A Review of WICEN HF Communications Capability

Abstract

During a recent event, some problems were experienced with the traditional lower HF band communications often used for WICEN events.

This paper describes what occurred, offers a summary of MF and HF propagation modes and propagation tools available to WICEN, examines some shortcomings in present WICEN practice, and makes some recommendations for exploitation of HF communications and for WICEN operator capability.

Introduction

A recent WICEN event was the Australian 4 Day Enduro (A4DE), held in the Mansfield area of north-eastern Victoria over 16 – 18 November 2016.

It was planned to use 40m HF during the day for one checkpoint and as a backup for others. However propagation was very poor and HF was essentially unusable in its planned role.

This failure, and the causes of it, have important implications for the ability of WICEN to offer local to medium range communications on HF.

To this end, this paper includes a summary of useful propagation modes in the MF and low HF bands, which are likely to be of use for this service. It examines failure of the mode used for the A4DE and what other options may be available. It also identifies a very useful propagation tool freely available to WICEN operators.

It ends with some recommended changes to current practices and some suggested additions to WICEN capability.

Communications Failure

The event Communications Plan called for use of 40 metres (40m) during the day for communication to one checkpoint in particular, and as backup in general. This would have exploited Near Vertical Incidence Skywave (NVIS) propagation. However NVIS was essentially nonexistent and 40m was unusable for the intended purpose.

Propagation on 40m during the day has been unusual for many weeks, often the usual strong NVIS signals are absent although longer range communication is perfectly usable (eg into New South Wales).

As will be discussed later, this is associated with low solar flux resulting in no reflection of high angle signals from the ionosphere although lower angle signals are reflected.

A Summary of HF Propagation for WICEN Purposes

There are 3 principal MF / low HF propagation modes useful for WICEN operation. These are:

. Ground Wave

. Near Vertical Incidence Sky Wave (NVIS)

. Surface Wave

Each has its own characteristics. Surface Wave is often included under Ground Wave but has some important properties which warrant treating it separately.

Ground Wave

Ground Wave is usually taken as propagation over a direct path from transmitter to receiver (the direct wave). It is not affected by the ionosphere.

Ground Wave is typically short range, although on the MF bands Ground Wave can extend to maybe 100km or so. This is actually a distinct propagation mode (Surface Wave) which is discussed later.

Ground Wave communication is possible with both horizontal and vertical antennas.

NVIS

As its name suggests, NVIS communication uses sky waves – propagation via the ionosphere, using near-vertical radiation from the transmitter which is reflected and returned to earth over a range of up to several hundred km.

Antennas

Successful NVIS operation requires antennas which can radiate or receive efficiently at high angles to the ground (near vertical) and also requires reflection of the near-vertical signal from the ionosphere.

Typically, low horizontal dipoles provide the required radiation pattern and are recognised as very suitable for the purpose. Vertical antennas generally do not produce much high angle radiation and are not suitable for NVIS.

There is a widespread belief that with a mobile HF antenna, pulling the whip to near horizontal will provide NVIS capability. This myth arose from a WW2 US Army communications manual describing exactly this practice. However more recent work has shown that this is not the case, although the myth persists.

Other antennas (such as end fed wires) may (or may not) provide efficient NVIS operation. In general horizontal dipoles (or related antennas such as inverted Vees) are recommended. Dipoles are also much less prone to other trouble such as RF feedback or “hot” RF on equipment.

Propagation – D layer Absorption

Absorption occurs during the day mainly in the D layer, due to ionisation created by radiation from the sun. D layer absorption hinders communication via the ionosphere during the day on 80 metres. However higher frequencies (for example 40m) are absorbed much less.

D layer absorption starts an hour or so after sunrise and increases during the morning, peaking around noon. The maximum absorption usually lasts 2 to 3 hours then gradually reduces until about an hour after sunset. It is the reason that 80m drops out in the morning but then opens up again in the evening.

Note that signals may still be usable in the morning and afternoon, because E layer reflection can still occur even though there is high D layer absorption. For example weak signal digital modes such as Pactor may still be usable whereas signals may be too weak for voice.

Propagation – E & F layer Reflection
Reflection occurs in the E or F layer, which are above the D layer. For NVIS, the E layer reflects signal up to maybe 4 MHz, with reflection in the F layer up to about 12 MHz (assuming reasonable solar activity).

Reflection is frequency-dependent, with only relatively low frequencies reflected straight back down (vertical incidence) with higher frequencies reflected at progressively more glancing angles as frequency increases.

Obviously as the angle becomes more glancing the reflection travels further before again reaching the ground. The maximum frequency at which this reflection will occur, for a given range (or associated angle) is called the Maximum Usable Frequency (MUF).

