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To: VSRT Group
 From: Alan E.E. Rogers
 Subject: Ozone spectrometer set-up for Chelmsford High School

Preliminary observations of the 11.072 GHz ozone line were described in VSRT memo #29. A simpler more spectrally efficient spectrometer (see figure 5 for the circuit diagram) has been built and tested with the set-up shown in figure 1. This spectrometer uses a 12-bit analog to digital converter (ADC) card from measurement computing. This is a PCI card whose Linux software driver has been developed by various groups using GNU radio. This card also has digital I/O lines which are used to control the synthesizer in the ozone spectrometer downconverter. In addition, one of the I/O lines is used to turn the frequency calibration lines on and off. Frequency calibration is needed to correct the LNBF local oscillator drift. For accurate frequency control at over controlled 10 MHz oscillator with better than 1 ppm accuracy was obtained (at low cost from ebay).

The DAC is operated at a 20 MHz sample rate to allow the analysis of a 10 MHz bandwidth of which only 2.5 MHz is used for the ozone observations. In addition, frequency switching is employed in which the ozone line is placed at 0.625 MHz in the first part of the cycle and inverted at 1.875 MHz in the second part of the switching cycle. The final ozone spectrum then spans a 1.25 MHz wideband following the taking of the difference between the lower and upper portions of the 2.5 MHz bandpass.

The data is written to disk about every 90 seconds in an ASCII text format with one line per record. The data is space delimited with the following data

| | |
|---------------|--------------------------------------|
| Column 1 | yyyy:ddd:hr:mm:sc UT date |
| Column 2 | Decimal hours |
| Column 3 | Starting frequency in the I.F. (MHz) |
| Column 4 | Spacing of spectral points (MHz) |
| Column 5 | Frequency of calibration tone (MHz) |
| Column 6 | Amplitude of calibration tone |
| Column 7 | Total power (dB) |
| Column 8 | “spectrum” |
| Column 9 | Ozone estimate |
| Column 10-137 | Spectral data 128 points (K) |

The frequencies are set to make the peak of the ozone line appear in frequency channel 67 which is in column 76. The ozone line has wings which extend out about ± 1000 MHz from 11.072 GHz. Only the ozone below above 30km contributes to the 1.25 MHz spectrum we can observe with the spectrometer. Even if we had a wider bandwidth spectrometer the wings of the line are so weak that it would be difficult to observe the

lower altitude ozone. Figure 4 shows sample spectra taken at Haystack Observatory over a period from 1 to 7 Jan 07. The mesospheric ozone varies strongly with the diurnal cycle.

Observations of ozone at millimeter wavelengths made from the ground make use of the pressure broadening to retrieve the height profile of the ozone concentration from the line shape. Ozone near the ground is pressure broadened over about 2 GHz while ozone in the upper stratosphere is pressure broadened by a few MHz. Thus the lower ozone contributes to the wings of the line while the higher ozone contributes to the signal near the line center. At an altitude above about 65 km the line width is no longer dependent on altitude as the Doppler line width due to the thermal motions of the ozone molecules dominates. At 11 GHz the line width still depends on altitude up to about 80 km because the Doppler line width, which is proportional to frequency is reduced in comparison with the pressure broadening which is largely independent of the line frequency. The reduced Doppler broadening of the 11 GHz line allows the ozone concentration to be retrieved from the spectral shape observed from the ground up to a greater height.

At altitudes above about 50 km the ozone concentration is extremely variable owing to the dynamics of the photolysis. Molecular oxygen is split into atomic oxygen by ultraviolet radiation from the sun. The atomic oxygen then combines with the molecular oxygen to produce ozone. This reaction is catalyzed by a third molecule such as nitrogen in a three body collision. Ozone is destroyed by ultra violet (between 240 and 320 nm) to produce atomic plus molecular oxygen. It is the absorption of the ultra violet in the destruction of ozone that protects life from excessive ultra violet. During the day the ozone is being destroyed as rapidly as it is produced by the ultraviolet radiation of sun. As a result the ozone concentration decreases rapidly at sunrise and then builds up again after sunset. The details of these poorly known mesospheric chemistry could be clarified using the variation of the ozone concentration with the solar illumination and altitude which can be retrieved from the 11 GHz line shape and intensity. Details of the diurnal variations derived from the 101.737 GHz are given by Wilson and Schwartz (1981) and by Dumitru et al. (2006) at 142.175 GHz line.

