EDGES MEMO #150

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Subject: EDGES Antenna Beamshift Resonance

Asymmetries in the EDGES antenna can result in an enhanced frequency dependent beamshift. While the beamshift due to asymmetry in the antenna topcap has been extensively studies see ASU EDGES memo #146) asymmetries due to limitations in the mechanical tolerances have not been studied.

Following the deployment of the EDGES-2 antenna in November 2014 a “resonance” in the beam pattern around 167 MHz was noticed (see memo #149). This resonance can be made more evident by plotting the residuals to a 5 parameter fit as shown in Figure 1. The resonance shows up clearly as it is sufficiently narrow in frequency so that it is not removed by the fit. It is noted that the “bump” in the spectrum changes sign at about 0 hours Galactic hour angle (GHA) as expected for a frequency dependence in the beam in the EW direction. Since the antenna is oriented NS this implies a change in beam due to some hidden asymmetry in structure which is asymmetric in the EW direction. After looking at a number of possibilities it was discovered that the capacitance at the tips of the panels produces a resonant beam tilt in the presence of any asymmetry in these capacitors. This resonance is at about 165 MHz for tip capacitance of 3 pf and moves to about 180 MHz for 2 pf. The resonant frequency is relatively insensitive to the capacitance of the topcap and the balun tuner. The equivalent capacitance for Teflon spacers used in EDGES-1 is about 1.4 pf and this is small enough to move the resonance to about 200 MHz where it would not be noticed.

Figure 2 shows a simulation of the spectrum due to the beam shift using FEKO for the EM simulation of the beam which is then convolved with the 408 MHz Haslam et al. sky map assuming a spectral index of 2.5. An asymmetry of only 1% was required to produce the variation at 167 MHz of about 2K. In contrast Figure 3 shows the effect of a 5% asymmetry when the tip capacitance is reduced to 1.2 pf. The bump at about 165 MHz is the result of a swing in the beam maximum from being 1 degree to the west below 165 MHz to 1 degree to the east above 165 MHz.

This problem occurred because being unaware of this resonant beam tilt due to asymmetry the tip capacitance was increased to get the best S11. However, based on recent FEKO simulations, it should still be possible to get a good S11 by holding the tip capacitors to a maximum of 1.4 pf and optimizing the topcap and balun tuner capacitance.

Figure 4 shows an optimization with FEKO under this constraint. In order to reduce the tip capacitance it is proposed to replace the 1×0.75×0.2 inch quartz with 1×0.75×0.35 inch quartz along with a reduction in the thickness of the aluminum spaces from 0.25” to 0.175”.

Further tests show that the resonance makes the beamshift extremely sensitive to an asymmetry as small as 1% whereas without resonance it takes an asymmetry of about 5% to produce a beam tilt of 1 degree or an asymmetry in gain of order 0.5 dB. Some of the tests which have an asymmetry in gain under 0.1 dB include off setting the height of one of the panels by 1mm, extending the tip of a panel by 5 mm. In general any dimensional change, except for the thickness of the quartz or the panel separation, of under 1 mm will produce an asymmetry of less than 0.01 dB in the beam and less than 0.01 degrees beam tilt. For quartz of 0.35” thickness the tolerance needs to be within 3 thousandth of an inch and the panel separation within 10 thousandths.

