware, sky-wave radio propagation, operating procedures, co-operation and knowledge of the F2 Layer (obtained from the Internet), used by radio operators who need reliable regional communications. It fills the gap between line-of-sight ‘’ground-wave” and long–distance “skip” sky-wave communications (*Fig 2*). Figure 2 shows that the loss on the NVIS path is just 22dB compared to the skip path of 54dB, due in part to the higher angle through the D-Layer, and the overall path length, the losses are much lower. Looking at this another way, any long-distance stations will cause minimal interference to the local link and no interference will be caused to them by the NVIS signals.

If the frequency is too high the signal will go straight through the F-Layer and be lost in space (*Fig 3*). Also, the angle of transmission has an effect. For a given frequency a low angle will reflect back better than one straight up.

If the frequency is too low (*Fig 4*) there will be greater losses in the D-Layer and there is often more noise and interference at the lower frequency.

The usable frequencies for NVIS communications are between 1.8MHz and 15MHz. The most common bands used in amateur radio for NVIS are 80 metres at night and 40 metres in the day, with experimental use of 5MHz (60 meters) frequencies. Military NVIS communications mostly take place on 2-4MHz at night and on 5-7 MHz during daylight.

The lowest layer of the ionosphere, (the D-Layer), causes attenuation of lower frequencies during the day. This layer disappears at night enabling improved communications at the lower frequencies during this time.

The 80, 40 and 60-metre bands (the latter requiring a NoV) are normally used for NVIS. On some occasions such as when 40, 60 & 80 metre signals pass through the F-Layer in the early hours and signals break up, 160 metres may have to be used. So in an ideal scenario an aerial also covering top band is advisable.

NVIS Propagation when using a *resonant* Horizontal Dipole.

When a **horizontal dipole** is a ½-wave high (*Table 1*), it has a wide null overhead, and a main signal

