EDGES MEMO #168

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
HAYSTACK OBSERVATORY
WESTFORD, MASSACHUSETTS 01886

May 20, 2015

Telephone: 781-981-5400
Fax: 781-981-0590

To: EDGES Group

From: Alan E.E. Rogers

Subject: FEKO tests of slot resonances

1] Introduction

The EDGES is extremely sensitive to poor connections on parts of the antenna and ground plane. The carries the study in memo #138 further by looking in more detail at resonant slots. It is well known that RF leakage from enclosures is dominated by leakage at the seams and consequently panels and lids need to be fastened by screws placed a small fraction of a wavelength apart. However, as mentioned in memo #138 the slots in the seams between the screws can resonate at surprisingly low frequencies. For example, a slot 9 inches wide naturally resonant at 980 MHz will resonate at 175 MHz. when loaded with 19 *pf* capacitance across the gap. Resonances can still occur when there is only capacitive contact between the screws and can move down to surprisingly low frequencies.

2] Expected strength of resonances in the spectrum

If the resonant slot is viewed as an antenna the reflected power is given by the radar equation

$$\mathrm{P_r} = P_T G_T G_S A_T A_S \Big/ \left(4\pi r^2\right)^2$$

$$= P_T A_T^2 A_S^2 \Big/ \left(\lambda^2 r^2\right)^2$$

Where P_r = power received

P_T = power transmitted

G_T = Gain of transmitter antenna

G_S = Gain of slot antenna

A_T = Effective aperture of transmitter antenna

A_S = effective aperture of slot antenna

$$\left|S11\right| = A_T A_S \Big/ \left(\lambda^2 r^2\right)$$

To estimate the effect on the spectrum consider the reflection of the outgoing wave from the LNA is the antenna which is returned to correlate with the noise waves of the LNA.

In this case

$$P_s \simeq P_{LNA} \left|1 + S11\rho\right|^2$$

Where ρ =correlation coefficient

For example if the outgoing LNA noise is 40K, the correlation coefficient is one and S11 is -60 dB the peak to peak "ripple" due to the changing phase of the reflection will be about 80 mK.

Another mechanism is the reflection of the sky noise from the antenna. In this case

$$P_s \simeq P_{sky} \left|1 + S11\Gamma\right|^2$$

Where P_{sky} is the sky noise and Γ is the antenna reflection coefficient. For $P_{sky} = 300\ K$, a – 20 dB reflection coefficient and S11 equal to –60 dB the peak to peak ripple is about 60 mK.

The effect of the slot resonance should be measurable in the S11 for these examples as it is at a level of about 0.05 dB in the difference at resonance for an S11 of – 15 dB.

Figure 1 shows a FEKO simulation for a 6" slot in the middle of the ground plane loaded by 19.2 *pf* in series with 0.1 ohm resistance.

Another effect of a resonance is a change antenna beam with frequency around the resonance. In this case the spectrum change will be a function of the local sidereal time.

The resonance of figures 1 and 2 was generated using FEKO and since the slot was located in the center of the ground plane it produced a change in S11 of 0.05 and produced an estimated effect on the spectrum due to reflection of the LNA noise of about 10K peak to peak whereas the effect on the spectrum due to frequency dependence of the beam was about 40 K peak to peak. As the resonant slot is moved away the effects on the spectrum due to a change in S11 are expected to decline with distance squared while the effects on the beam scale with distance at least for a point source which dominates the sky noise. There are many other factors which will reduce the effects. These include orientation and resistive loss in the slot.

A resonance shown in Figure 3 has been observed in the EDGES high band data started around 2 May 2015. It has a complex spectrum centered at about 175 MHz. It is relatively weak with a maximum of about 100 mK peak to peak. It varies with Galactic Hour Angle (GHA). The complex spectrum might be the result of the two or more cavity slots resulting from poor contact between the antenna baseplate and the rest of the ground plane. The resonance is not evident in the S11.

