Skywave HF Propagation:

Hourly, Seasonal, and Solar Characteristics & Their Effect on Skywave HF Coverage Predictions

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HF Skywave Propagation: The Variability and the Variables

High frequency (3 MHz to 30 MHz) skywave radio frequency propagation is highly sensitive to environmental characteristics; sunspot number, month/season, time of day, receiver noise environment, etc., will all alter a point-to-point or point-to-area HF skywave analysis to some degree. Different combinations of the variables will yield different variations in the skywave coverage plot. Some environmental characteristics have a bigger impact than others.

For this reason, HF skywave coverage will vary on an hourly basis. To most accurately predict the reliability of HF skywave communication between two points or from one point to many points, one must know the variables that are inherent to HF skywave analysis and be able to obtain real-time or predicted values for those variables. This is often difficult, since information about the state of the Earth's ionosphere, the Earth's layer that is most responsible for changes in HF skywave propagation, is difficult to find. For this reason, averages and calculated predictions must often be used.

The following analysis for a hypothetical HF station will demonstrate a simplified view of how some of the environmental effects alter the resultant coverage plot. A hypothetical 4 kilowatt station is set up in Virginia Beach, VA. It is assigned frequencies of 4 and 10 megahertz to simulate an ALE (automatic link establishment) system since ALE systems are commonly used for HF communications due to the unpredictable environmental constraints. The station is assigned a generic horizontally-polarized medium- to long-range antenna for greater real-world relevance. Only one parameter will be varied at each time to isolate and analyze the effects of the alteration of that parameter.

ATDI Spectrum-E is used to create the coverage predictions in this simplified analysis. The ATDI Spectrum-E web application uses the most up-to-date version of the International Telecommunication Union's HF propagation model: ITU-R P.533, Method for the prediction of the performance of HF circuits. The tool features both point-to-point reliability for HF skywave communications as well as point-to-multipoint area coverage for network analysis and design.

Time-of-Day Variations

HF skywave propagation is greatly dependent on solar activity in general, not just the sunspot number that measures the amount of anomalous activity on the sun's surface. HF skywave propagation is typically weaker during daylight hours due to changing conditions in the Earth's ionosphere that are not conducive to signal propagation. Various layers in the Earth's atmosphere will either prove to be absorptive or not prone to signal reflection, yielding poor propagation characteristics in a propagation method that is strongly reliant on reflection.

The two figures below show the difference in expected HF skywave propagation from the hypothetical Virginia Beach, VA, station at the hours of 1600 UT and 400 UT for a summer month in a year with a relatively high sunspot number. The coverage is shown for signal-to-noise ratios between 5 and 45 dB. The hours chosen are 12 hours apart and represent daytime and nighttime, respectively.

