# NEAR VERTICAL INCIDENCE SKYWAVE COMMUNICATION

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### Introduction

Over the last few months, there have been a number of references to Near Vertical Incidence Skywave (NVIS) communication. By chance, these coincided with some things that I had recently come across and prompted me to share this material more widely.

What follows is far from a comprehensive theoretical analysis. There are other members much better qualified to write on such matters and further comments would be most welcome. This article is simply an outline of the basic features of the mode, with some comments on the way in which the British Army has used it.

The concept of NVIS is not new, although its use may often be unintentional or unappreciated – both amongst the military and amateur communities. Indeed, NVIS as a term seems to have come into use only since the Vietnam war. In British military circles, it was simply known as short range skywave communication.

### The basics

The first and probably rather obvious question is whether there is anything special about NVIS as such. After all, any HF communication beyond ground wave range depends on ionospheric reflection (or more strictly refraction) and the angle at which this needs to take place is a matter of simple geometry. This says that the angle at which the signal hits the ionosphere is determined by the height of the reflecting layer and the distance between the two stations. For a single hop over a distance of about 100 miles, the angle of incidence, and the angle from the vertical at which the signal leaves the transmitter, will normally be about 10-15 degrees.

To the extent that there is a case for distinguishing NVIS from other skywave communication, it is simply the absence of a skip zone. But in some situations NVIS has distinct advantages compared with ground wave or line of sight links. A particular benefit of the mode is that terrestrial obstacles, such as mountains or dense vegetation, can effectively be bypassed. Another feature is that the path length will not vary significantly, since the geographical distance to be covered is likely to be small in relation to the height of the reflecting layer. This means that almost uniform coverage can be achieved within that range.

### Frequency selection

So why does this make NVIS different from larger angles and longer ranges? Well, the first point is that the nearer the angle of incidence gets to the vertical, the more important the frequency selection becomes. Above the 'critical frequency', a vertical signal will go straight through the ionosphere. It is a compromise between making the frequency low enough to be reflected at these angles, and keeping it high enough not to be absorbed in the lower (mainly D) regions. Both factors vary with the state of the ionosphere.

Frequency prediction charts have been available for quite some time, although I am unclear as to the extent to which this sort of information was readily available during WW2. The operational parameters for using skywaves over short and medium distances seem to have been seriously considered for the first time in 1943.