see "Mesospheric mysteries "by Paul Crutzen in Science 26 Sept. 1997 vol 277 no 5334 pp 1951-1952

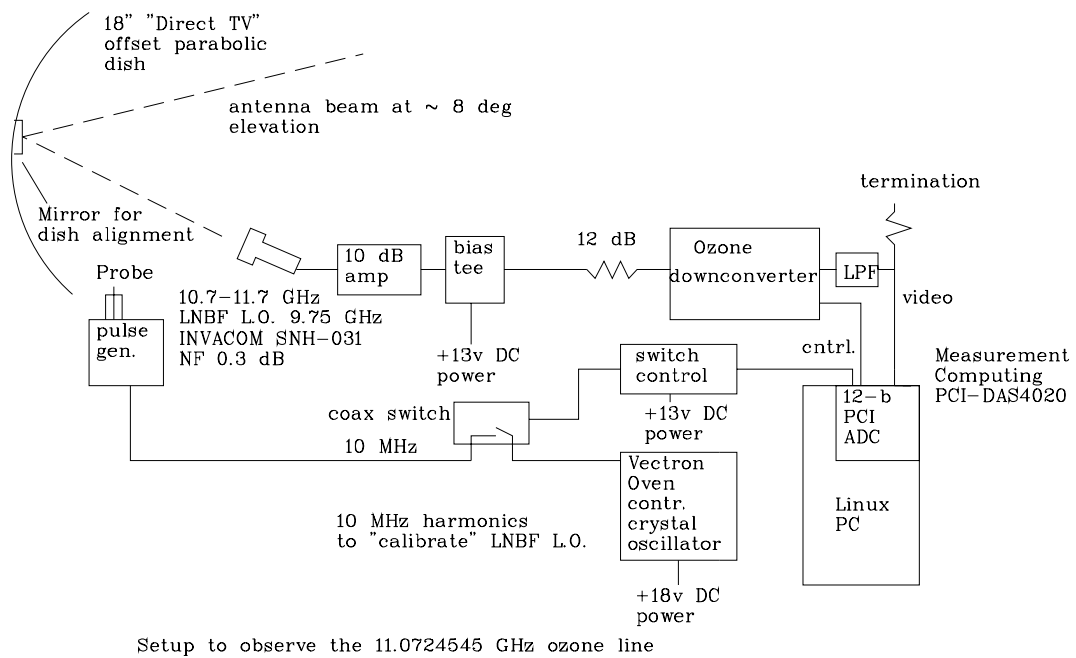


Figure 1. Setup to observe the 11.0724545 GHz ozone line



Figure 2. Fixed 18" dish set to observe at 8 degrees elevation at about 180° azimuth at the Haystack Observatory. The dish and LNB assembly weighs about 10 lbs.



Figure 3. Rear view of the dish showing the frequency calibration probe and the mounting to the building wall. The cables from the LNB and the calibrator are about 10 feet long. [It is highly desirable to keep the cable to the LNB as short as possible.]

