The Detection Of The Neutral Hydrogen Line With An Amateur Radio Telescope (Part 2) (1)

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(1) Radio Observer #67, 1/93

Part 2. Observations

Abstract: The Galactic Plane is a rich source of HI emissions and was observed with the instrument discussed in part 1. In this part, the calibration of the instrument and observations made with it of the Galactic Plane are-discussed.

1. Calibration

Local Oscillator (LO) set up was performed with an Optoelectronics model 2600 frequency counter with the 10,000000 MHz (temperature compensated) time base option. Testing of the center frequency of each of the channels were performed with a General Radio model 1621 unit oscillator fitted with a small dipole antenna, with the frequency counter monitoring the oscillator output.

The system was equipped with a noise source, which was calibrated by NoiseCom, was found to have an ENR of 34.68 dB. With a programmable attenuator string of 39 to 50 dB attenuation, the calibration signal could be set (in steps) from 100 to 16 degrees K. In order to test the system sensitivity, and noise source calibration, the setup in figure 1 was used. Here a Styrofoam box was made with a fan at one end (IMC model PWS2107F), which dissipates 22 watts, and the feed line with a 50 ohm termination at the other. The fan was connected to an appliance timer set to turn on the fan for a half hour and turn it off for 1 hour per cycle; 8 cycles were set.

Figure 2 shows the results of this test. The top curve is the chamber temperature as monitored by a Temperature to Frequency converter [1] (backup to this is a: Radio Shack Min/Max thermometer, part # 63-843) The curve just below this is the feed temperature. The two lower curves are the 1425 MHz channel (top) and-the 1420.5 MHz channel (bottom), which are purposely offset from each other for presentation purposes. What is crucial to the operation of this telescope is the relative gain of the two channels, this is also shown in figure 2. Here it can be seen that over a termination temperature range of 10 degrees C, the 1425 MHz channel varies from 2.6 V to 3.8 V. The 1420.5 MHz channel, over the same temperature range varies from 2.1 V to 3.35 V, the difference being .05 volts. This difference has since been nulled out.

From this data the author was able to conclude a system sensitivity of .12 volts/degree (1.2 volts peak/10 deg. K). Please note that the temperature scale in figure 2. is degrees F. With this it was found that the noise source-portion of the system had 3dB of unaccounted for loss due to attenuation and reflection. The previously noted noise source attenuator string takes into account this extra 3 dB of loss.