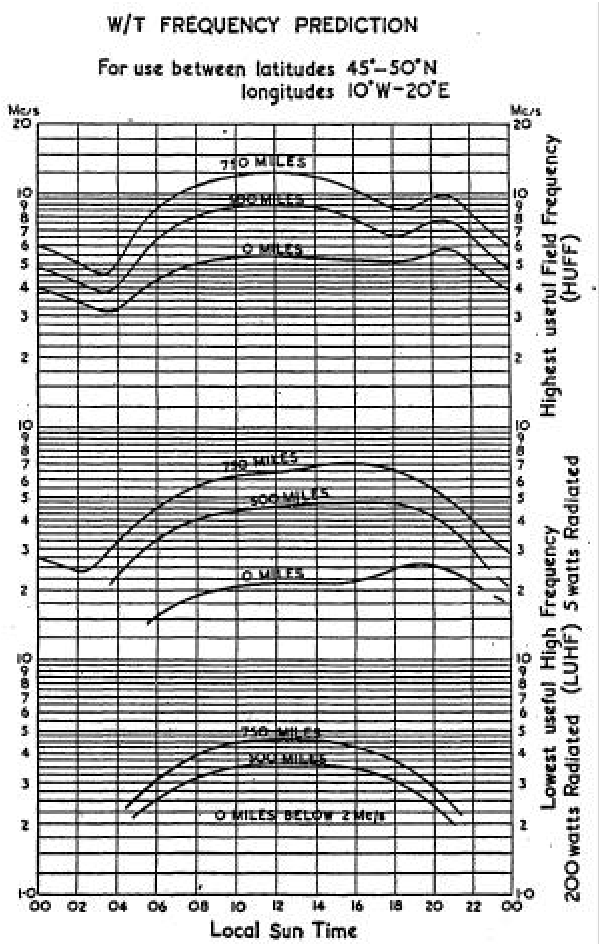


**Fig.1 – Typical frequency prediction chart**

The chart shown in Figure 1 is taken from an Army manual dated 1945. It has three sets of curves. The top set shows the Highest Usable Field Frequency (HUFF). This is 15% below the critical frequency, in order to allow a margin of error. The second and third set represent the Lowest Useful High Frequency (LUHF), based on two different assumptions as to radiated power, since this determines the ability to overcome absorption at the lower end of the frequency spectrum. The set in the middle of the chart are for use at low power (5 Watts radiated) and the third, lowest set, for use at high power (200 Watts radiated).

Within each set are three curves, corresponding to the distance between the sending and receiving stations. For NVIS, the '0 Miles' curve would be used.

Taking this chart as an example, one would be able to work out that at local noon, a suitable NVIS frequency would lie between 5.5 Mc/s and 2.1 Mc/s on low power, the lower limit extending down below 2 Mc/s on high power. One would try to pick a frequency as near as possible to the top end of the range, in order to minimise path losses. In practice, I suspect that this was not always possible, as the lower end of the HF spectrum was extremely congested in WW2[1].

The general principle is to stick as closely as possible to the HUFF, but in order to avoid a large number of frequency changes, it would be normal to pick only two frequencies, one for day and the other for night.

This sort of chart continued in use well into the Clansman era, and for all I know still is. However, frequency predictions can now be presented in a wealth of computer generated charts of much greater complexity, and these are generally available. Perhaps more significantly, there are also automatic systems of frequency selection, which are based on real time path tests.

### *Aerial design*

Equally important is the use of an aerial system that directs its radiation upwards, preferably in a fairly narrow cone. A vertical aerial is obviously out of the question, but a horizontal wire will have some vertical component in its radiation: the trick is to maximise it for full efficiency. This also has advantages in reception, as it minimises ground wave interference.

Most aerial systems designed for use with NVIS make use of the ground as a reflector. In principle, the optimum height depends on where the conducting stratum of the earth is located. The aerial should be 0.25ë above this level. In practice this stratum may be anything up to 30 feet below the surface. The rule of thumb is that the active element - usually a dipole - should be about 0.15ë above ground level. Waterlogged ground requires the full 0.25 ë – no doubt we have all been raising our aerials over the last six months!

By and large, ground and skywave working were (and should still be) regarded as mutually exclusive, as signals arriving along two different paths will cause fading at the receiver. Some care was therefore taken in the design of military aerials, which had to compromise between efficiency as a radiator in the vertical direction and convenience in being put up. These factors apply just as much for amateur work with simple wire aerials.

For military use, a vertical rod aerial was fine for ground waves but, even if sloped, was not a particularly good radiator of skywaves. A long wire would improve efficiency, but would radiate some groundwaves unless it could be kept horizontal for the whole of its length. The vertical part of an inverted L would thus need to be kept as short as possible.

Happily, this factor and the use of the earth as a reflector work together to a certain extent, so that the typical inverted L would be no more than 10 or 15 feet above ground level. This is not necessarily the ideal height from the point of view of the radiation pattern, but the Army also had to take into account the advantage of speed and simplicity in erection. In the extreme, an aerial could be extended from the back of a truck to the nearest tree.

More complicated forms of skywave aerial, basically forms of half wave dipole, were confined during WW2 to higher powered sets such as the WS53 and ET-4332B[2]. However, most of the immediate post war HF sets had a dipole as one of the basic options and, with the advent of Larkspur, dipoles became part of normal equipment.

### *NVIS in the post war era*

Almost immediately after the end of WW II, the British Army began the change to VHF for tactical communications. Despite its many advantages, however, VHF was unsuited for certain theatres in which our forces were to be involved for many years to come. The most obvious example was the jungles of Malaysia, which could reduce ground wave range to a few hundred yards or less. For these conditions, NVIS was ideally suited. It found general use, as well, for long range patrols outside the normal range of a VHF manpack.

