Paper ID #35304

Using NIST's Shortwave Broadcast Signals to Experience and Understand Ionospheric Radio Propagation

Dr. Paul Benjamin Crilly, United States Coast Guard Academy

Paul Crilly is a Professor of Electrical Engineering at the United States Coast Guard Academy. He received his Ph.D. from New Mexico State University, his M. S. and B.S. degrees at Rensselaer Polytechnic Institute, all in Electrical Engineering. He was previously an Associate Professor of Electrical and Computer Engineering at the University of Tennessee and was a Development Engineer at the Hewlett Packard Company. His areas of interest include laboratory development, antennas, wireless communications, signal processing, and instrumentation.

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By
Paul B. Crilly, Ph.D
U.S. Coast Guard Academy

Abstract

We discuss the use of NIST's high-frequency (HF) broadcast signals to enable undergraduate engineering students to experience and thereby better understand how the ionosphere can enable transcontinental wireless communication. We will demonstrate this phenomenon using signals of opportunity such as NIST's 5 and 10 MHz time/frequency broadcasts. We also discussed how the *D*-layer absorbs signals below 8 MHz and thus inhibits long distance transcontinental sky-wave radio propagation during the daylight hours.

Introduction

Radio waves, like light waves normally travel in a straight lines. However, they can traverse the earth's curve by means of diffraction, reflection, refraction or reflection. Signals that propagate below 10 km from the earth's surface, are referred to as *ground-waves*, and those that propagate via refraction or reflection off the ionosphere are referred to as *sky-waves*. These two means are illustrated in Figure 1. Ground wave propagation occurs over relatively short distances and is either a direct wave, a wave that reflects off a terrestrial object, or in cases where the distances are greater than line of sight (i.e. greater than 30 miles) occurs via the Norton Surface wave where the signal traverses the earth's surface. In a few cases, VHF and UHF signals will refract off of dense air layers in the troposphere. This is a relatively transient occurrence. See references [1] – [4] for more information on these means of deflecting radio waves. Generally, long distance communication for signals below 3 MHz are typically by the Norton Surface wave. However as the frequency increases, signal attenuation also increases. Practically this method of propagation is limited to frequencies below 3 MHz.

Sky-wave propagation is where the signal seemingly "bounce" off the *E* or *F* layers of the ionosphere and thereby enable long distance communications in the medium frequency (MF) and high frequency (HF) bands. This is why international broadcast signals such as the BBC and VOA as well as NISTs and CHU-Canada's time signals can be heard across continents. Prior to satellite relay, most distant communication was done using either sky or surface wave means.

Sky-wave propagation does have limitations. During the day, when the propagation path is facing the sun, signals below 8 MHz will be absorbed by the *D*-layer. This is the reason why local AM broadcast stations are only heard via the ground-wave during the day. While at night when the *D*-layer goes away, AM stations can be heard at distances exceeding several hundred miles away. There is also an upper limit on the maximum frequency that will enable refraction off the *E* or *F*-layers. This is typically 15 MHz, but will vary based on solar conditions. Finally, with sky-wave, some destinations could be "skipped over" as shown in Figure 2.

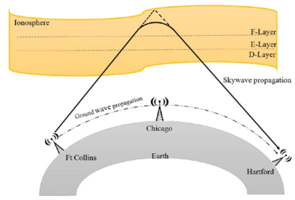

Figure 1. Ground wave and sky-wave propagation [1]

Experimental

Using a short wave receiver and a 100 foot wire antenna located at Old Lyme, CT, the 5 and 10 MHz NIST signal levels were recorded over a 24 hour period and is plotted in Figure 2. Note that the 10 MHz signal is received almost 24/7, whereas, the 5 MHz signal is only received during the night-time hours. Again, the 5 MHz signal was prevented from propagating to Old Lyme, via *D*-layer absorption.

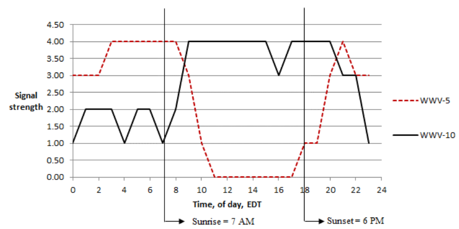

Figure 2. Signal strength versus time of day for 5 and 10 MHz NIST signals transmitted from FT Collins, CO to Old Lyme, CT. Terrestrial distance is approximately 1800 miles [1].

Classroom experience

To enable EE students at the Coast Guard Academy in New London, CT, to experience and thereby better learn about HF propagation, they repeated the above experiment. Each hour they listened, recorded and then plotted the 5 and 10 MHz NIST signals using a Kenwood IS-590 HF receiver and a 100' wire antenna in nearby New London, CT. Their results were similar to that plotted above. More importantly however, by listening to the NIST broadcasts over a long period of time they were able to experience first-hand HF propagation phenomena, get a "feel" for the behavior of the HF band and thereby better learn and understand HF propagation.

Conclusions

Using relatively simple and low-cost apparatus, students will readily observe and thereby better understand sky-wave propagation.

References

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