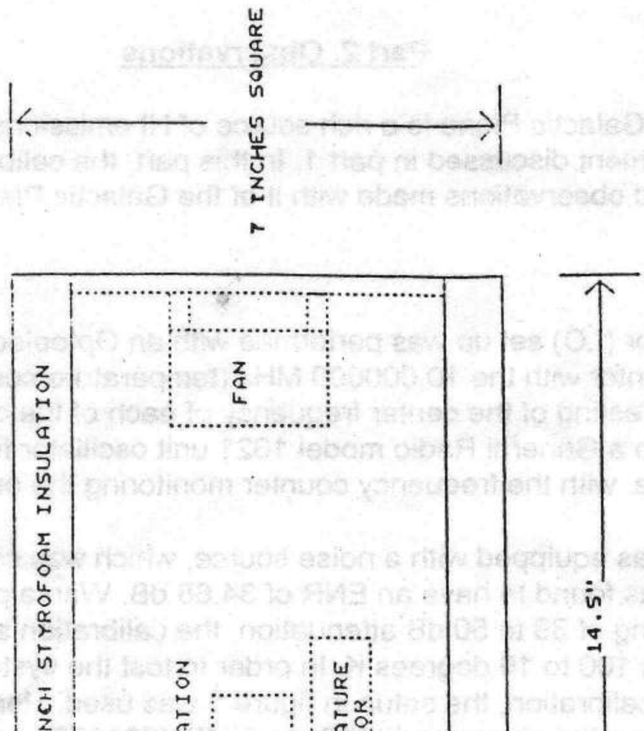

Figure 1. Calibration Chamber

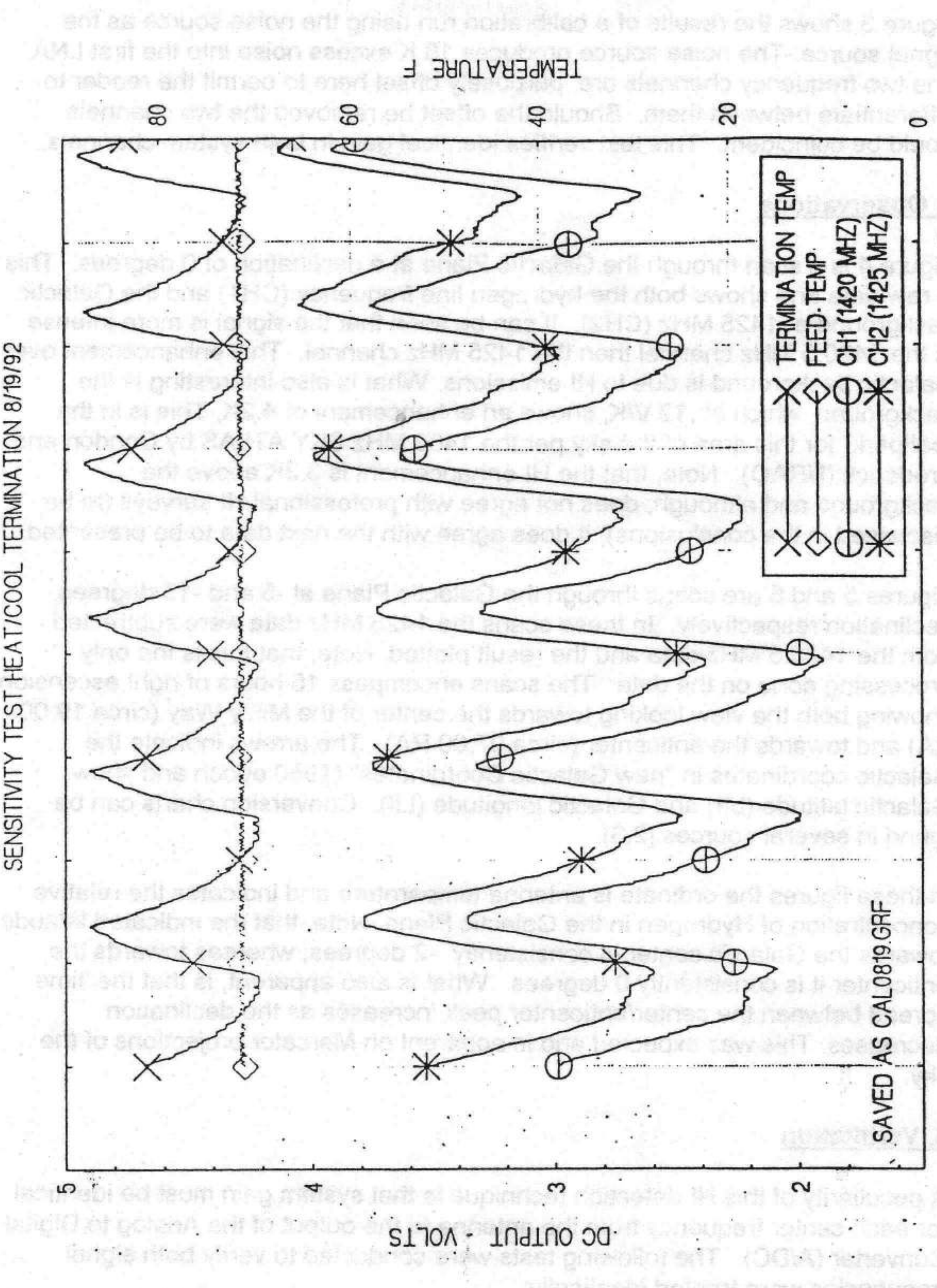

Figure 2. Sensitivity Test Heat/Cool Termination 8/19/92

Figure 3 shows the results of a calibration run using the noise source as the signal source.-The noise source produces 16 K excess noise into the first LNA. The two frequency channels are purposely offset here to permit the reader to differentiate between them. Should the offset be removed the two channels would be coincident. This test verifies identical gain in both system channels.