### *The Shirley aerial*

The Malayan emergency led directly to the development of perhaps the best known NVIS aerial, and one of the most efficient. This is the Shirley, which is actually two phased dipoles with the ground as a reflector; further details are given in the appendix. In some respects it is the reference aerial for NVIS work. *[See Fig.2 – Ed]*

It was designed in about 1950 by (the then) Major John Shirley, a New Zealander who was by all accounts a most enterprising and engaging character. At the time, he was serving in the Royal Signals and on attachment to the Army Operational Research Group in Malaya.

The problem was communicating with small units in the jungle. The base station, in these operations, were usually outside the main jungle and relatively static. In addition, the same frequency could be used day and night (E region propagation, possibly?) and the opposition was not thought to have much in the way of a signals intelligence capability. After some thought

[1] The amateur bands these days are not exactly clear, either, but we are not of course allowed the luxury of being able to pick a frequency at will.

[2] In these cases, the manual suggests that the dipole should be as high as possible, up to 0.25λ. This is probably explained by the fact that such sets were basically used for long range communication.

and research, the Shirley aerial was the result. In Shirley's own words, 'the results were spectacular'.

Although troublesome to construct – a problem obviously shared with any multi-element system - the Shirley aerial remained in the Army's repertoire for many years, and probably still does.

As well as being used in Malaya, a classic example of the system is given in *The Vital Link*[3], during the Kenyan emergency. Communication had to be established across 50-100 miles, the area including the 12,000 foot high and thickly forested Aberdare Mountains. Shirley aerials and the A510 were used 'with good results.'

### *The PRC-316*

While the Shirley, and similar aerials, remained in the repertoire, it seems gradually to have become appreciated that such lengths were not always necessary. The aerial system on the PRC-316 is the ultimate simplification and, together with a superbly designed piece of equipment, was thoroughly successful.

Many readers will no doubt know this set and John Teague's excellent article in Newsletter 14 describes it in more detail. It is in brief a transistorised HF manpack designed from the outset for NVIS work in jungle conditions. Its dipole aerial is designed to be connected direct to the set, the wires then being thrown over any convenient tree, or even bush.

Various aerials were tested during user trials in the Far East. The reference aerial was a normal or 'high' dipole about 25–30 feet above the ground, connected to the set by a coaxial feeder. This was compared with a V dipole connected direct to the aerial terminals on the set, but elevated at each end by about 25 feet, and a 'bush dipole' again connected direct to the set but thrown across bushes 4–6 feet high. The V dipole was about 10db down on the high dipole and the bush dipole was only slightly worse. These figures may have been about 3db overstated, however, because of current limiting circuits, which are not operational when using the coaxial output.

Experiments were also conducted with a 'Maypole' aerial, comprising two inverted Vs at right angles to each other. Although allegedly similar in performance to the Shirley, it was found to be 3-5db worse than a high dipole in open country, and useless in dense jungle. When taken with the fact that it took almost an hour to erect, as against two minutes for the bush dipole, it was, as one might say today, a complete no-brainer.

To be fair, however, one reason for the success of the PRC-316 aerial system was probably the use of insulated wire, which meant that it could simply be thrown over a branch or bush, regardless of whether it was wet. Until then, most British sets had used bare wire or braid aerials[4], which are easy to repair but need a clear path through damp foliage – an evident source of annoyance to the soldiers expected to cut it away!

### *Current developments*

In earlier Newsletters, reference was made to current military interest in NVIS. Clearly, there is a lot to be said – both by military and civil users – for a system capable of providing reliable communications across two or three hundred miles, regardless of terrain, and without having to rely on an elaborate infrastructure (if that's quite the word) of communication satellites or fixed masts and landlines.

The problem has always been that of devising a suitably compact aerial for use on the move. At the frequencies involved, short, simple aerials are almost inherently inefficient. To an extent, this can be solved by simply turning up the power. Modern solid state transmitters can provide power outputs that fifty years ago needed a truck to carry the transmitter and probably a generator on a trailer as well. A more elegant solution is provided, however, by various forms of loop aerial. While promising, these can be quite tricky to design, as well as to keep in tune. But there does seem to be a lot of activity in this field.