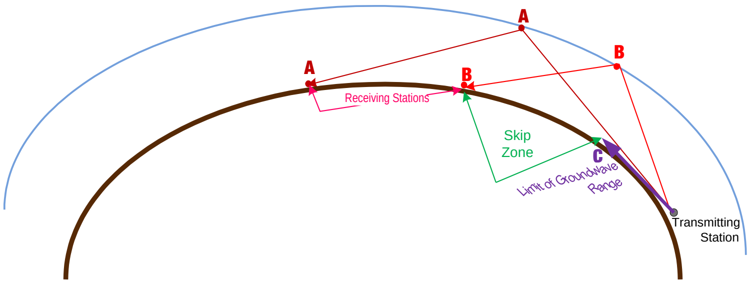


Fig 1

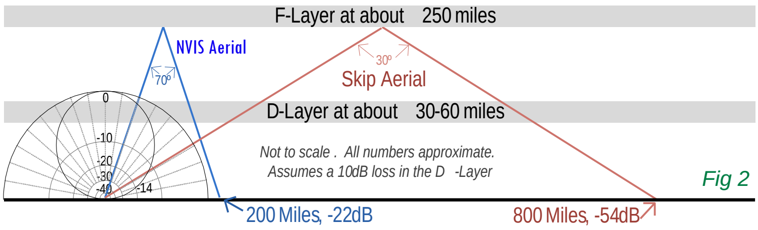


Fig 2

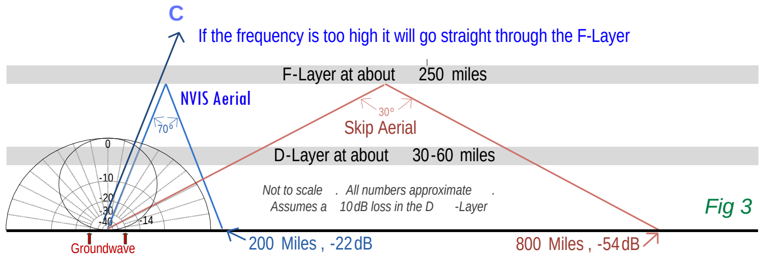


Fig 3

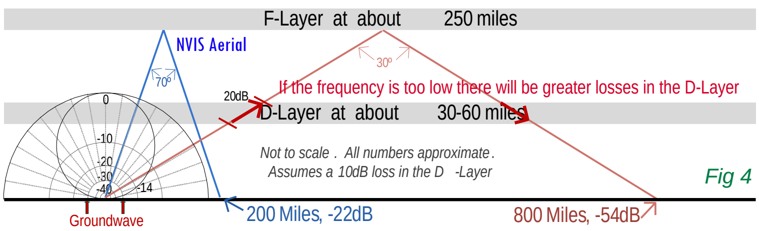


Fig 4

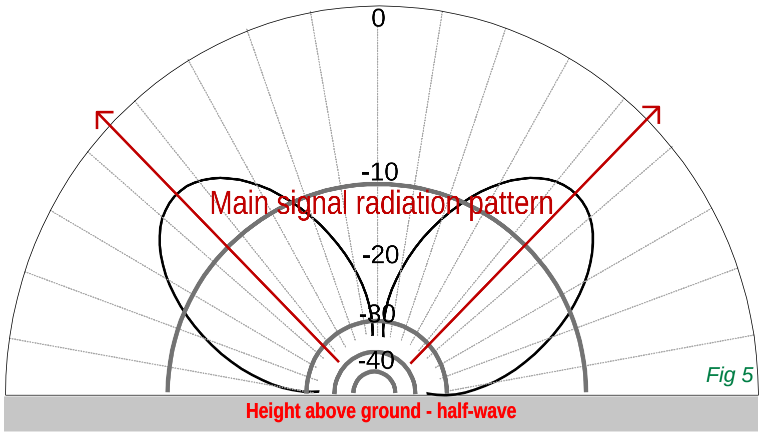


Fig 5

Freq	Band	½ Wavelength above average ground height
3.75	80	130ft 40mtrs
5.3665	60	91ft 27.7mtrs
7.05	40	69ft 21mtrs

Table 1

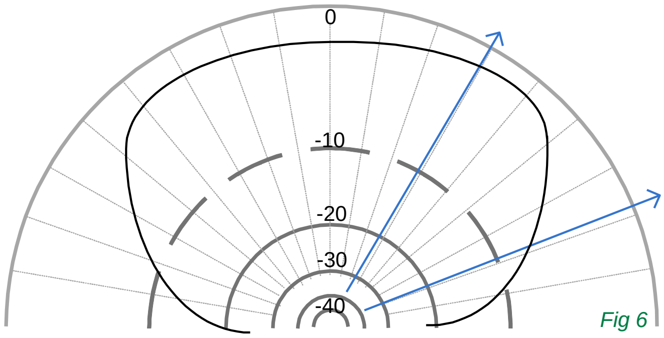


Fig 6

Sig pattern of an 80-metre dipole at 3/8th λ.

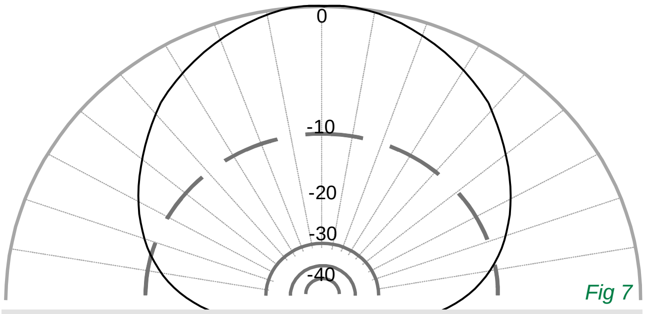


Fig 7

Signal pattern of an 80-metre dipole at 1/4 λ.

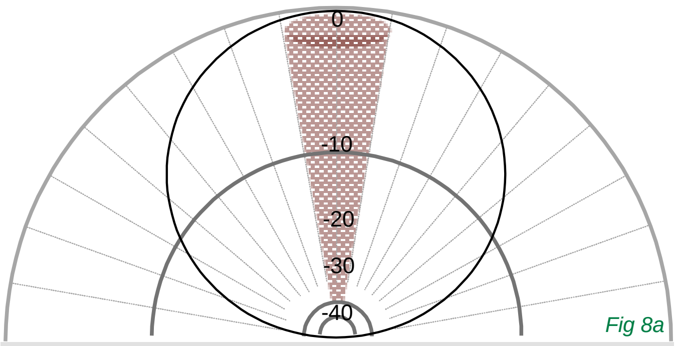


Fig 8a

80-metre dipole at 20ft agl the signal will hit the Ionosphere at a very narrow angle.