2. Observations

Figure 4 is a scan through the Galactic Plane at a declination of 0 degrees. This is raw data and shows both the hydrogen line frequency (CH1) and the Galactic background at 1425 MHz (CH2). It can be seen that the signal is more intense in the 1420.5 MHz channel than the 1425 MHz channel. This enhancement over Galactic background is due to HI emissions. What is also interesting is the background, which at .12 V/K, shows an enhancement of 4.2K, This is in the "ballpark" for this area of the sky per the 1400 MHz SKY ATLAS by Condon and Broderick (NRAO). Note, that the HI enhancement is 3.3K above the background and although, does not agree with professional HI surveys (to be discussed in the conclusions), it does agree with the next data to be presented.

Figures 5 and 6 are scans through the Galactic Plane at -5 and -15 degrees declination respectively. In these scans the 1425 MHz data were subtracted from the 1420.5 MHz data and the result plotted, Note, that this is the only processing done on the data. The scans encompass 15 hours of right ascension showing both the view looking towards the center of the Milky Way (circa 19:00 RA) and towards the anticenter (circa 07:00 RA). The arrows indicate the Galactic coordinates in "new Galactic Coordinates" (1950 epoch and show Galactic latitude (bII) and Galactic longitude (LII). Conversion charts can be found in several sources [2,3].

In these figures the ordinate is antenna temperature and indicates the relative concentration of Hydrogen in the Galactic Plane. Note, that the indicated latitude towards the Galactic center Is consistently -2 degrees, whereas towards the anticenter it is consistently 0 degrees. What is also apparent, is that the 'time spread between the center/anticenter peak increases as the declination decreases. This was expected and is apparent on Mercator projections of the sky.

3. Verifitation

A peculiarity of this HI detection technique is that system gain must be identical for each center frequency from the antenna to the output of the Analog to Digital Converter (A/DC). The following tests were conducted to verify both signal frequencies were treated identically:

