EDGES MEMO #058

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
HAYSTACK OBSERVATORY
WESTFORD, MASSACHUSETTS 01886

February 4, 2010

Telephone: 781-981-5407
Fax: 781-981-0590

To: EDGES Group
From: Alan E.E. Rogers
Subject: RFI Statistics at Boolardy

The EDGES system was run continuously at Boolardy from day 235 through day 315 2009.

For EDGES RFI is removed by excising data blocks, each of which contains 18 seconds on the sky, followed by 18 seconds on the load and 18 seconds on the load plus calibration noise. If there is a RFI transient shorter than 18 seconds we still lose the entire 3×18 seconds of data. In addition to excising data in time individual frequencies are excluded based on the detection of the presence of RFI in an individual frequency channel or group of channels.

On a typical day (24 hour period) the following table shows the fraction of time and frequencies lost due to filtering:

Filter	Description	Time excised %	Frequencies excluded %
0	Total power	1	3
1	FM	15	3
2	Orbcomm	88	2
3	150 MHz sat.	21	3
4	Ch 6 DTV	3	3
5	Ch 7 Analog	3	3
6	Ch 7 DTV	0	3
7	Ch 8 DTV	0	3
8	Aircraft	20	3
9	All except 2	51	2
10	All except 2 and 8	27	3

Comments on filters:

In general the filters are set for a significant detection of RFI in 18 seconds of EDGES data with sensitivity of about 10 K in 6 kHz bandwidth. The total power filter examines the total power across the entire spectrum and in addition uses the strongest peak in the spectrum. The other filters all use only the relevant portions of the spectrum and averaging over the region where the signals are expected and use the adjacent regions for comparison. For example, the FM carriers are expected at odd multiples of 100 kHz between 88 and 108 MHz. The spectral regions within 50 kHz of the FM channels are compared with the regions within 50 kHz of the even multiples of 100 kHz. For digital TV the detection is difficult because the only comparison comes from the 200 kHz guard

band between channels. However, the FM and analog TV filters act as a "proxy" for the presence of digital TV.

Comments on results:

As mentioned in memo #55 there is very little time when the signals from the Orbcomm satellites are not present so it is not practical to use the Orbcomm filter. Some cases of very strong Orbcomm signals will be excised by the total power filter although most cases that trigger the total power filter come from the transmission from nearby aircraft.

After performing excision in time there will be some 6 kHz frequency channels which are still corrupted by RFI at the level of about 300 mK. Typically however, this is only about 2 to 3 percent, based on a full day's integration.

After the RFI is filtered out the EDGES system allows integrations for which the noise continues to decrease with the square root of the product of the resolution and integration time.

Elapsed time	Integration	Resolution			
(sec)	(sec)	10 kHz	100 kHz	1 MHz	10 MHz
10^2	3	4500 (4500)	1475 (1423)	439 (450)	156 (142)
10^3	30	1528 (1423)	507 (450)	133 (142)	-
10^4	3×10^2	456 (450)	159 (142)	46 (45)	-
10^5	3×10^3	135 (142)	47 (45)	13 (14)	-
10^6	3×10^4	53 (45)	18 (14)	7 (5)	-

Table 1. Noise in EDGES spectra in millikelvin vs integration time where the numbers in parentheses are the theoretical noise.

Table 1 shows the noise in the EDGES spectra taken from day 239 to 292 in 2009. The noise was measured from 105 to 205 MHz after the removal of a 13^{th} order polynomial for resolutions from 10 kHz to 1 MHz and with a 7^{th} order polynomial at 10 MHz. Beyond 100 seconds at 10 MHz resolution a higher order polynomial is needed to remove the systematics but at 10 MHz a higher order polynomial also absorbs some of the noise. The theoretical noise of EDGES using the DP310 12-bit ADC is relatively high because the amount of data processed in 18 seconds is only about 1.5 seconds owing to the overhead in the FFT calculation and data transfer. Both the total elapsed time of the integration and the actual integrative time corresponding to the total data processed on the sky are given in Table 1. The time periods chosen for each day were for when most of the galactic plane was below the horizon and the average antenna temperature at 150 MHz was about 280 K.