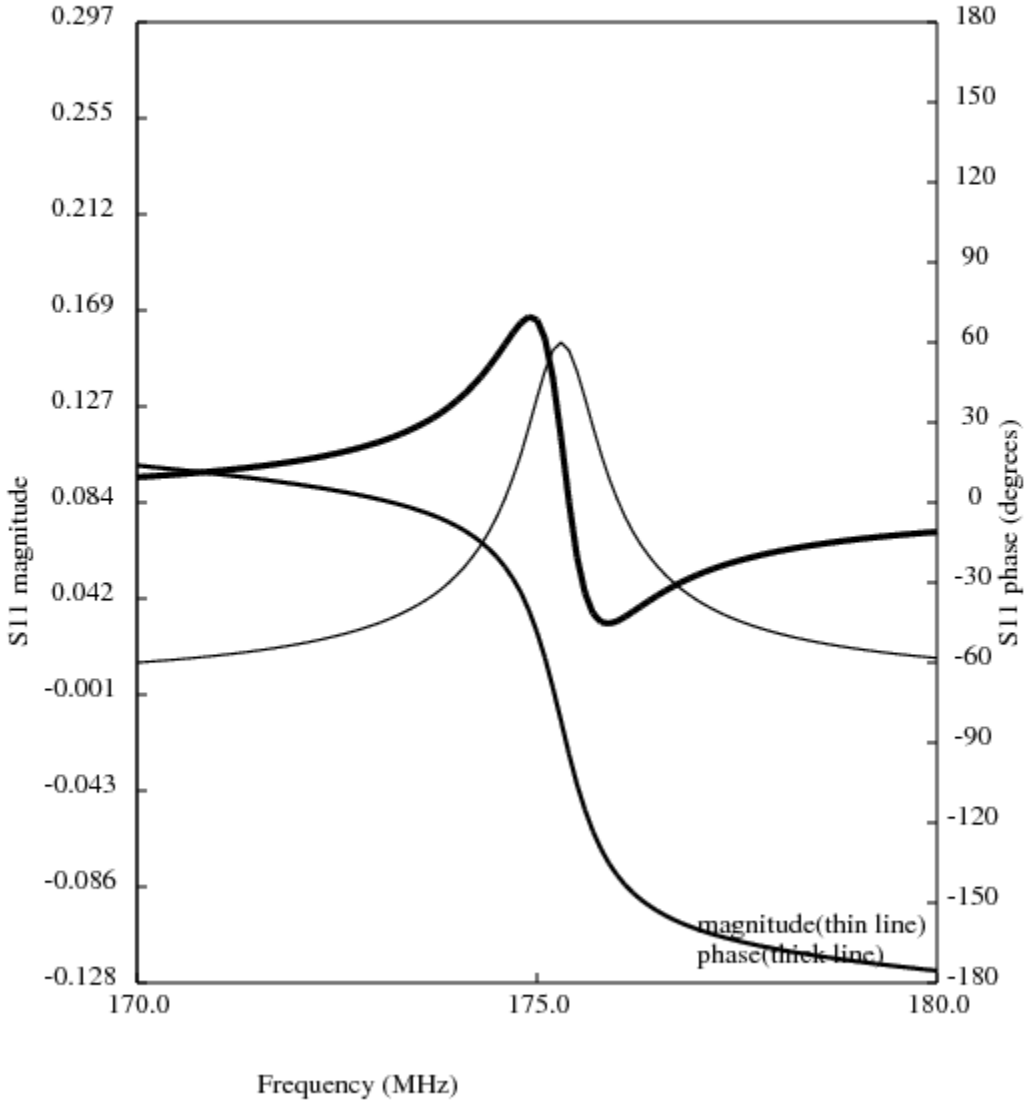

Figure 1. The amplitude (thinnest line), phase (thicker line) and spectrum example (thickest line)