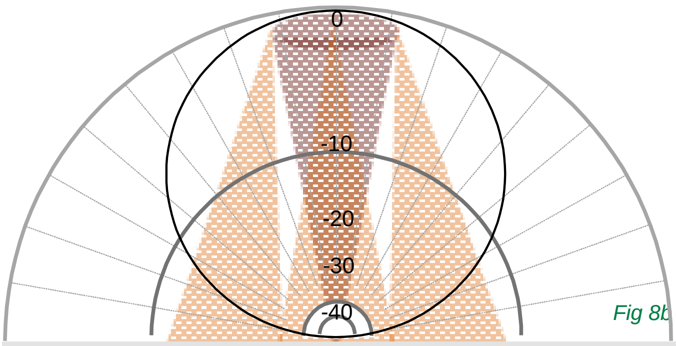


Fig 8b

. . . the return path to Earth will be equally narrow

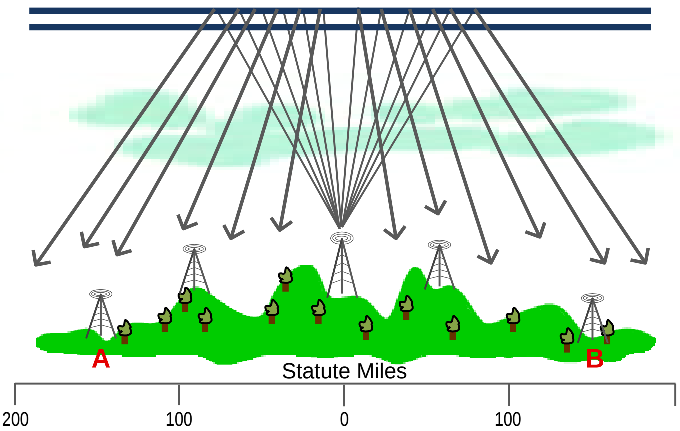


Fig 9

radiation pattern shaped like an inverted cone. The reflected wave from the ground is out of phase with the antenna and so causes partial phase cancellation overhead (*Fig 5*). This makes a good "DX" antenna, with gain at relatively low angles, and a wide skip zone. However, problems arise on regional nets and rag chews, because of the skip zone, i.e the limit of line-of-sight ground-wave. Most of the power radiates at about 42 degrees.

Compare *Fig 5* with *Fig 6*. *Fig 6* shows the signal pattern of an 80-metre dipole at $^3/_8$th wavelength with most of the power at about 30 to 60 degrees, down to -10dB at 22 degrees.

Fig 7 represents the pattern of an 80-metre dipole at ¼ wave above ground. Most of the power in this case goes upwards, down to -10dB at 28 degrees.

In *Fig 8a* we see the resulting pattern of an 80-metre dipole at only 20ft above ground (0.08 wave-length). See *Table s 2, 3 & 4 for* comparative heights depending on wavelength. With the majority of the power reaching the Ionosphere at such a narrow angle, the return path to Earth will be equally narrow, providing good local communications – *Fig 8b*.

The 'illumination' of the ground for good local communications using NVIS avoids the problem of line of site communication as signals will project into valleys (*Fig 9*). To achieve the same result using VHF Stations A and B would need 3 repeaters to communicate!

From the foregoing we have established that as a dipole is lowered below a half-wave high, the inverted cone closes up, the overhead null disappears, and most of the power is radiated upward in a wide lobe shaped like an egg. With a horizontal antenna suspended well under a half-wavelength high, we deliberately illuminate the F-layer (which varies from about 100 to 300 miles up) with a wide RF flood, which causes indirect RF illumination of the whole region. Ideal for emergency communications for incidents spreading beyond an immediate vicinity, such as widespread flooding or in very hilly areas.

A Consideration

The height of the horizontal dipole (above average ground level) affects the feed-point impedance as shown in *Table 5* overleaf.

The table indicates that regular dipoles (on 80mtrs) should be mounted about 41 feet high, if the lowest possible SWR is to be achieved, when feeding with 50-ohm coax. A lower height than this affects the feed-point impedance.

Alternately, to counter this effect a folded dipole (or loop) may be placed at about **5 Metres** (**16 feet)**. Since there is typically a 4:1 transformation ratio with folded dipoles, the feed-point resistance will be around 50 ohms. The folded dipole will also have a considerably broader bandwidth.

We see that for NVIS the best heights are 10, 14 & 20 feet for 40, 60 & 80 metres respectively. In a real emergency it is unlikely that many will have either the time nor the luxury of a mini-aerial farm so a good compromise is to standardise on 16 feet (5 metres) and use a folded dipole to reduce the match needed by any auto-tuner used. ➢

Table 2 - 3/8th Wave above agl		
Freq (Mhz)	Band	³/₈th Wave above average ground
3.75	80	97ft 30mtrs
5.3665	60	68ft 20.7mtrs
7.05	40	52ft 15.85mtrs

Table 3 - 1/4 Wave above agl		
Freq (Mhz)	Band	¼ Wave above av ground
3.75	80	65ft 20mtrs
5.3665	60	45ft 13.7mtrs
7.05	40	35ft 10.7mtrs