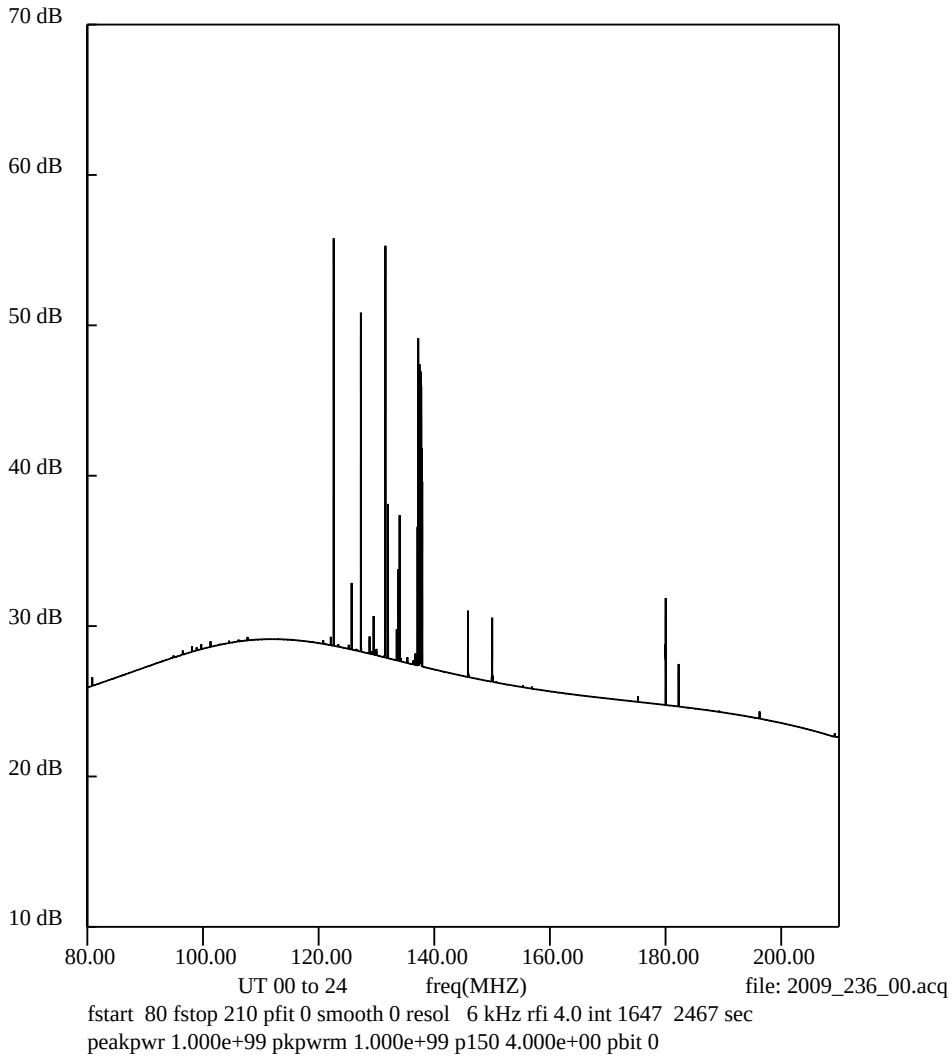

Figure 1. Unfiltered spectrum. The vertical axis is the antenna temperature in decibels above 1 Kelvin.