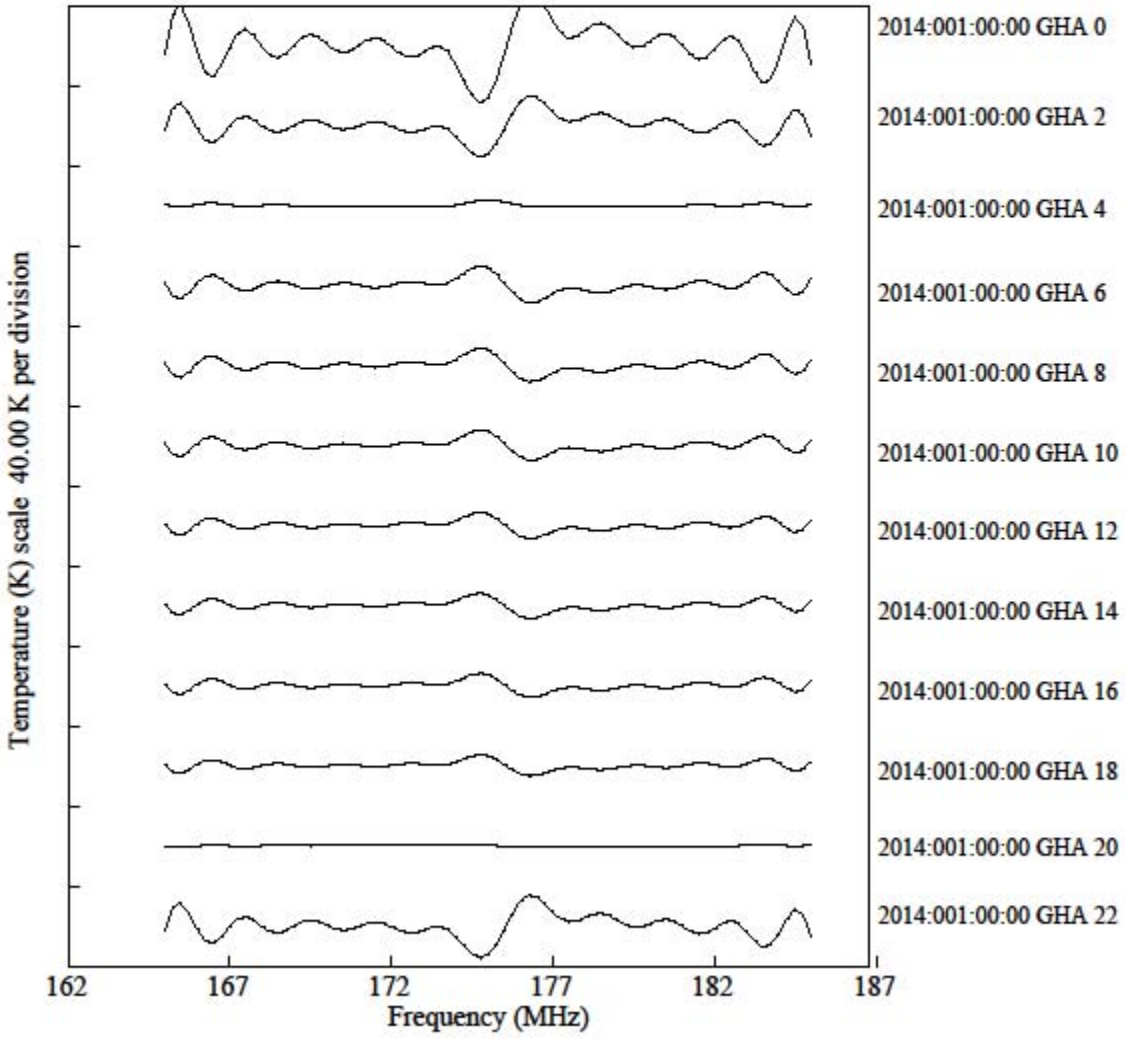

Figure 2. Effect of the resonance on the spectrum from its effect on the beam.