Frequency selection is the other aspect in which advances have been possible. Propagation predictions are no more than that, although one Army manual does regard them as more dependable than a weather forecast! Automatic test equipment provides a real time assessment of the optimum frequency for a given path. This is not, alas, something of which the amateur is able to take full advantage.

### *Summary*

It is clear that by the end of World War 2, the British Army were well aware of the potential of NVIS, and were consciously using it in places where it mattered. By the time the A510 arrived, in the early 1950s, NVIS was part of the standard doctrine (the maximum range expected with the set was 120 miles), but was not referred to as such. The operator's manual for the A510 goes to some lengths to stress the importance of using local frequency prediction charts. It does recommend an aerial height of at least 30 feett and, ideally, of 0.25$\lambda$, although this was in the context of achieving maximum range[5].

Other sets, such as the HF 156 and PRC-316, made less play of the issue in their manuals, but were equipped with preset channels in the approximate range 2–7Mc/s, designed to allow communication at any time of the day or night. Physical constraints – such as the height of the nearest available tree or the

[3] Philip Warner (Leo Cooper, London 1989), p. 137

[4] The light patrol sets such as the A510, HF 156 and SR 128 were exceptions to this.

[5] However, there is an interesting comment to the effect that if all else fails, an aerial 2 feet above the ground might make signals audible above the background noise - a significant factor in the tropics.

length of the feeder – would have kept the height of their aerials low in relation to the wavelength.

In most cases 30–35 ft would be the highest that could be achieved, which equates to roughly 4.5MHz, using the 0.15λ rule of thumb. Indeed, even when NVIS was not the primary objective, many horizontal aerials operating in the typical army bands would have given out a fair amount of vertical radiation, and it was probably unnecessary to labour the point unless the skip zone became particularly troublesome - and the same can probably be said of many amateurs, with an 80m dipole at less than 40 feet agl.

It would be nice to try out a Shirley aerial one day. Unfortunately, it uses rather more real estate than most amateurs are likely to have available, but it might be possible at a show. Over to you, Events Co-ordinator!

### *References and further reading*

*Signal Training Pamphlet No 2* – Part IX Aerials and Frequency Selection for Corps and Divisional Signals (War Office, 1945)

*Near Vertical Incidence Skywaves in World War II: an Historical Perspective* (Dr B A Austin, IEE Conference Publication No 474)

*Swift and Sure – A History of the Royal New Zealand Corps of Signals* (Laurie Barber and Cliff Lord, New Zealand Signals Incorporated, 1996)

The material on the PRC-316 user trials is drawn from two unpublished reports, which I found in the archives of the Royal Signals Museum. On the same occasion, by sheer co-incidence, I also met the head of the team which had designed the set! A worthwhile occasion, indeed.

*Near Vertical Incidence Skywave Communication* (David M Fiedler and Edward J Farmer, Worldradio Books, 1996)

A good deal of interesting information on the present day use of NVIS can be found at [www.tactical-link.com](http://www.tactical-link.com). (Turn down the sound if you don't like Wagner!)