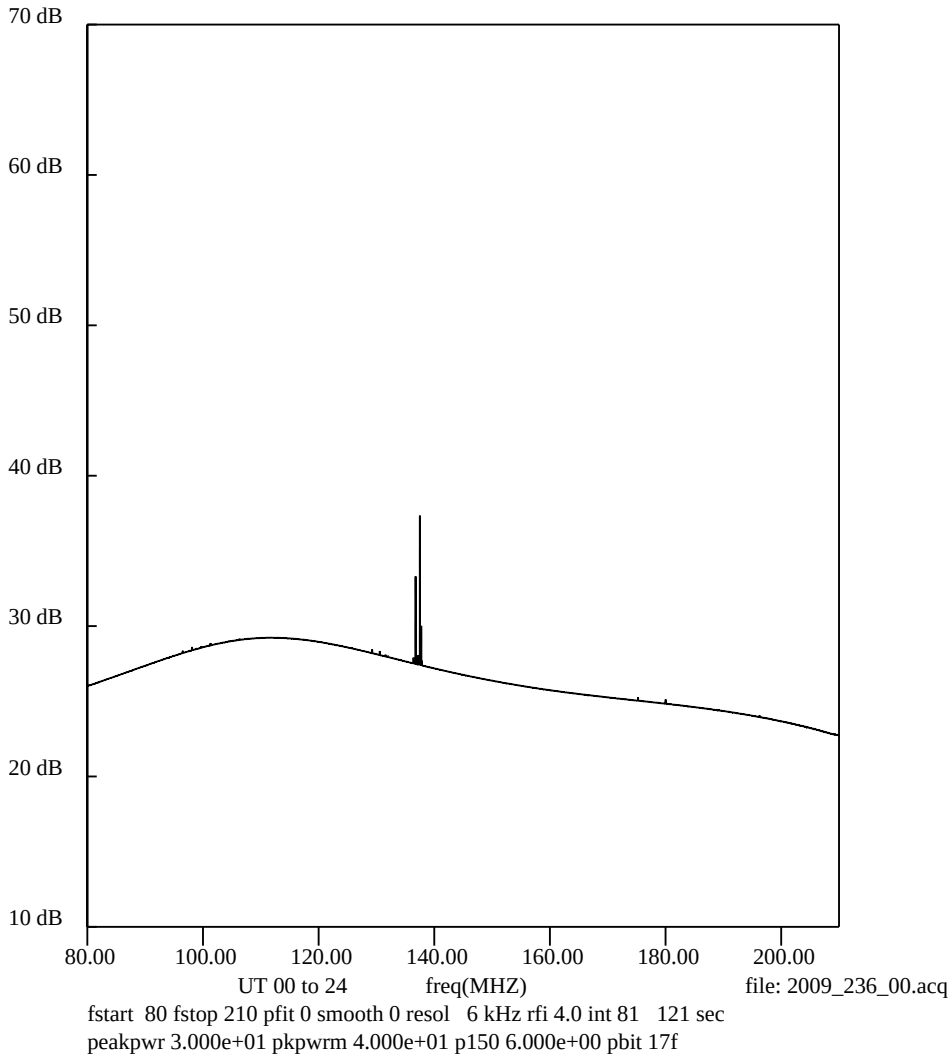

Figure 2. Spectrum after filtering by excision of data for periods when RFI is present using filter #9 of table 1.