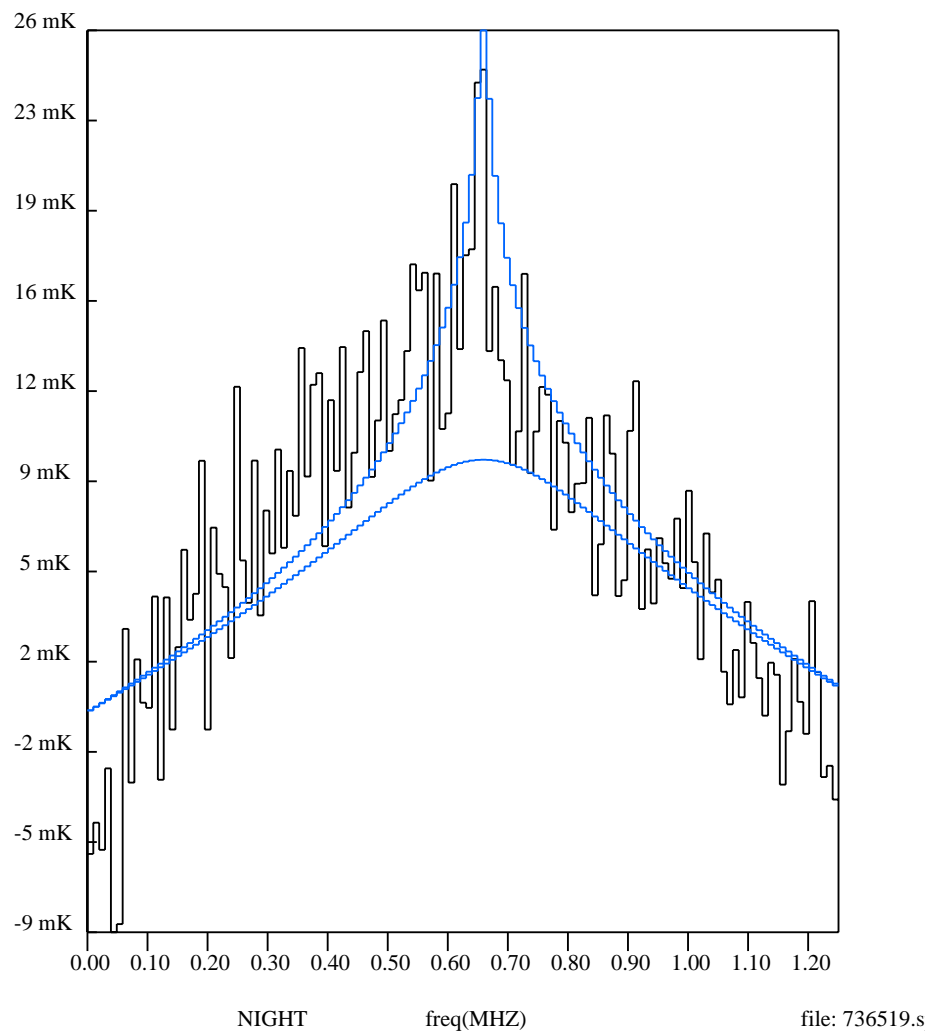


Figure 4a.

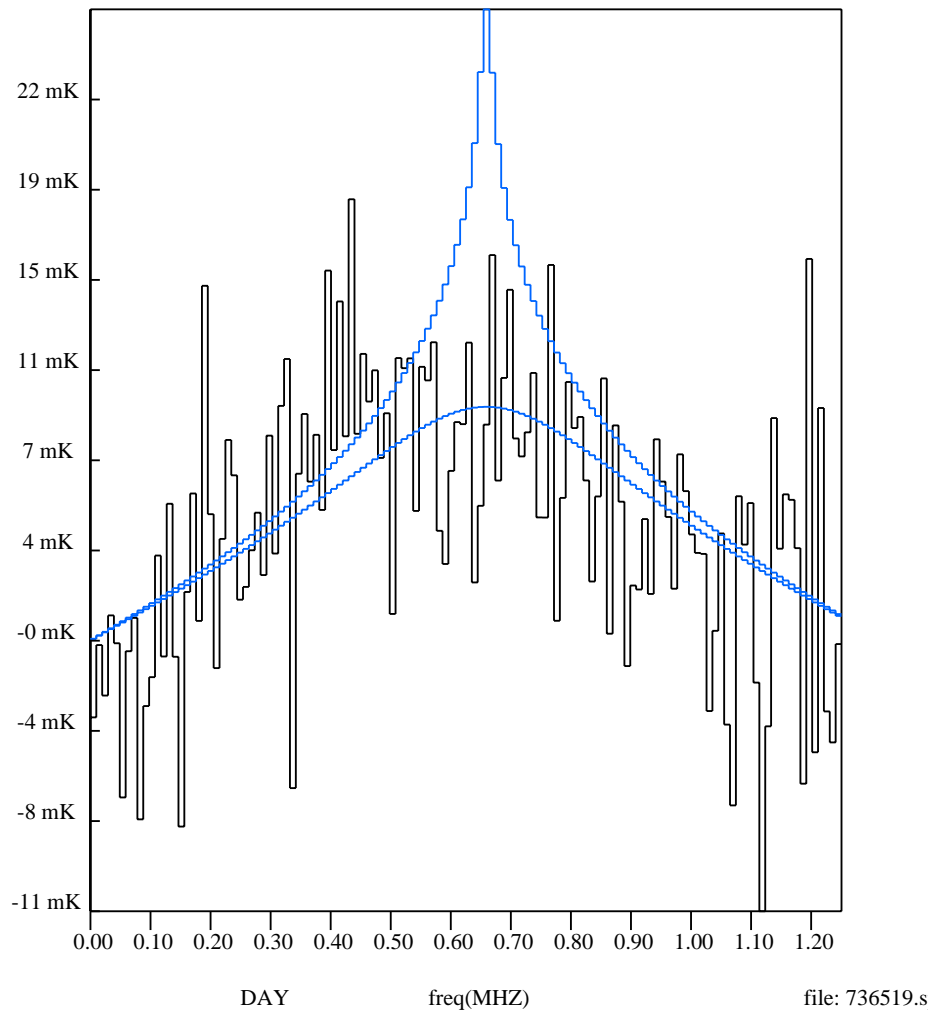


Figure 4b.