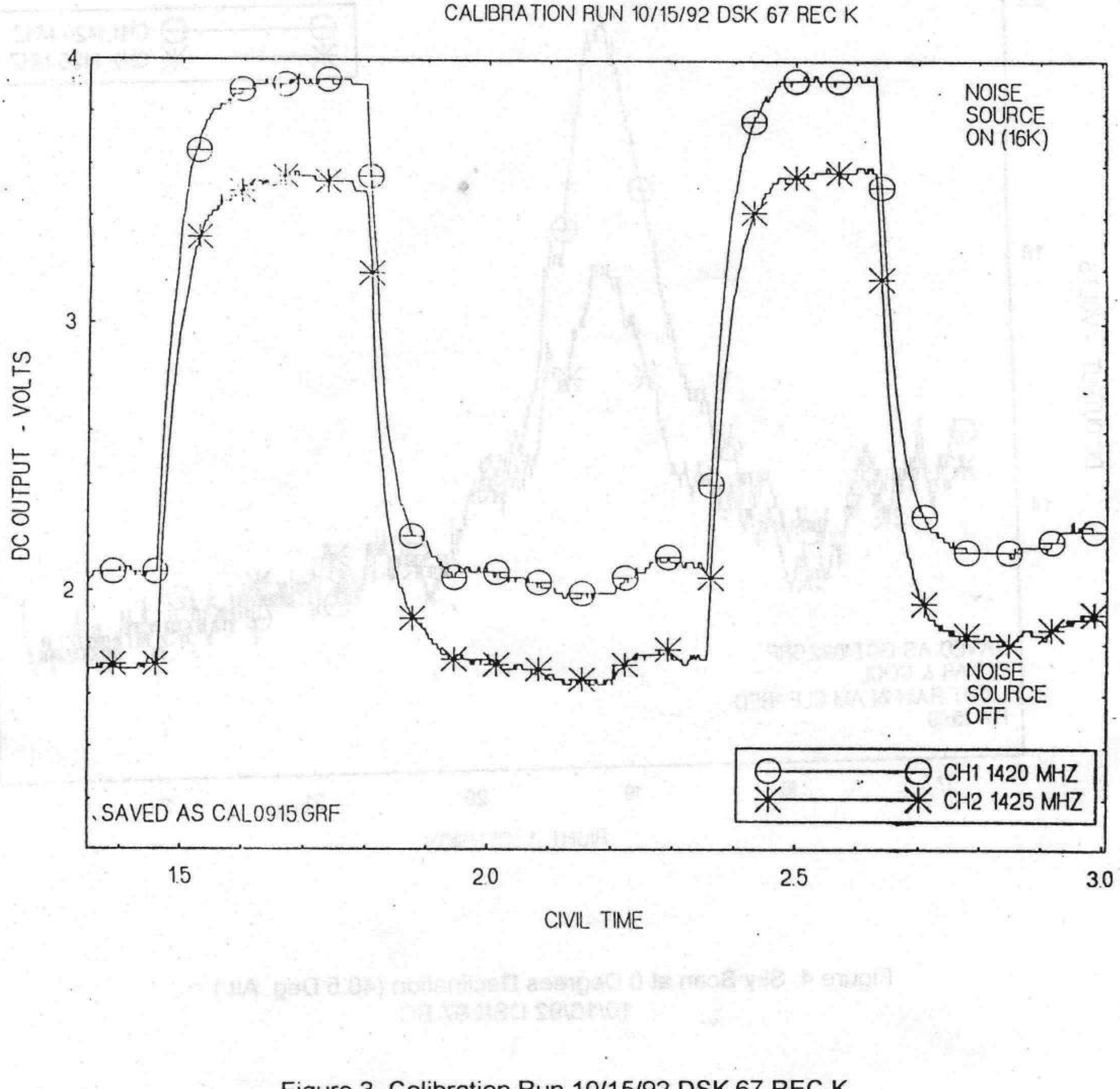

Figure 3. Calibration Run 10/15/92 DSK 67 REC K

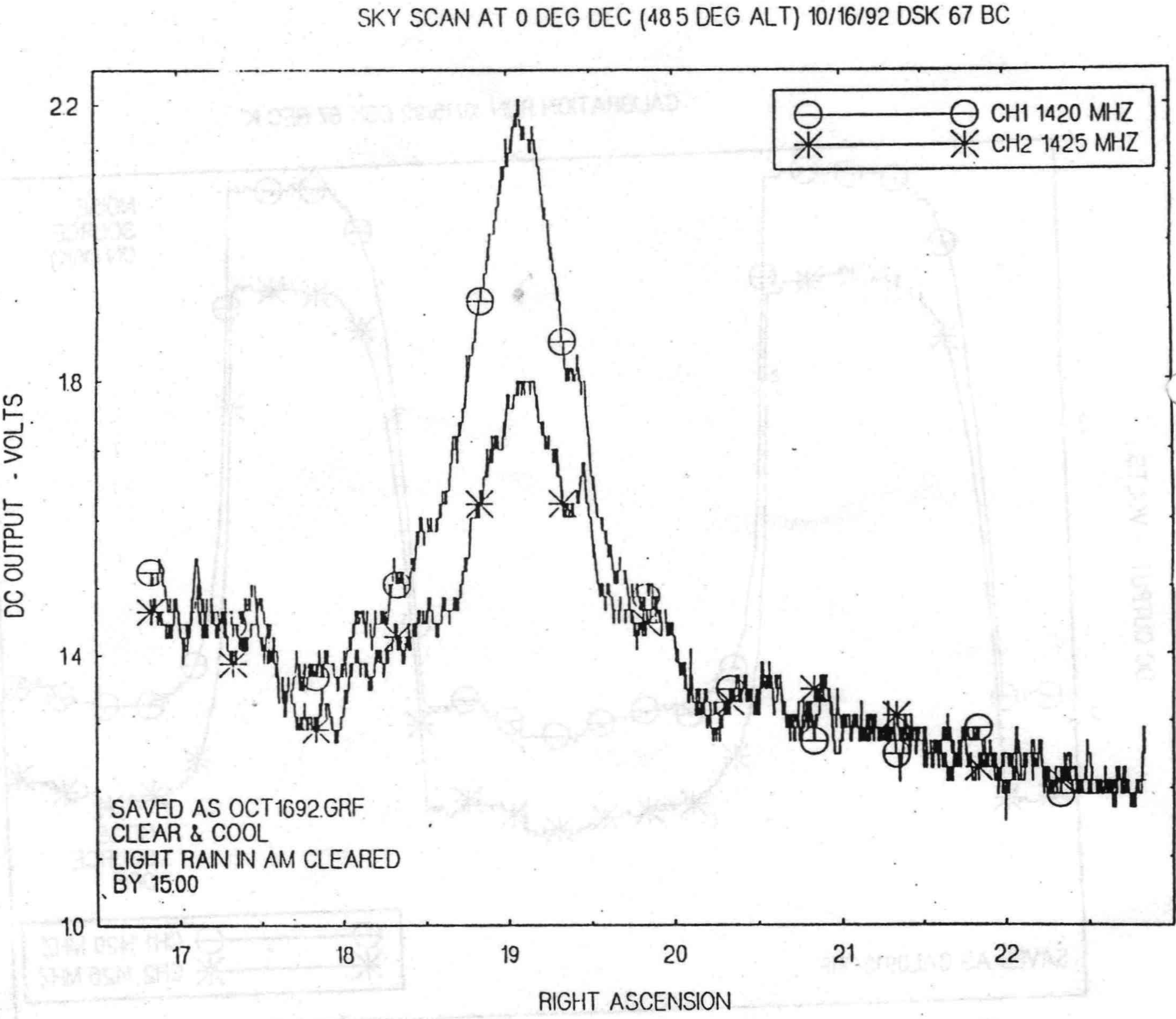