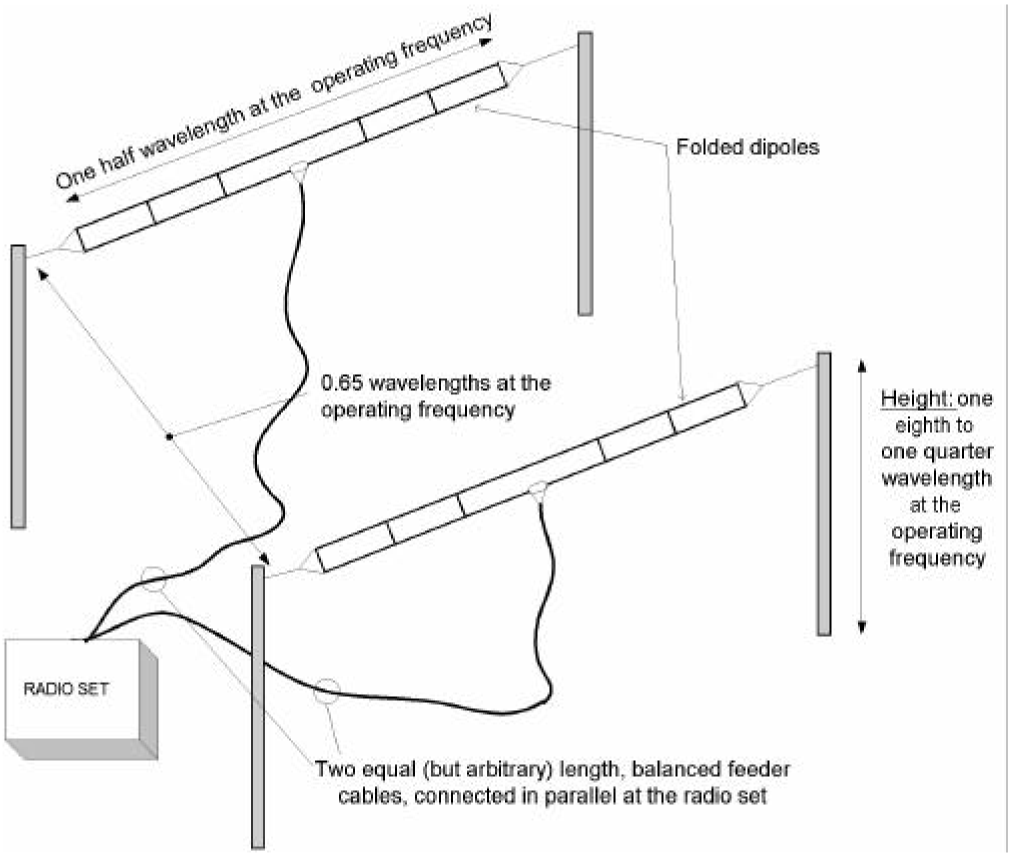


***Fig.2 – a sketch of the Shirley antenna***

*(basic design from Blandford School of Signals Antenna Handbook.)*

## Appendix – some dedicated NVIS aerials

### *The Shirley*

In its original and simplest form, the Shirley aerial seems to have comprised two half wave open dipoles, fed by twin mine detonating cable. An important factor was ease of construction from readily available stores!

In this configuration, the dipoles have a rather low input impedance and there must have been mismatches all over the place. The whole system, however, could be resonated with the aid of the output tuning circuits in the transmitter. If necessary, the length of the feeders could be altered, by equal amounts, to enable this to be done.

A development of the original version is to raise the input impedance by using folded dipoles. 150Ù twisted feeder can then be used to give an approximate 75Ù match. Again, it seems possible to use a variety of more or less ad hoc feeders - including lighting flex, which often has an impedance of about the right figure. *[See Fig.2 for a sketch of this particular type – Ed]*

The ultimate stage, perhaps, is to make the whole thing out of 300Ù ribbon, with a balun transformer in the middle.

### *The Jamaica*

A relative of the Shirley is the Jamaica, so called from its use on that island. In this case, the dipoles are full wave, but it is otherwise similar in design. See Fig.3.

### *Other designs*

The main problem with both these aerials, apart from construction, is that they are essentially fixed frequency. Alternatives are possible, such as fan dipoles, but as you go up the scale, things inevitably become more complicated. A vertically directed log periodic dipole is all very well in theory, but is hardly likely to be suitable for an amateur's back garden, or even as a 'field expedient' aerial for military use.

The great prize remains that of designing an efficient aerial for mobile use. It seems that a great deal of effort has been put into this problem in recent years, and solutions are usually based on some form of loop. The IEE conference papers, mentioned in the references given above, include a couple of interesting papers, for example. But they are really outside the scope of this article.

**Fig.3 – a sketch of the Jamaica antenna**