Table 4 - 0.08 Wave agl		
Freq (Mhz)	Band	0.08 Wave Height agl
3.75	80	20ft 6.1mtrs
5.3665	60	14ft 4.27mtrs
7.05	40	10ft 3mtrs

Table 5
Feed-point examples for an 80-metre Dipole Height Above Average Ground

Metres	Feet	Feed-Point Impedence (Ohms)
4	13	8
5	***16***	***12.5***
6	20	15
8	26	25
10	32	35
12	40	46
12.65	***41***	***50***
14	46	57

Many Amateurs do not use a resonant aerial but resolve this with a tuner or auto-tuner like the LDG. Initially the author used a full size G5RV with an auto-tuner which covered 80 to 10 metres. This has a length of 102 feet with a 30 foot phasing line (Moonraker £39.95 outside rallies!).

Subsequently a 3 band ½ wave resonant aerial for 80, 60 and 40 metres was used. Both aerials worked well up and down the country and in the first test between Medway and West Kent RAYNET Groups where the author worked G7KNS who put up a temporary NVIS inverted V aerial at 5 metres in the field while also covering the Tunbridge Wells half Marathon. G7KNS was located at river level near Penshurst, over 42km from the author's location in Sittingbourne (*Fig 10*), and with the North Downs and other hills in between.

Path Loss = 163dB

Free Space Loss:	79.4dB
Diffraction Loss:	21.4dB
Reflection Loss:	62.2dB
Siting Loss:	0.0dB
Round Hill Excess:	0.0dB
At 5.3Mhz over	42.33km

This path via NVIS, not possible using Groundwave

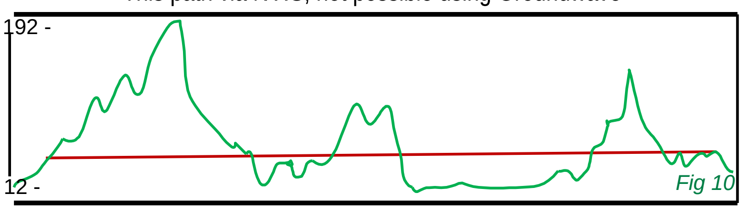


Fig 10

A simple NVIS G5RV aerial

Tests between other stations up and down the country on NVIS using the aerial shown in *Fig. 11* at a height of 5 metres have been successful with signals of 5&9+ when there was no contact with a Delta loop at 10 metres.

Operation around the UK on 5MHz have confirmed good NVIS operation (for example, Southern England into Scotland).

The author initially chose to use a non-resonant full size G5RV as this aerial was easy to implement without significant outlay, not needing a balun, and it worked on all NVIS bands being tested and was quick to deploy for RAYNET purposes. The dimensions of the antenna and its matching section are as shown (*Fig 11*) should a reader choose to make their own from available material. The "flat-top" should, if possible, be horizontal and run in a straight line, and should be erected for NVIS operation as explained earlier, at about 5 metres above ground.

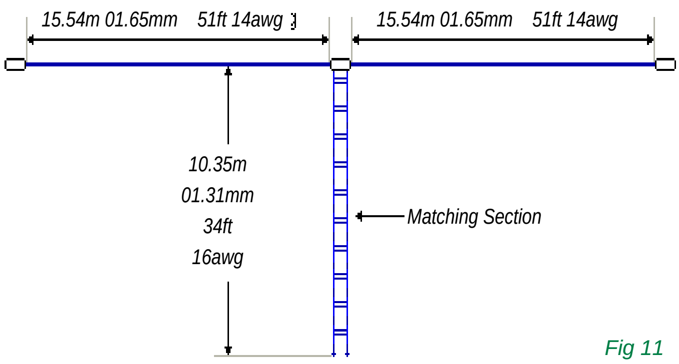
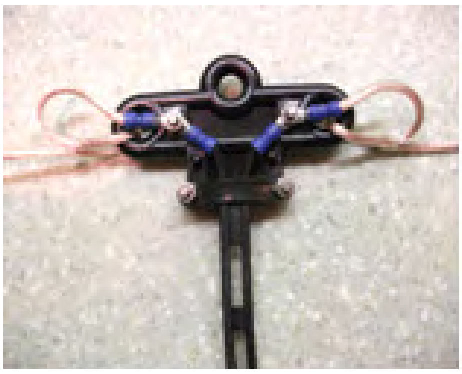
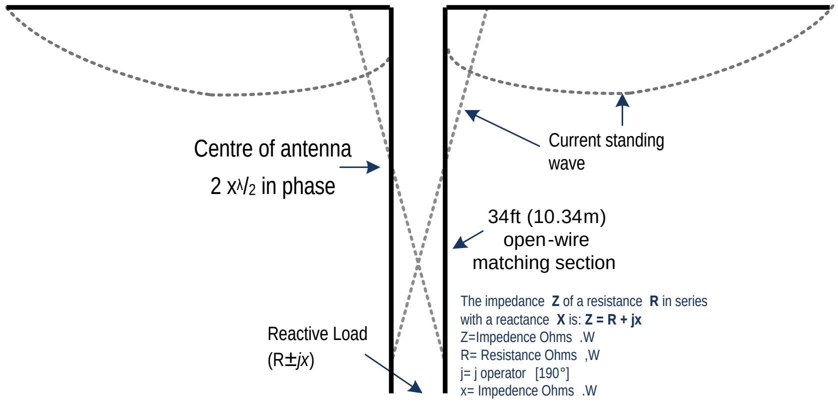