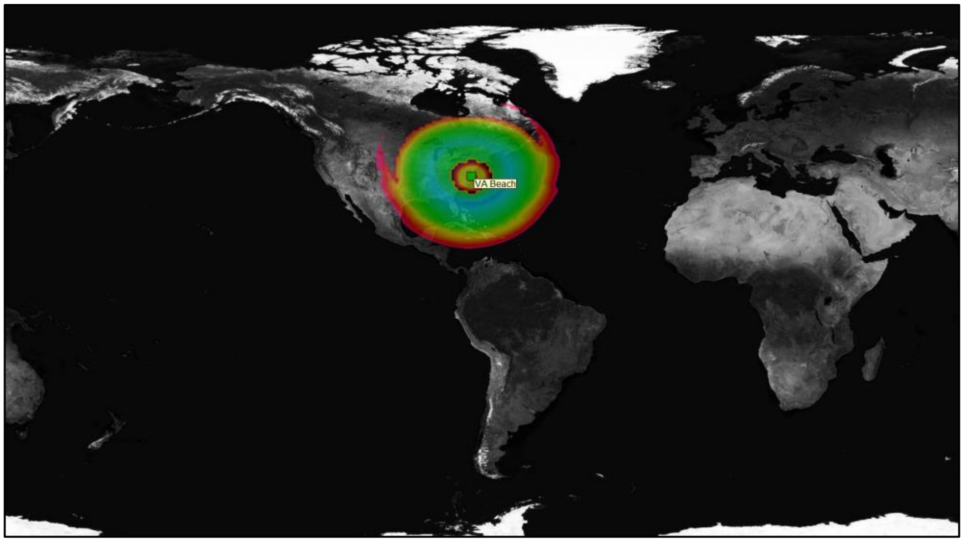

Figure 1: HF skywave propagation at 1600 UT

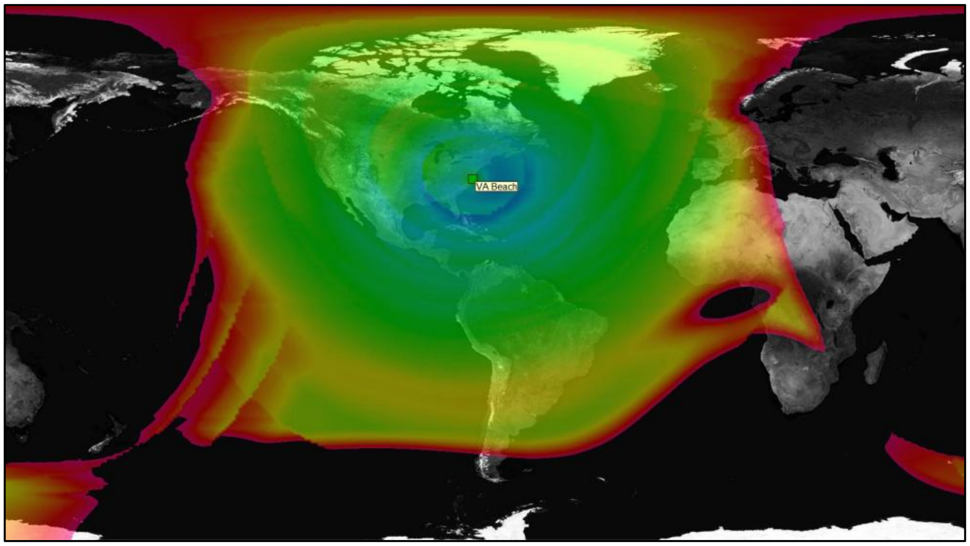

Figure 2: HF skywave propagation at 400 UT

As can be seen above, the difference in the extent of the coverage predictions is vast in this example. The HF skywave coverage that would be offered by the hypothetical Virginia Beach, VA, station at night is many times larger than during the daytime. Understandably, if the user is to cycle through a 24-hour period of coverage predictions, the differences on an hour-by-hour basis would not be as vast.

The time-of-day will thus have the greatest impact on HF skywave propagation, especially during summer months when there are more daylight hours then there are night-time hours. During the winter months, when the night-time hours take precedence, the difference in coverage may not be as vast. The effects of monthly / seasonal variations are summarized in the following section.

Monthly / Seasonal Variations

As with the difference between hourly HF skywave coverage plots, differences can be noted between months and, more generally, the four seasons. Monthly and seasonal variations can be attributed to differing daytime and nighttime lengths, variations in the Earth's ionosphere, and other more general seasonal differences.

The figure that follows displays the difference in area percentage-of-day coverage prediction between the months of December and July for a year with a relatively high sunspot number. There are two shades on the map; a dark green area represents coverage for 90% or more of the day while a light green area represents coverage for 75% or more of the day. In this case, and as is often true, the coverage prediction shows greater breadth of coverage for the month of December.