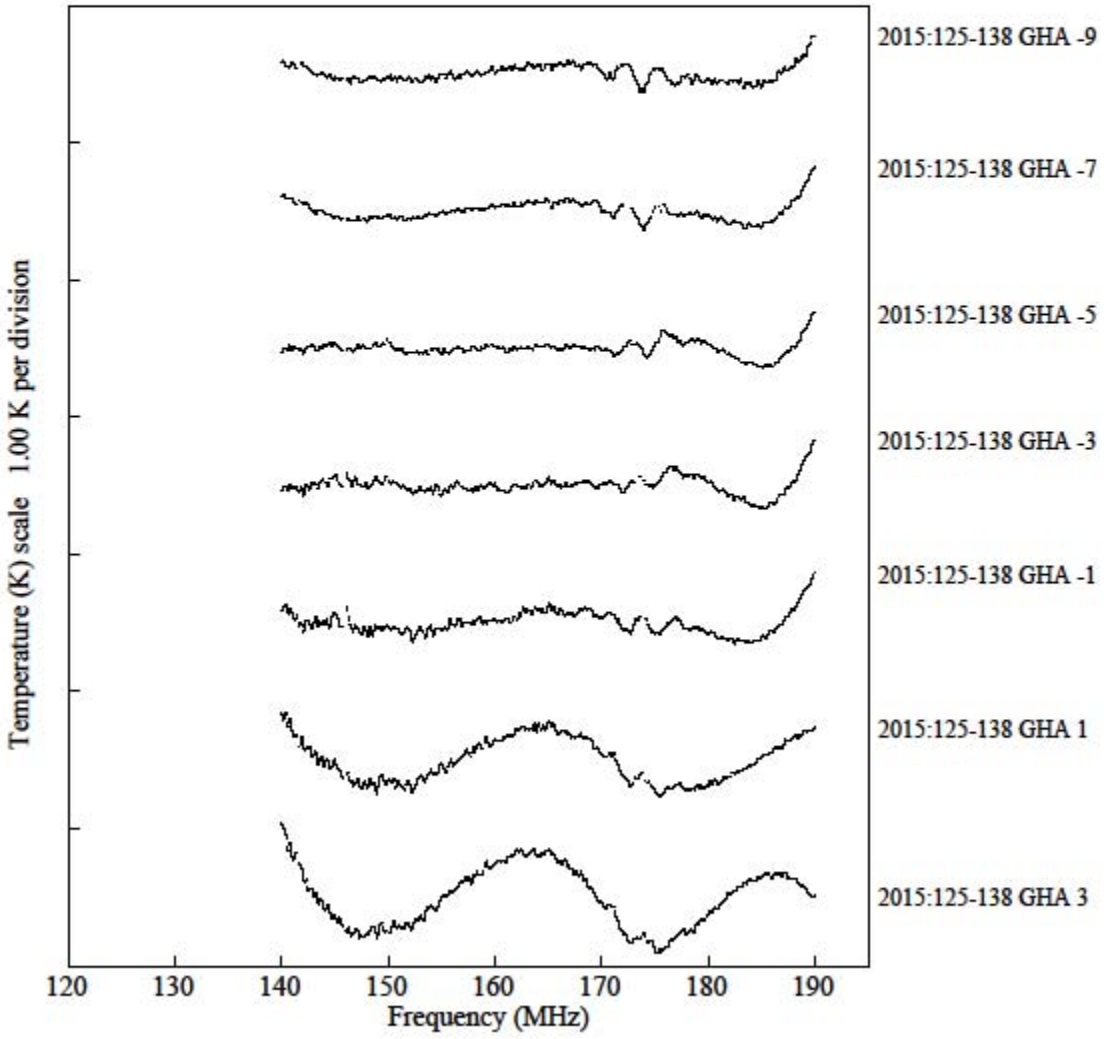

Figure 3. Resonance at 175 MHz shows signature change with GHA.