Plishner Radio Astronomy

and

Space Science Center

Multiband Feed Operations for Neutral Hydrogen

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Abstract

The Plishner Radio Astronomy and Space Science Center is operated by the Deep Space Exploration Society based out of Colorado Springs, Colorado. The largest antenna system is a 60 ft. parabolic reflector. This paper describes the operations of the new multi-band feed system for measuring neutral hydrogen.

1.0 Introduction

The Deep Space Exploration Society (DSES) is a not for profit organization whose primary purposes are research and education of space communications and radio astronomy. The DSES primary asset is the Plishner Radio Astronomy and Space Science Center which is located in a radio quiet area near Haswell, Colorado. The primary asset of the DSES organization is a 60-foot parabolic reflector that was built in the 1950s for the study of tropospheric communications. The DSES team has designed a multi-band feed and pointing indicator system as well as multiple transceivers and analysis equipment in order to conduct radio astronomy experiments plus Earth-Moon-Earth and tropospheric communications.

This paper shows the operations of the feed system for measuring neutral hydrogen sources.

2.0 Multi-Band Feed System

A multi-band feed system was developed for use with the 60-foot diameter dish in order to achieve the radio-astronomy goals of measuring neutral hydrogen (1420.406 MHz), and communicating EME and tropospheric using 1296 MHz, 432 MHz and 144 MHz frequencies.

2.1 Neutral Hydrogen (HI) 1420.406 MHz

Neutral hydrogen (HI) is a major component of the interstellar medium (ISM). HI emits a discrete frequency at 1420.406 MHz. The radio astronomy community have developed receivers that measure this base frequency and scan for the frequency shift. The frequency shift from the baseline is indicative of the relative motion of the Earth and HI source from each other. This frequency shift allows for the calculation of Doppler and relative radial velocity. The formula for calculating Doppler shift is:

$$Doppler\ Shift = \frac{\Delta f}{f_{base}}$$

The relative radial velocity is therefore: (Doppler Shift) x (speed of Light)

For example, if the measured frequency of a neutral hydrogen line is 1420.410 then the relative radial velocity would be:

$$\frac{1420.410MHz - 1420.406MHz}{1420.406MHz}\left(\frac{3x10^{8}m}{s}\right) = 844.8m/s$$

Since the answer is positive this means that the Earth and the source are moving toward each other at 844.8 m/s. By taking multiple measurements of radio sources throughout the Milky Way, it is possible to estimate how fast the Milky Way is rotating. This will be one of many experiments the DSES organization will attempt using the new feed system.

3.0 The 60 ft. Diameter Dish

The multi-band feed is designed to be installed on the 60-foot diameter dish at the DSES site at Haswell, CO as seen in figure 1.

Figure 1: DSES 60 ft. Dish

The 60-foot diameter parabolic dish is massively strong and has sat for years in a harsh environment. The surface finish root-mean-square (RMS) holds its shape up to full capability from 35 mph winds up to 50 mph winds. The dish is stored in the 90-degree elevation in order to limit any wear or tear due to wind load. In most cases, there are no spare parts. The broken parts must be removed and taken to a machinist and reproduced. The DSES team replaced the 3-phase drive motors through eddy current couplers with three phase variable frequency drive motors. The controller develops the third phase. The 3-phase power for the site was removed years before DSES processed the property. The site is now equipped with a single phase propane powered generator.

The antenna position control can be operated locally or inside the communications van. The position indicator can be monitored next to the antenna controller. This allows the operator to control the antenna using azimuth-elevation or Right Ascension-Declination indications.

The feed will be installed by using a pulley to raise the assembly while personnel on top of the platform bolt the assembly on to the end of the three support structures.

4.0 Multi-Band Feed Design

The multi-band feed design goal was to develop a multi-band feed for the 60-foot dish that allowed for receive only radio astronomy and also 2-way communications. The feed design should also allow for easy installation and removal as well as being weather resistant in the harsh weather of the Haswell, CO environment. All controls and RF connectivity for the feed need to be accessed from the communications van which is approximately 130 feet away. The communications van contains the transceivers and computers. The van will also provide

capability of remote monitoring of the radio astronomy experiments from the DSES members over the internet.

The completed feed is shown in Figure 2 with the 4 frequency antennas.

Figure 2: Multi-Band Feed

4.0 Installation

5.0 Operations

The purpose of the antenna and feed system is to conduct radio astronomy experiments as well as conduct EME and tropospheric communications. The communications trailer provides interfaces to allow for quick experimental and communications setup.

5.1 Radio Astronomy Operations

The radio astronomy experiments will be centered around the detection of the neutral hydrogen line centered at 1420.406 MHz. The currently installed receiver is the SpectraCyber system which was built by Radio Astronomy Supplies (Lichtman, 2016) as shown in figure 20. The system was prototyped using a 9-foot dish and separate feed.

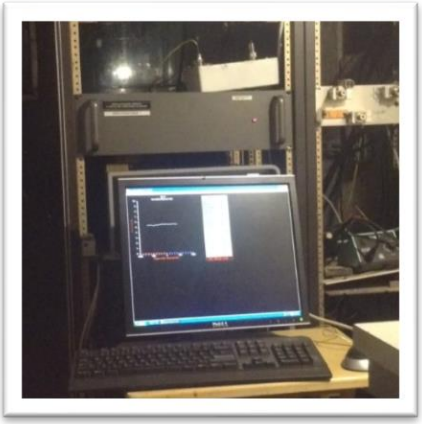

Figure 3 SpectraCyber System

The prototype antenna was pointed at various astronomy sources. The resultant products show the Doppler shift of the neutral hydrogen line. Figures 21 and 22 show the results of the observation of Cygnus A and Cassiopeia A radio sources. The 60-foot dish and the new antenna feed are expected to significantly enhance the capability of the neutral hydrogen measurements as well as enable the measurement of pulsars.

