[poster] The Importance of Circular Polarization for Diversity Reception and MIMO in NVIS Propagation

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The Importance of Circular Polarization for Diversity Reception and MIMO in NVIS Propagation

Near Vertical Incidence Skywave (NVIS)

Ionospheric radio propagation can be used to create a continuous coverage area of 200 x 200 km without intermediate infrastructure. To achieve that, radio waves must be launched nearly vertically, typically 70 to 90º. Hence the name "Near Vertical Incidence Skywave" (NVIS).

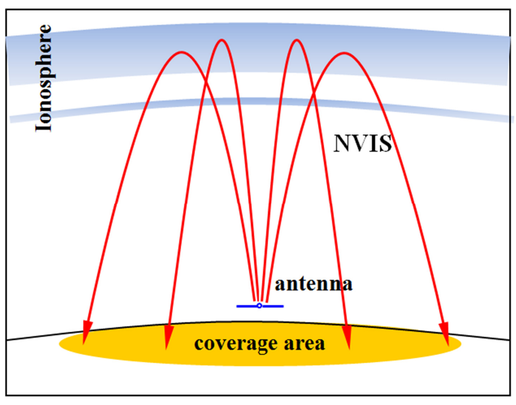

Fig. 1: Near Vertical Incidence Skywave (NVIS).

The independence of a ground-base infrastructure makes NVIS ideally suited for Disaster Relief operations.

It is also used extensively in Third World countries in areas where telecommunication infrastructure is lacking or unreliable.

NVIS radio wave propagation is very efficient: a single 100 Watt transmitter will produce a received signal >60 dBµV in the entire coverage area if half-wave dipole antennas are used.

That is: if an appropriate frequency is selected. Typical frequencies range from 3 to 10 MHz.

Signal Impairment: Fading

The NVIS signal varies substantially over time.

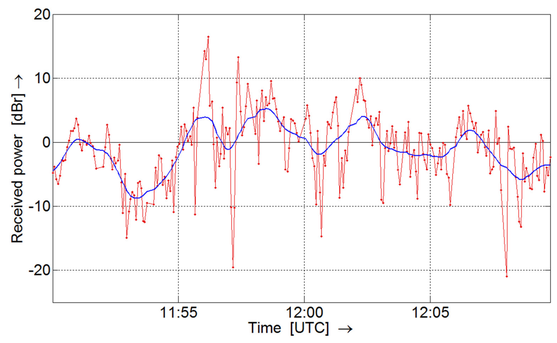

Fig. 2: Variation of the received NVIS signal over time. Red: received signal. Blue: 30-second floating average.

Fast (millisecond tot second) variations of +10 to -20 dB are superimposed on slower (seconds to minutes), generally less pronounced, variations.

This phenomenon is called "fading" and is typical for ionospheric radio wave propagation.

Fading adversely influences radio link reliability and throughput.

Diversity Reception and HF MIMO

The adverse influence of fading can be reduced significantly if two (or more) antennas and two (or more) receivers are used.

Diversity Reception

If the fading on both antennas is different, the output of the receivers can be combined to produce a more stable signal. This process is called "spatial diversity reception". Only one transmitter is needed.

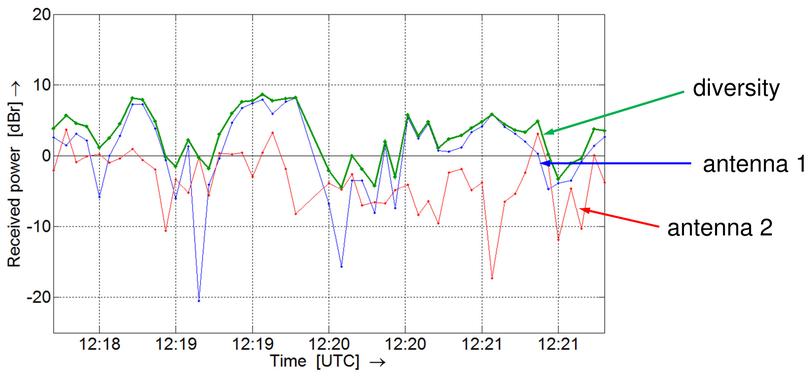

Fig. 3: Diversity: combination of two received signals with different fading.

HF MIMO

In Multiple Input Multiple Output (MIMO) the data is coded in two different data streams which are send over two transmit antennas, on the same frequency. Two transmitters are needed.

On HF (3 - 30 MHz), after ionospheric reflection, the superimposed signals from these two data streams arrive at the two receive antennas. If both transmission paths are sufficiently decorrelated the original data streams can be reconstructed, increasing the data throughput.