Figure 4. Sky Scan at 0 Degrees Declination (48.5 Deg. Alt.)
10/16/92 DSK 67 BC

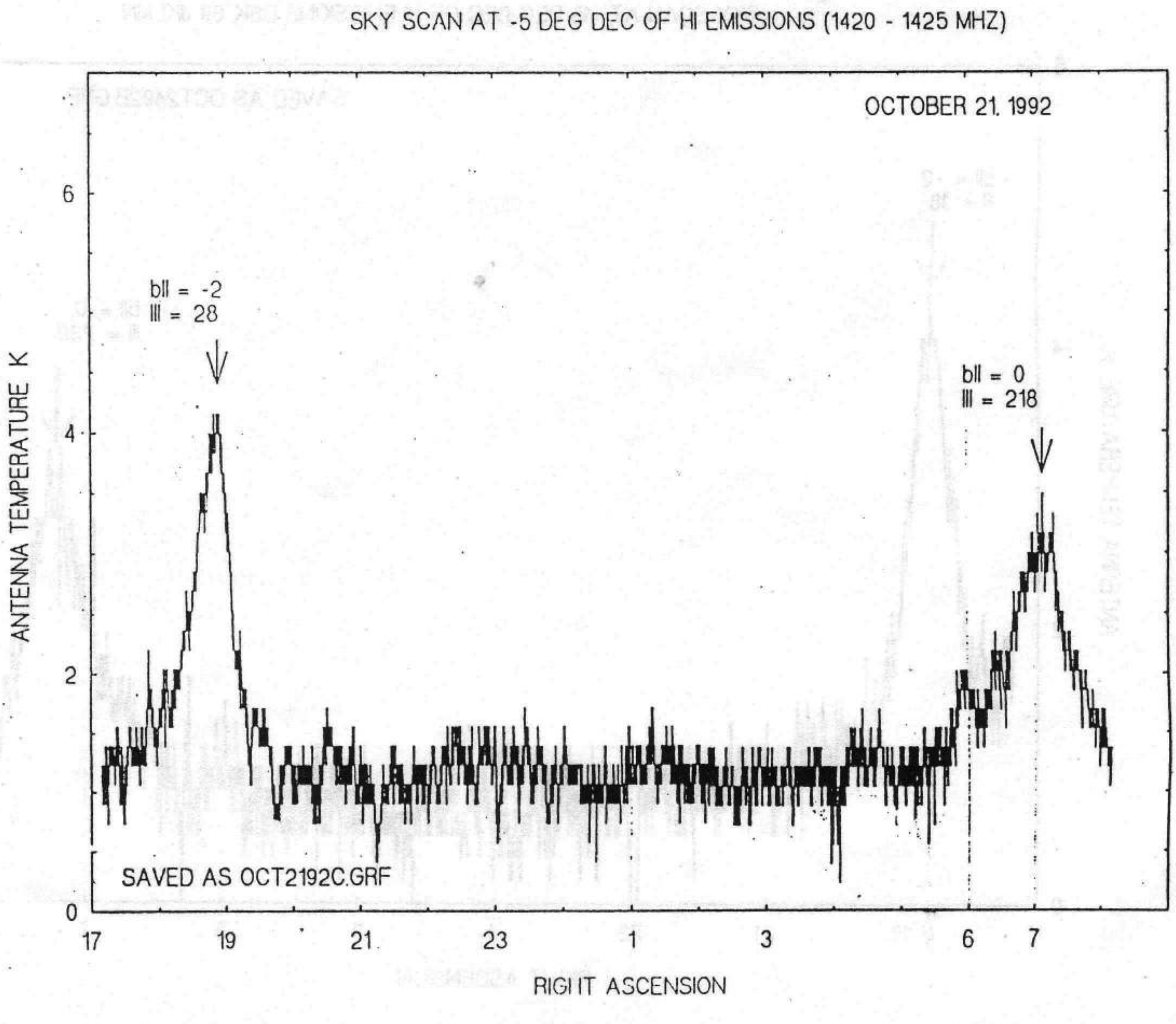

Figure 5. Sky Scan at -5 Degrees Declination of HI Emissions
(1420 - 1425 MHz)