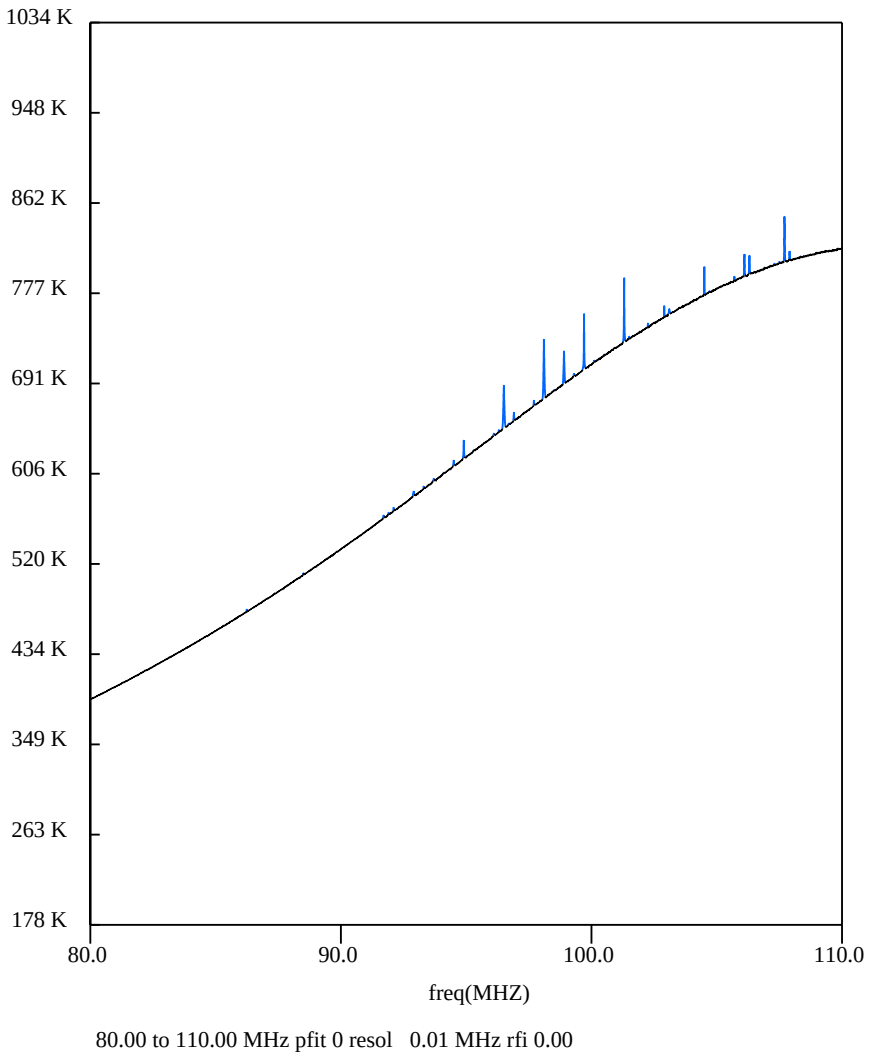

Figure 3. Typical FM spectrum. The periodic enhancement of the FM spectrum comes from a combination of short “bursts” of reflection from meteor trails and longer duration reflections from aircraft.