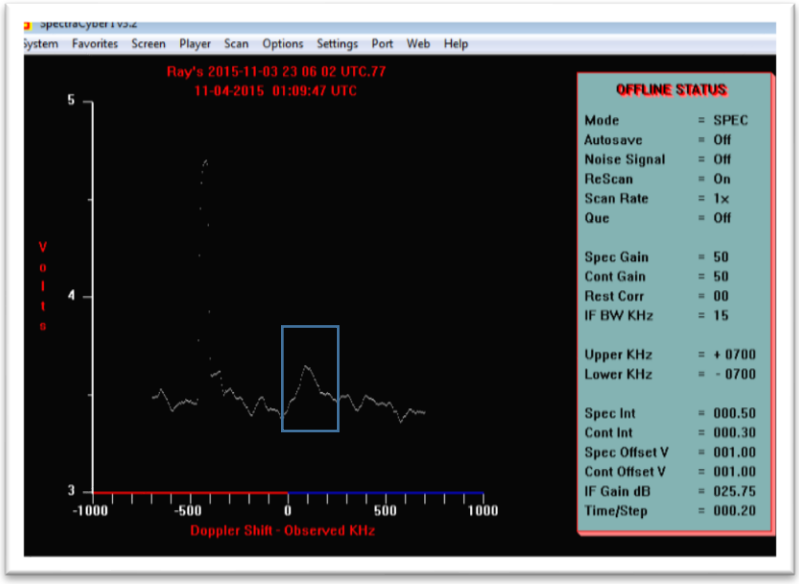

Figure 4: Cygnus A HI Measurement using prototype antenna

The measured frequency is 1420.406MHz + 0.100 MHz = 1420.506 MHz

The Doppler is:

$$Doppler = \frac{1420.506 - 1420.406}{1420.406} x3x10^8 = 21{,}120.7 m/s$$

Closing velocity

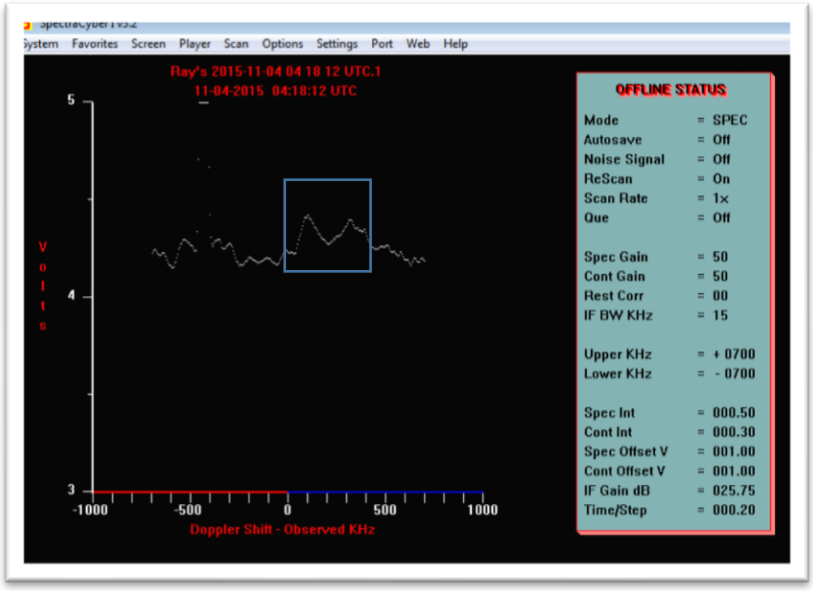

Figure 5: Cassiopeia A HI measurement using prototype antenna

The measured frequency of the first signal is 1420.406MHz + 0.100 MHz = 1420.506 MHz

The measured frequency of the second signal is:1420.406 MHz + 0.350 MHz = 1420.756 MHz

The Doppler is:

$$Doppler(1st\ Signal) = \frac{1420.506 - 1420.406}{1420.406} x3x10^8 = 21{,}120.7m/s$$

Closing velocity

$$Doppler(2nd\ signal) = \frac{1420.756 - 1420.406}{1420.406} x3x10^8 = 73{,}922.5m/s$$

Closing velocity

What does this mean?????? _____

5.0 Installation of feed (Move up)

Figure 6: Multi-Band Feed Installed

13.0 Summary

This paper summarized the development of a multi-band feed for the DSES 60-foot dish at Haswell, CO. The feed was specifically designed to conduct radio astronomy observations as well as EME and tropospheric communications. The feed covers 1420.406 MHZ for the neutral hydrogen line and 1296 MHz for EME as well as 432 MHZ and 144 MHZ for tropospheric communications.

The VK3UM tool was used to calculate the theoretical parameters for the feed and then used updated with the actual physical parameters in order to determine the link budget for all operating modes.

Detailed notes on electronic design and fabrication showed how the feed was developed to be remote controlled by a remote feed controller at the operator station.

Installation and testing is planned for the September, 2016, time frame.

Operational testing will be conducted to test all of the feed modes which included radio astronomy observations of the neutral hydrogen line for numerous astronomical sources, as well as successful EME and tropospheric contacts.

Future experiment are planned to conduct pulsar observations and classification. When fully operational, the DSES antenna will be one of the few radio astronomy antennas to simultaneously measure signals in three different radio bands. The antenna system will be setup in drift scan mode and the combined signals will be plotted. This may reveal unique astronomy sources.

DSES is now positioned to accept proposals to host experiments on the antenna system from universities and other scientific organizations. Please contact Dr. Richard Russel, DrRichRussel@netscape.net to coordinate usage of the antenna system.

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