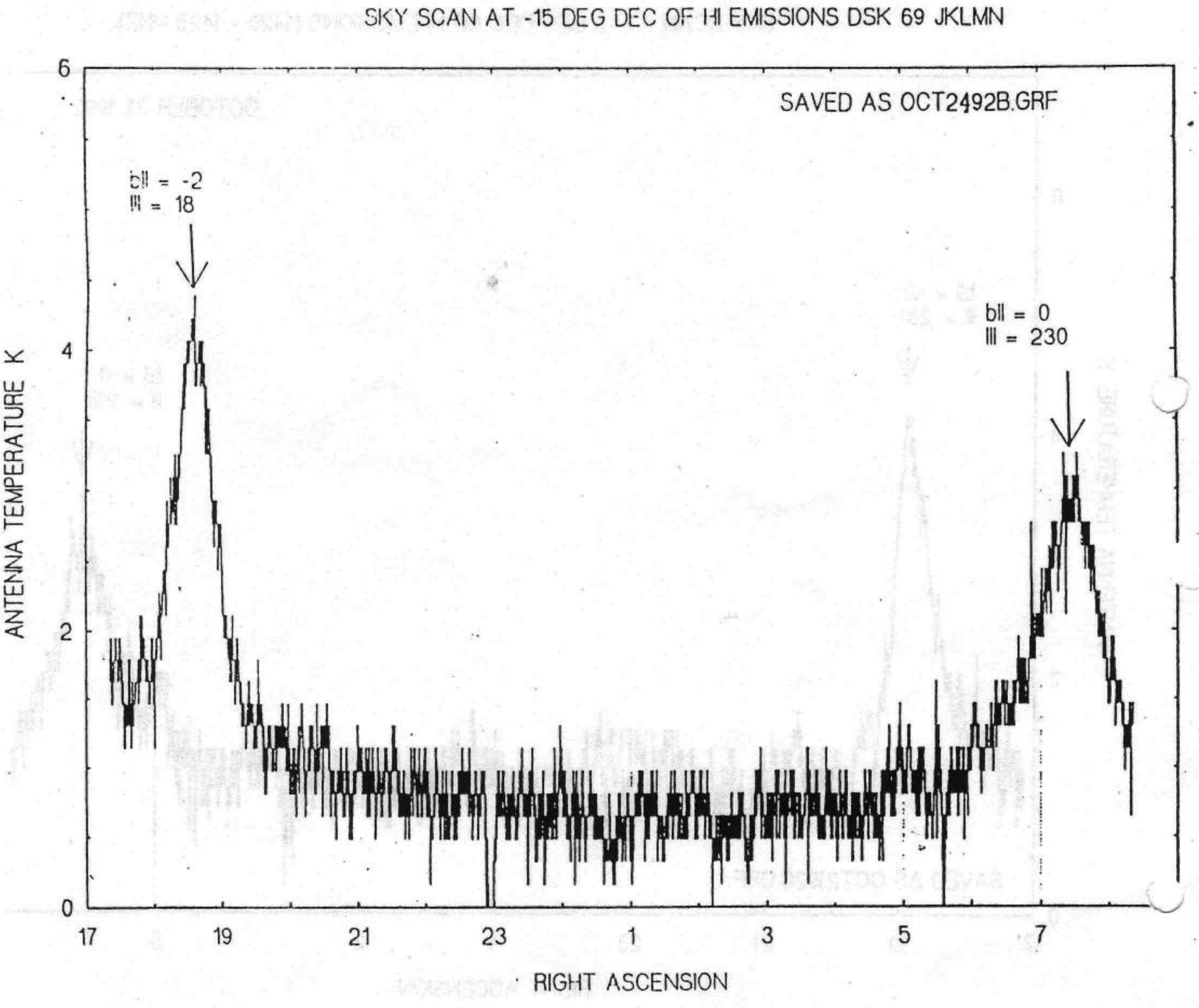

Figure 6. Sky Scan at -15 Degrees Declination of HI Emissions DSK 69 JKLMN

1) Swap VCO control from 1425 MHz channel (CH2) to the 1 MHz channel (CH1) to put the 1425 MHz signal on CH1 and the 1420.5 MHz signal on CH2, Then do a scan of the Galactic Plane.

2) Lower the 1420.5 MHz LO frequency from 1464.5 to 1459 to change the center frequencies to either side of the HI rest frequency. Then do a scan of the Galactic Plane. This test was done just in case the Galactic backgroud synchrotron radiation was brighter at 1420.5 than at 1425 MHz. If so it would be even brighter at 1415 MHz.

3A. Verification Results

1) Figure 7 shows a scan of the Galactic Plane with the VCO control line tied to the CH1 side of the circuit. Here the stronger enhancement is in CH2 whereas before the swap, it was in CH1 (compare to figure 4).

2) The VCO control line was restored to original (channel 2 drive to put the 1420.5 MHz signal on channel 1. The VCO was then adjusted to provide 1415.5 center frequency on channel 1, channel 2 remained at a center frequency of 1425 MHz. A scan was done along the Galactic Plane and the result was identical signal intensity in both channels.