Although communications could be established using the MUF, a somewhat lower frequency is usually more successful. This is called the Optimum Working Frequency (OWF) which is typically about 80% of the MUF.

A special case of the MUF is when the radiation is straight up and returns to earth. This is called the *critical frequency* and is important to NVIS propagation. If the critical frequency is lower than the frequency in use, NVIS is not possible.

During times of low solar flux (such as at present) it is possible for the critical frequency to fall to 2 MHz or less. D layer absorption increases at lower frequencies, so if the critical frequency is low, no NVIS operation may be possible.

High Reliability HF Communications
Contrary to common opinion, highly reliable HF operation CAN be achieved despite the vagaries of propagation. RECOM achieved 100% reliability in more than 140 activations over 14 years. So it can be done.

The factors RECOM (and now WICEN SCU) employ are:

- Forecast propagation information to operators
- Active frequency management
- Multiple frequency options
- Location diversity
- Modes suitable for weak signal operation.

Active frequency management means taking active control of frequency choice, based on the best available propagation information. This is covered in the next section.

Provision of forecast propagation data to operators is challenging for voice modes but is easily done with digital systems.

Multiple frequency options are necessary to exploit propagation forecasts to best advantage.

An example of location diversity would be a station located in central New South Wales to take advantage of single-hop 40m propagation from Victoria during the day, which will still usually be possible even when NVIS operation is not. EMCOM have a Network Station in Darwin for similar reasons.

Weak signal modes are an advantage. Voice needs +10 to +15 dB signal to noise ratio. Some digital systems can reliably decode to better than -20 dB S/N, a huge advantage. For example, this can enable operation on 80m during the day when E layer reflection still exists but D layer absorption precludes voice operation. (This actually happened during the A4DE).

Propagation Prediction
A very useful tool is the Ionospheric Prediction Service web pages established initially for RECOM and now used by the EMCOM group and the WICEN Special Communications Unit. They are publicly accessible and are located here:
http://www.sws.bom.gov.au/Products_and_Services/5/4

There are two sets of maps, the Hourly HAP charts and the Daily HAP charts. (HAP = Hourly Area Prediction). The differences are as follows:

The Hourly HAP charts are derived from near real time ionosonde measurements of present propagation and show the MUF. In general, it will be necessary to use a somewhat lower frequency (about one colour bar) to obtain reliable communications.

The Daily HAP charts are forecast propagation based on measurements of solar X-ray flux. The values shown are the forecast Optimum Working Frequency (OWF). The Daily HAP charts are useful to plan any frequency changes necessary due to changing band conditions.

The most useful propagation maps (for WICEN purposes) are the Daily HAP charts for Regional Melbourne. The central area of the “donut” shows the highest frequency usable for NVIS propagation. Essentially, if the OWF over the Melbourne region falls below about 7 MHz, NVIS propagation during the day will be poor on available amateur bands, so other means will be required.

Recently night-time propagation on 80m has also been somewhat unstable. This is an indication that the MUF for NVIS operation (ie critical frequency) is very low, probably below 4 MHz. The MUF can fall to as low as 2 MHz making all amateur NVIS operation impossible, day or night.

Surface Wave

Surface Wave propagation is a mode unique to the MF spectrum. It is only useful below about 2 MHz. Essentially the radiated wave from the transmitter “creeps” over the surface of the earth. It can only occur with vertical polarisation, meaning vertical antennas are essential.

Surface Wave propagation on 160m can offer very reliable propagation out to maybe 80 to 100 km – essentially the same as offered by a MW broadcast station (which also uses this mode). Even a 160m mobile whip (which is quite inefficient) is reliable to more than 50 km. A better antenna can offer more range.

This mode, using vertical antennas on 160m, should be considered for use as the “fallback mode” when NVIS communication on HF is not available.

160m operation will always involve antennas which are short in terms of wavelength, meaning tuning and matching networks are necessary.

A “screwdriver” type mobile antenna forms a good basis for a 160m portable system, with the addition of an insulated vertical mast (6 to 10 metres), an additional loading coil, and some on-ground radials to form a counterpoise. The screwdriver can be used to bring the antenna to resonance. A base matching unit for a HF whip can be used for the same purpose. Fixed-tuned HF antennas such as helical whips, "Hamsticks" and similar are not so suitable.

Recommendations

1. Seek to improve WICEN operators' understanding of the propagation modes available on the MF / lower HF bands, and the foibles of each;
2. Encourage operators to make effective use of the IPS web pages which are there for their use;
3. Encourage construction and use of effective NVIS antennas, especially dipoles which are known to work well;
4. Discourage use of mobile HF antennas (which are known NOT to work well) for portable operation;
5. Encourage operators to develop the capability to exploit the surface wave propagation on 160m, for use when NVIS is not available. This will require development of suitable vertical antennas with tuning and matching systems.