

# Ionospheric Propagation

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## Purpose

On the High Frequency (HF, 3 - 30 MHz) radio bands, radio waves are able to travel around the world without the help of satellites, repeaters, or any other intermediate equipment. They do this by bouncing between ionosphere and the earth before reaching their final destination. Amateur radio operators, shortwave broadcasters, ships on the high seas, and the military are just some of the groups that make use of this phenomena, known as sky-wave propagation. Because the ionospheric conditions are dependent on solar activity, it is important to study how solar phenomena affects radio propagation.

## Location

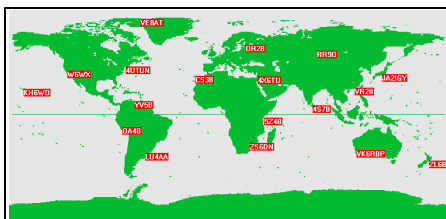
The radio listening equipment for this project is located at Montclair State University in NJ, eleven miles outside of New York City. The antennas are located on the roof of the fourth floor of the science building in an environment heavily light polluted at all wavelengths.

## Radio JOVE

Radio JOVE was developed by NASA and the University of Florida to monitor radio bursts from Jupiter and the Sun. The radio telescope consists of a 20.1 MHz receiver connected to a calibrator and dipole array. The output of the system connects to the sound card of a computer that uses the *Radio Skypipe* data logging program by Jim Sky. It records amplitude changes versus time and provides various graphical and analytical tools, as well as the ability to share data with other astronomers on the internet. Members of the Radio JOVE community share and archive their data on a website maintained by the Goddard Space Flight Center. More information about Radio JOVE and *Radio Skypipe* is available at <http://radiojove.gsfc.nasa.gov>, <http://jovearchive.gsfc.nasa.gov>, and <http://www.radiosky.com>.

## DX Beacons

DX Propagation Beacons are automatic radio stations that help amateur radio operators know what locations in the world they can make contact with. The network of radio beacons monitored in this study is a project of the Northern California DX Foundation (NCDXF) and the International Amateur Radio Union and consists of 18 transmitters spread throughout the world. Each beacon uses Morse code to transmit its call sign and four pulses (100 W, 10 W, 1 W, 1/10 W) into a vertical antenna. It repeats this on each of five different frequencies: 14.100, 18.110, 21.150, 24.930, and 28.200 MHz. The beacon network is carefully timed, so that no two stations ever transmit on the same frequency at the same time. It takes three minutes for the beacon network to complete one full cycle.



Call Signs and Locations of NCDXF Beacons

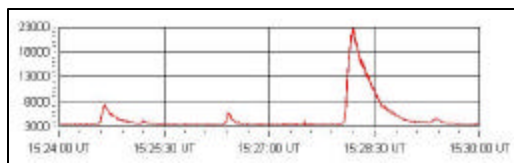
To monitor the NCDXF beacon network, a Cushcraft R7 Vertical Antenna and Icom 746PRO HF radio were used. The audio output of the radio was connected to the sound card of a computer that recorded all measurements. A radio-computer control interface was also used in order to automatically switch between all of the different beacon frequencies. The software package *Faros*, by Alex Shovkoplyas (VE3NEA), monitored each of the five frequencies and recorded the signal to noise ratio (SNR) for each beacon. *Faros* then prepared a graphical display of all of the SNR readings, as well as provided a text log file that could be used for later analysis.

Data from the log file was uploaded to a MySQL database, from which the SNR data for any beacon, date, and frequency could be graphed, viewed, and downloaded through a web-based interface (<http://school.w2naf.com/beacons>).