How To Decrease Path Correlation?

Diversity Reception and MIMO become more effective when the correlation between the received signals decreases.

But achieving low correlation is difficult at HF (3 - 30 MHz). Other HF MIMO research reports correlation factors of 0.5 to 0.8, using crossed dipoles or verticals separated by several wavelengths.

Ordinary and Extraordinary Wave

Entering the ionosphere radio waves split into two characteristic waves with circular polarization (CP) of opposite sense. Both waves travel independent paths through the ionosphere, with different delay and attenuation. Can we exploit this natural phenomenon?

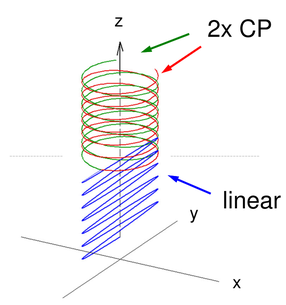

Fig. 4: A linear polarized wave is split into two CP waves in the ionosphere.

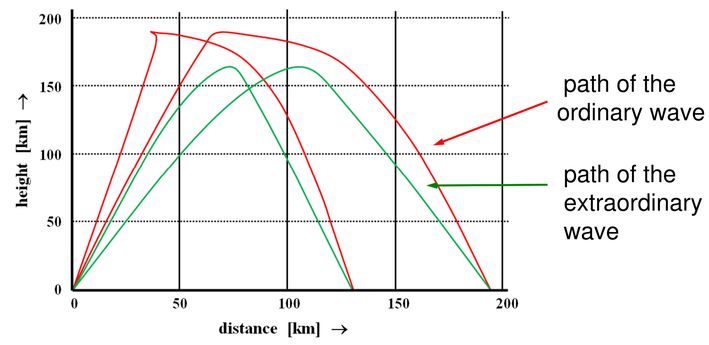

Fig. 5: Both characteristic waves follow different paths through the ionosphere.

Circular Polarization Experiment

Using an NVIS antenna that has circular polarization with switchable sense of rotation, the field strength of the ordinary and extraordinary wave can be measured separately.

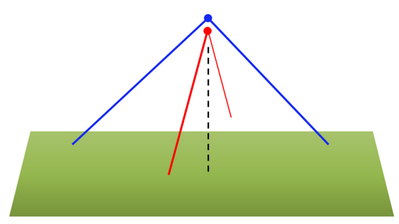

Fig. 6: Turnstile antenna: two perpendicular Inverted Vee dipoles, quadrature fed.

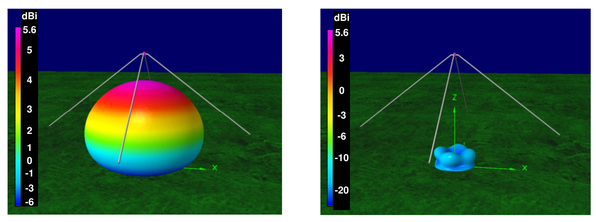

Fig. 7: Co-polar and cross-polar radiation diagram.

After sunset, the ionization of the ionosphere slowly decreases.

At a certain point NVIS propagation is no longer possible for the ordinary wave, while the extraordinary wave is still reflected.
In this interval we can measure the decoupling of both waves.

This measurement is also possible in the morning, during ionization build-up, when NVIS propagation starts.

Repeated measurements show more than 25 dB isolation!

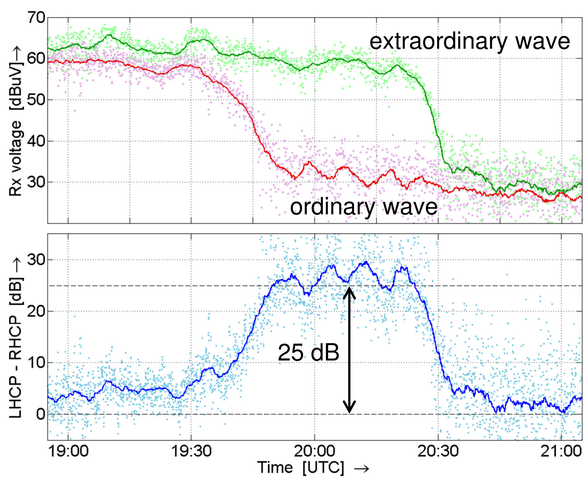

Fig. 8: Measurement of the ordinary and extraordinary wave, showing their isolation.

More than 25 dB isolation!

The experiment proves that two highly isolated paths through the ionosphere can be created by transmitting and receiving with left hand and right hand circular polarization.

Application of this technique will greatly improve the performance of HF MIMO in NVIS.

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