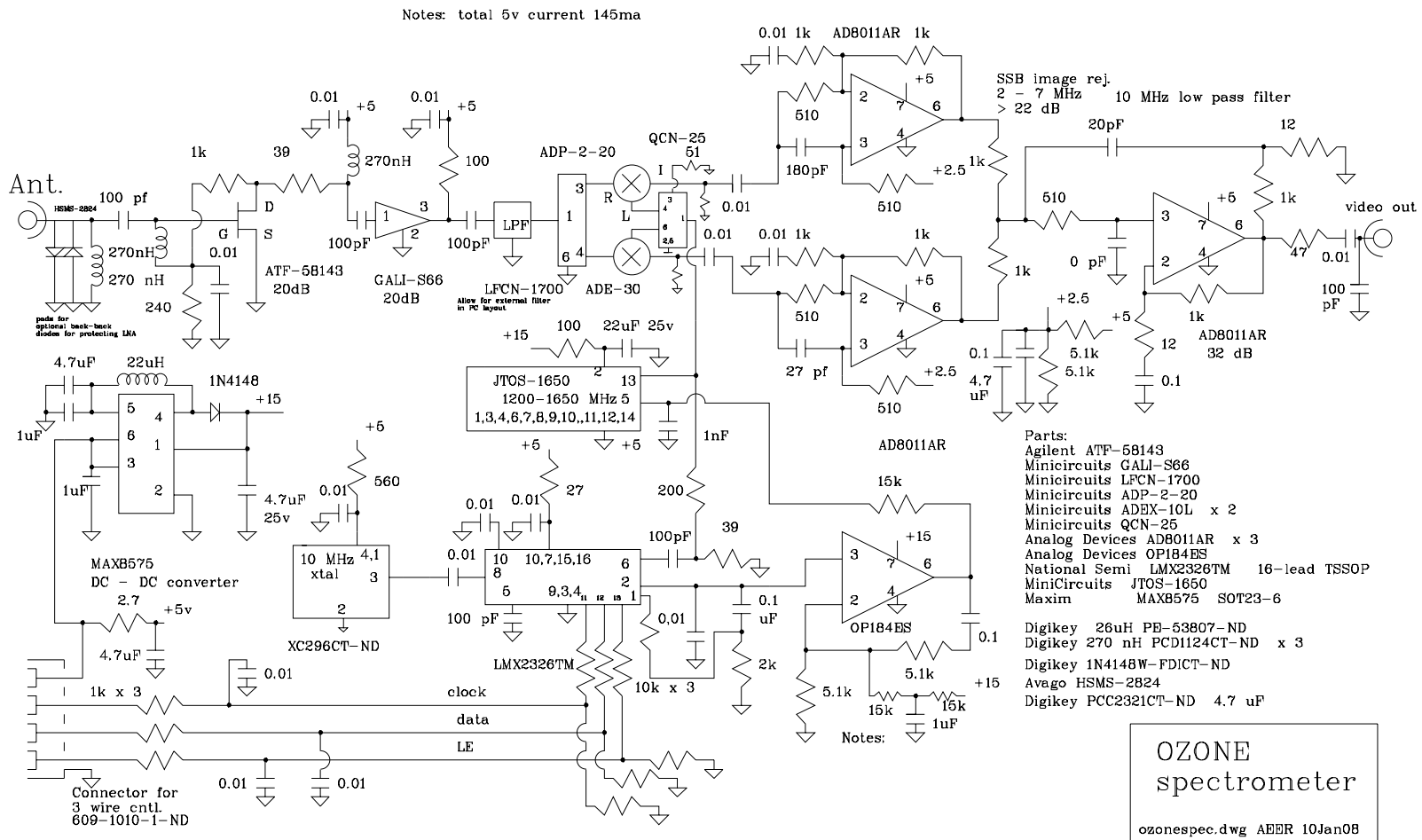


Figure 5.