Another verification is the equatorial coordinates of the scan and how they relate to the Galactic Plane. Figures 5, 6 and 7 are labeled with galactic coordinates and these agree well with professional observations [4,5]. The author saw this labeling technique used elsewhere [6] and found it helpful in picturing how the scans relate to "slices" through the Galactic Plane.

4. Conclusions

Based upon the observations made thus far it is clear that HI studies can be made in the experimenters back yard with (relatively) modest equipment. The next obvious step would be to expand this "2 channel" spectrum analyzer approach to more channels to do doppler shift work.

One side benefit of this frequency switching technique is an automatic noise cancellation, similar to a Dicke switch. This noise cancellation improves 1/f and "Popcorn" noise as well as baseline drift. Although, the author has not tried this to date, it seems plausible that a non-spectral line telescope could also use this technique. If a total power receiver were to be switched between it's operating frequency and same frequency outside the pass band of the LNA's, it is conceivable that some system noise improvement would result.

One aspect of the observations to date has been a lower than expected antenna temperature enhancement due to HI emissions. The expected temperatures were on the order of 25 to 100 K (above background).

Note: References ([ ]), refer to Part 1 of this two part series.

SKY SCAN AT 0 DEG DEC (48.5 DEG ALT) 9/28/92 DSK 64 DE

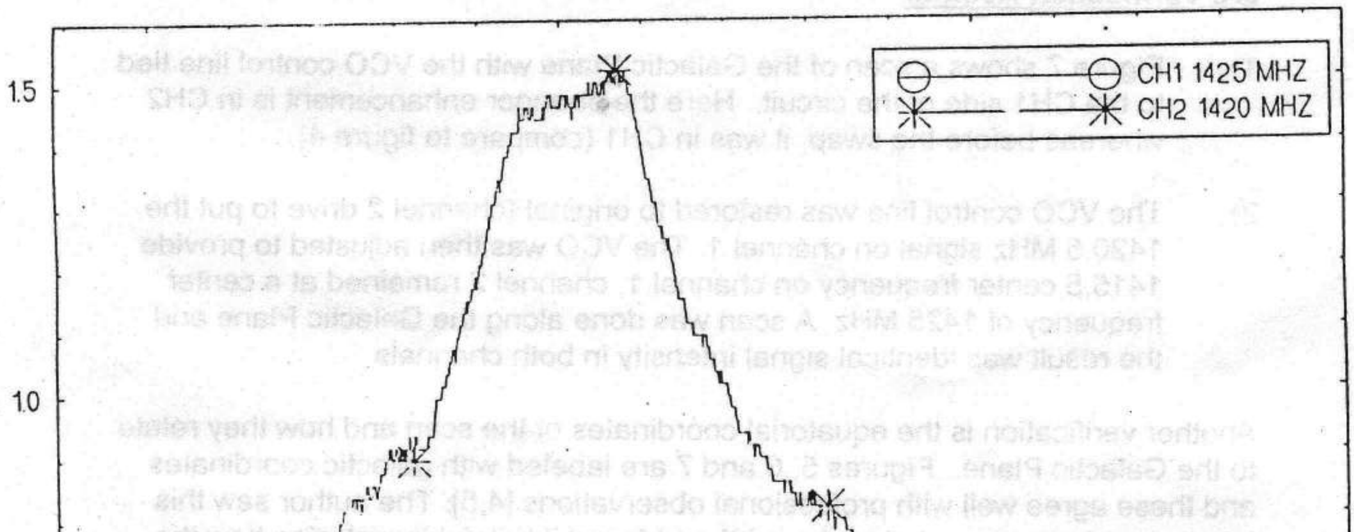

Figure 7. Sky Scan at 0 Degrees Declination (48.5 Degrees ALT.) 9/28/92 DSK 64 DE