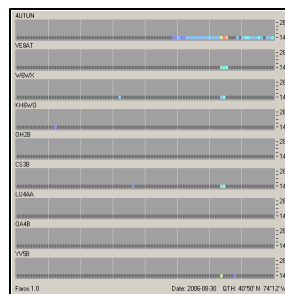
## Radio Events

Event of August 29, 2006, 15:28 UT

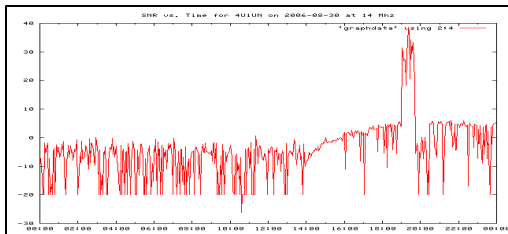
This was the strongest radio burst and the most active radio day from August 15 to the end of 2006. The Jove community usually posts five to ten observations per day about a few events. However, on August 29 there were 74 observation reports about 46 separate radio events, with one of them being 78 million K in antenna temperature. The beacons responded the next day with a ground swell and then a large strong spike of excellent propagation. The spike was at the same time for all six beacons (California, United Nations, Canada, Venezuela, Madeira, and Israel), 27.5 hours after the strongest radio burst.



Radio JOVE Data from 29 AUG 2006



Faros Beacon Data from 30 AUG 2006



Faros Beacon Data from 30 AUG 2006 for 4U1UN at 14 MHz

## X-Ray Events

During the day, the ionosphere is composed of four regions: D, E, F<sub>1</sub>, and F<sub>2</sub>. When a radio wave hits the ionosphere, one of three things can happen. If the radio frequency is too low, it will be absorbed by the ionosphere. If the frequency is too high, it will cut through and go into space. If it is in the middle, it will be reflected back to earth. When the ionosphere is strong, the threshold values for each of these boundary frequencies increase.

UV and X-Ray emissions from the sun directly affect the strength of the ionosphere. UV rays ionize the F regions, soft x-rays (10 to 100 Å) ionize the E region, and hard x-rays (1 to 10 Å) ionize the D region. If the lower regions are strong, frequencies up through the middle of the HF band may be absorbed, and therefore will not propagate. Frequencies above this could cut through the D and E layer, but still be reflected by the F layers.

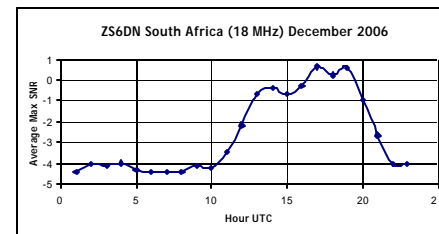
Active Region 930 produced a string of strong x-ray events on December 5, 6, 13, and 14, causing the astronauts to take protective cover in the ISS. These were small radio events and had a different effect on our beacon detection than the large radio bursts of August.

Only a few beacons showed any effects, and that was an immediate drop at the lower frequencies (3.4 and 19 MHz), but also in strength at the higher frequencies (24 and 30 MHz).

## Procedure

Although it is possible to hear radio stations from around the world on the high frequency radio bands, not every station can be heard all of the time. Of the eighteen NCDXF beacons, only a handful could be heard reliably every day. The United Nations in NY, 4U1UN, was strong all of the time because of its close proximity to Montclair State University. Many beacons could be heard rarely, or not at all. North Eastern Canada (VE8AT), California (W6WX), Hawaii (KH6WO), South Africa (ZS6DN), and Madeira, Spain (CS3B) were all received reliably on a daily basis between 1200 and 2200 UT.

Because of this behavior, a baseline was created so that we could identify times when the reception of a beacon varied from these average results. On a given channel we averaged the SNR (Signal to Noise Ratio) for each hour UT for a whole month. This established a baseline of average SNR versus hour which was then subtracted from the individual SNR readings throughout that given month. Below is a sample baseline that shows that the South African beacon ZS6DN can usually be heard between 10:00 and 21:00 UT.



## Conclusions

The delay time between a large radio burst on the sun and the response of the ionosphere is linear (but with only three solid events). The stronger the radio burst the quicker the CME arrives at earth. Speeds ranged from 1520 to 500 km/s, normal for such energetic events.

In our observations there is an inverse relationship between the strength of a radio burst and the strength of an x-ray flare. The X9 flare of December 5 was hardly detectable by the Radio Jove equipment or by the beacon network.

## Future Work

Future work will include putting beacon and radio JOVE data collection online 24/7. We will look for better propagation in higher frequency bands as solar activity increases in the next few years. These findings will then be compared to models of propagation such as CAP (Coverage Analysis Program).

Special thanks to the Radio Jove Community, especially Jim Thieman, Jim Sky, and Jim Brown (Beaver, PA).



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