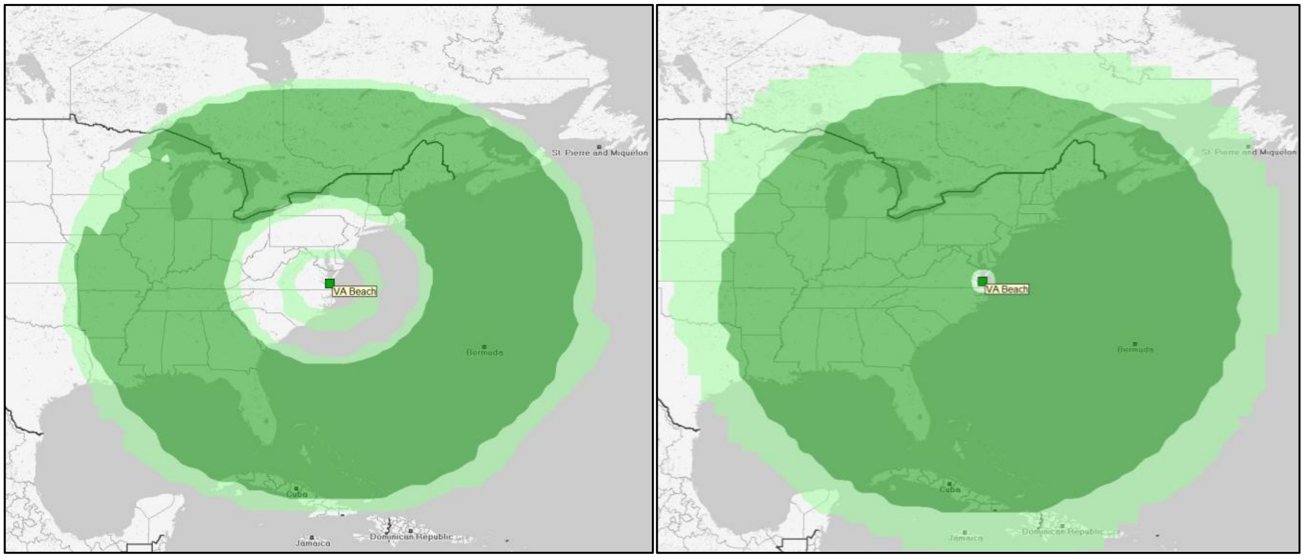

Figure 3: Effect of seasons (July on left, December on right)

Coverage is likely to be more reliable in the winter months because of the greater amount of nighttime hours when HF skywave propagation generally tends to offer more reliable coverage. Of interest is also the pronounced 'skip zone' that occurs around the transmitting station during the summer month of July. This shows a greater tendency for the HF signals to not reflect from the ionosphere but to travel directly through it at near-vertical incidence angles.

Solar Activity & the Sunspot Number

The sunspot number is a daily count of the number of areas on the Sun's surface where there is a significant drop in temperature (typically down to 3700 Kelvin from an average of 5700 Kelvin). These extreme temperature differences create strong magnetic fields that are several orders of magnitude stronger than the Earth's magnetic field. This alters the tropospheric conditions of the Earth and thus HF propagation which is highly sensitive to changes in the Earth's troposphere.

The sunspot number has been tracked for over 250 years. Analysis of the historical sunspot numbers reveals an eleven year cycle with an average value of 52. Typical low sunspot numbers are below 10 while high sunspot numbers may eclipse 100 and even 150. For the two figures below, the sunspot numbers used to generate the coverage predictions are 10 and 100 respectively.

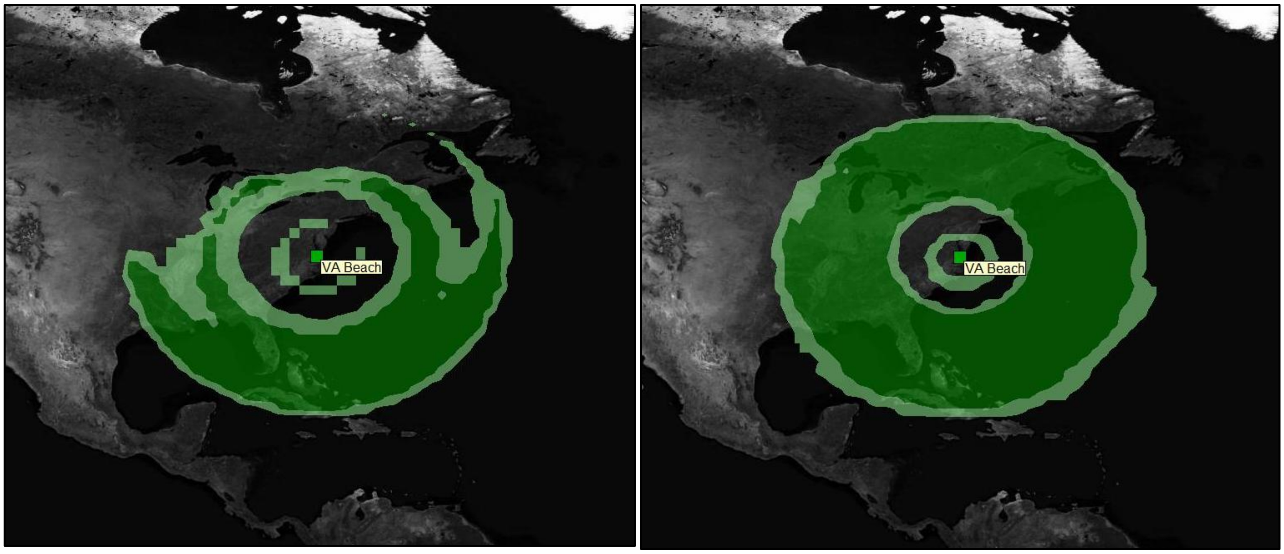

Figure 4: Effect of sunspot number (10 on left, 100 on right)

As with the coverage predictions shown for monthly/seasonal variations, the light green color in the figures above denotes coverage reliability of 75% and greater while the dark green color denotes coverage reliability of 90% or greater. While the general shape of the predictions is similar, the prediction generated for the lower sunspot number of 10 shows generally weaker reliability north of the hypothetical station. The coverage prediction generated for the higher sunspot number of 100 shows improved reliability north of the hypothetical station in Virginia Beach.

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