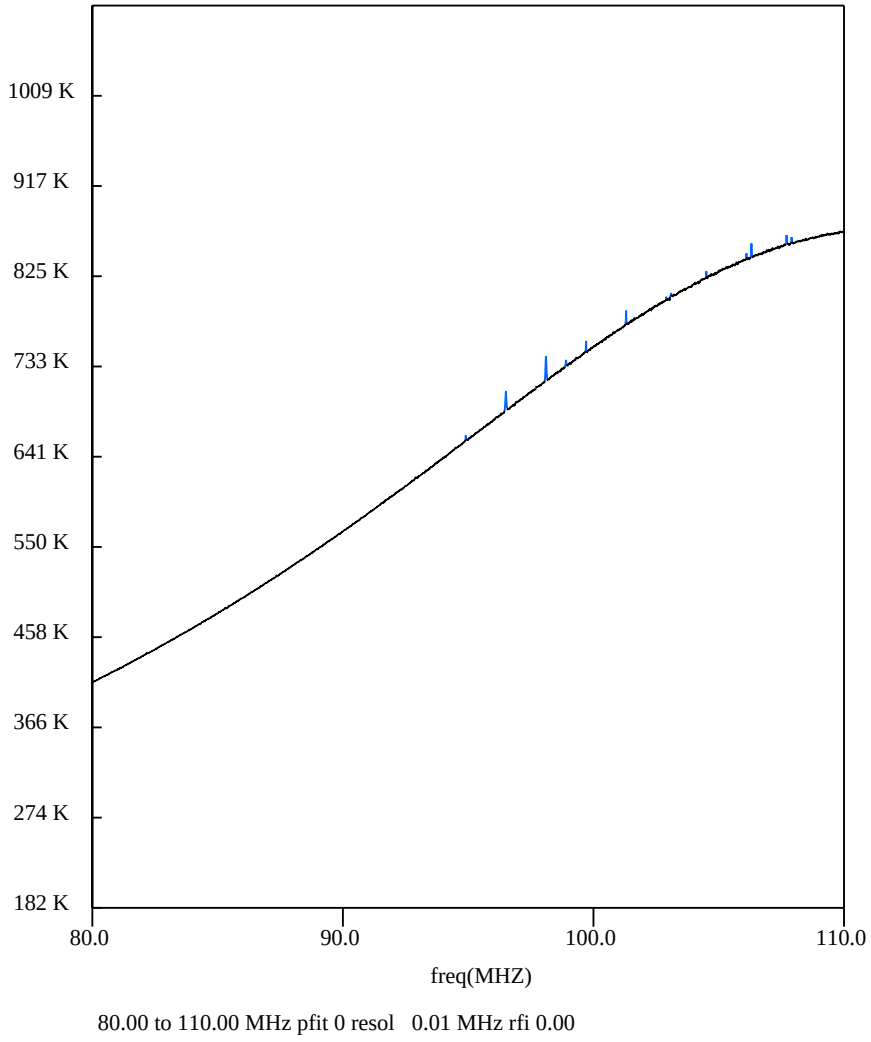

Figure 4. FM spectrum after time excision using filter #2 in table 1.

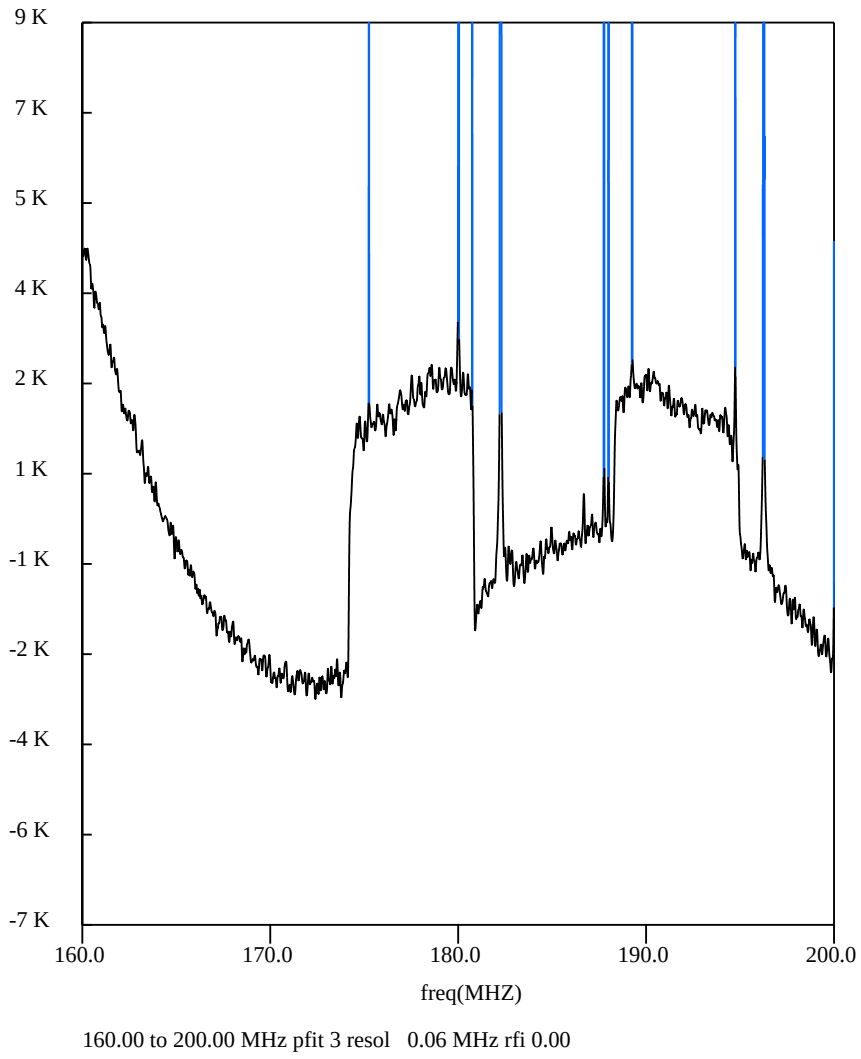

Figure 5. Digital TV on 23 September 2009 when the propagation of distant transmitters was most likely enhanced by refraction around the curvature of the Earth due to a low lying layer of water vapor. The usual propagation lasted from about 17 UT on about the 23rd to 03 UT on the 24th.