Fig 11

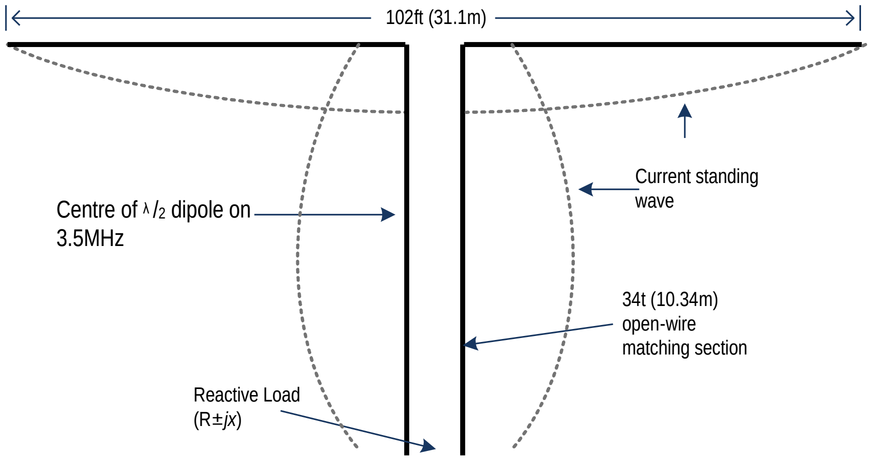


A typical central connection is shown and the Flexweave aerial wire and ribbon cable used in the author's installation.

If it is not possible to accommodate the 31.1m (102 ft) top in a straight line because of space restraints, up to about 3m (10ft) of the antenna wire at each end may be allowed to hang down at an angle or be bent in a horizontal plane, with little practical effect upon performance. This is because, for any resonant dipole antenna, most of the effective radiation takes place from the centre two-thirds of its length. This aerial also worked well on 60 metres with the auto tuner. It may also be used in the form of an inverted-V. However, it should be borne in mind that, for such a configuration to radiate at maximum efficiency, the included angle at the central apex should not be less than about 120°.



On 40 metres the "flat-top" plus 16ft (4.87m) of the matching section now functions as a partially-folded-up "two half-wave in phase", by using a suitable auto-tuner the system loads well and radiates very effectively on this band.



On 80 metres each half of the "flat-top" plus about 17ft (5.18m) of each leg on the matching-section forms a slightly folded up half-wave dipole. The remainder of the matching-section acts as an unwanted but unavoidable reactance and so an auto-tuner was needed. The polar diagram is effectively that of a half-wave antenna.

In his follow-up article the author gives his experience of using resonant aerial types and more detail of the parameters that need to be considered when working NVIS. He covers information gained from the 5MHz experiment, which reinforces the information and experience Michael acquired from his tests.

The author first became interested in NVIS on a cold windy day at the top of the Downs during RAYNET exercise 'Chainlink', where RAYNET groups proved paths between themselves and other counties. Having put up a guyed aerial with a V2000 on the top we proceeded to contact other groups on vhf and uhf with not a lot of success! The author thought as he retired wet and cold to the Mobile Control Unit, that he would investigate NVIS where he could operate not on the top of the hill but in a valley shaded from the high winds of that day and putting up an aerial that was only at 5 metres, that he could erect himself. These two articles are written to share the learning experience of NVIS with others with a hope of encouraging other groups to investigate the use of NVIS. NVIS is not proposed to stand alone but will be the long distance link to other groups and between counties, the information received feeding into the existing local RAYNET repeaters on VHF and UHF.