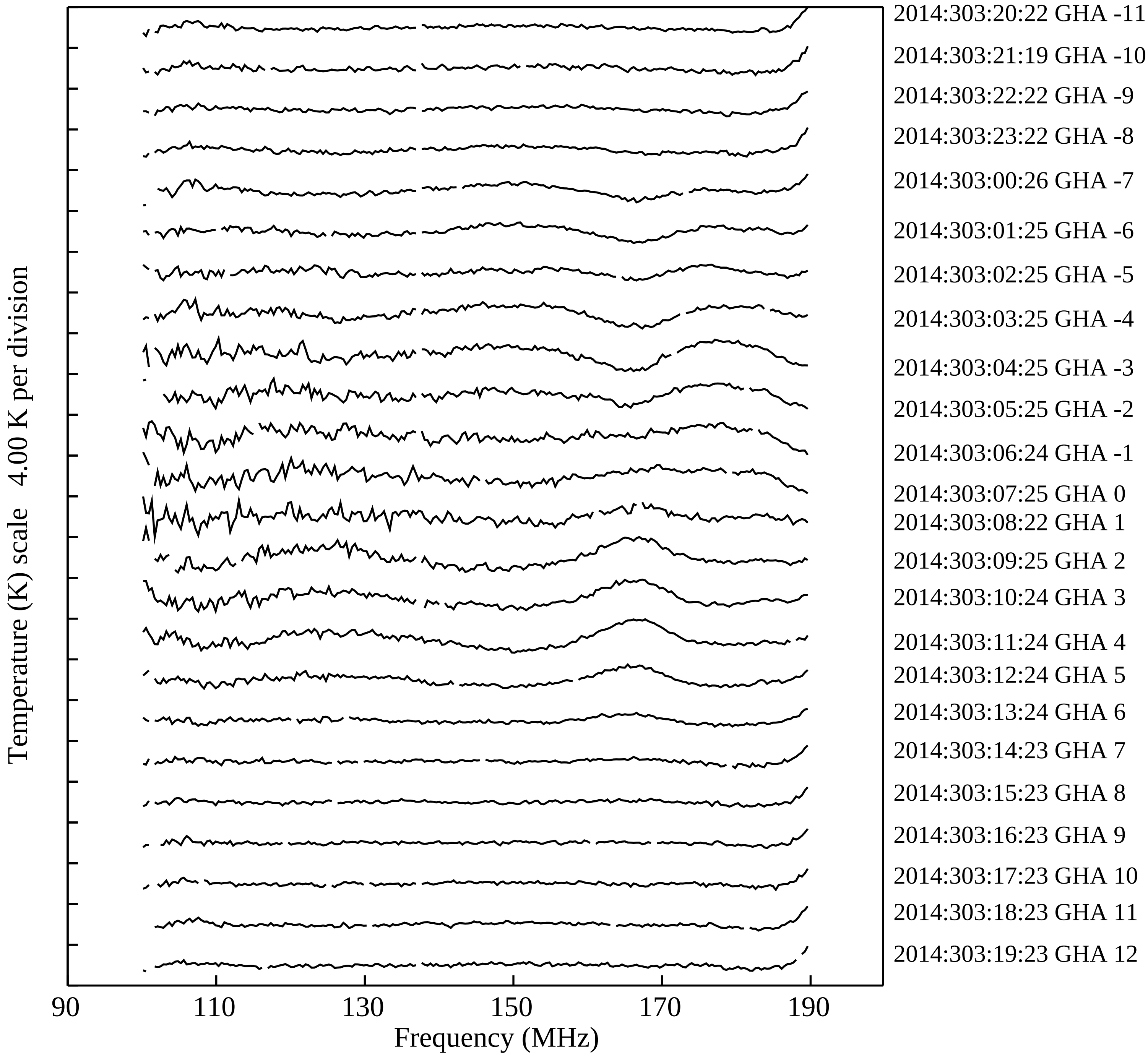

Figure 1. Observed "resonance" in frequency structure due to beam shift.

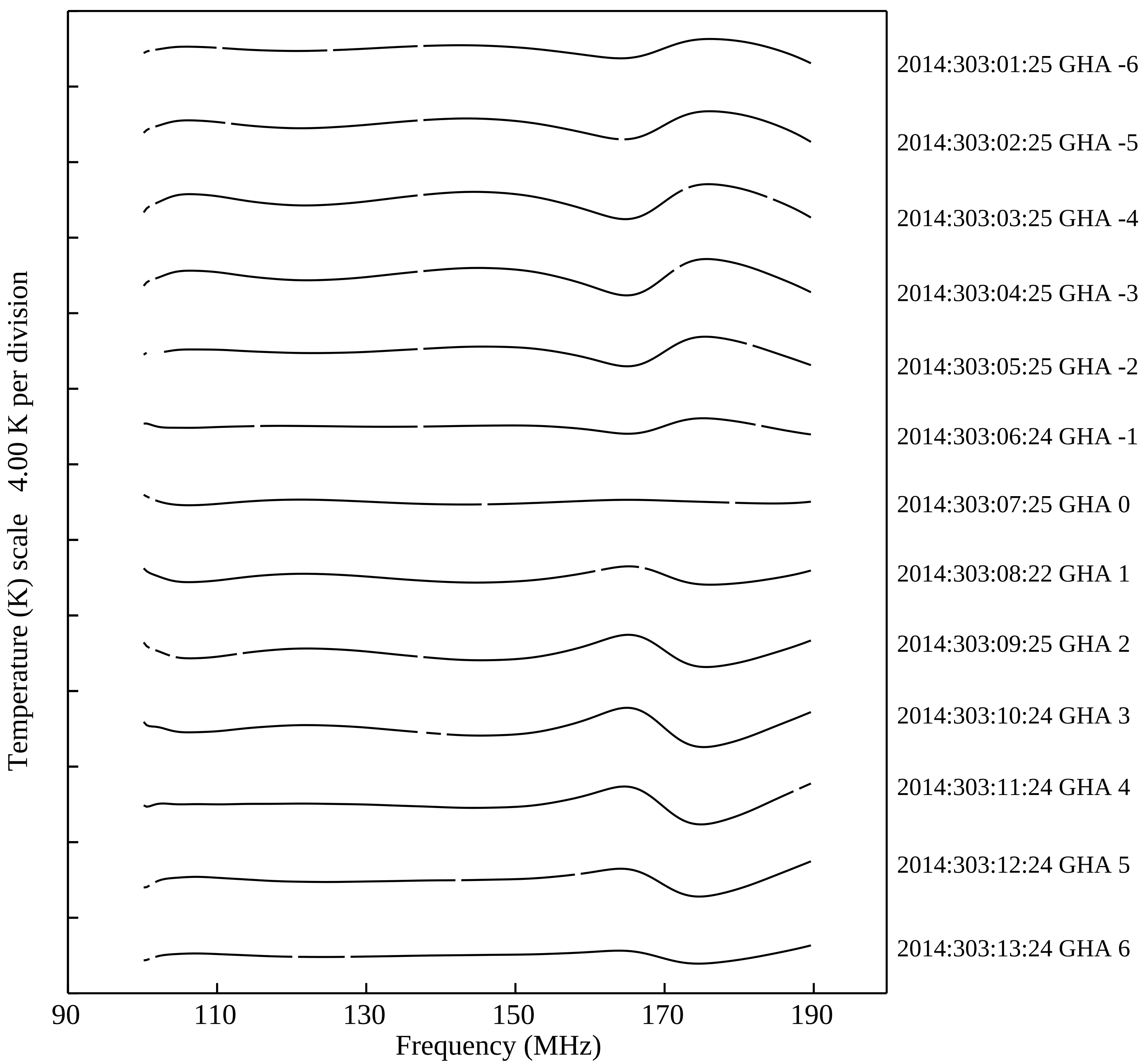

Figure 2. Simulation using FEKO with 1% asymmetry in “tip” capacitors of 3pf.

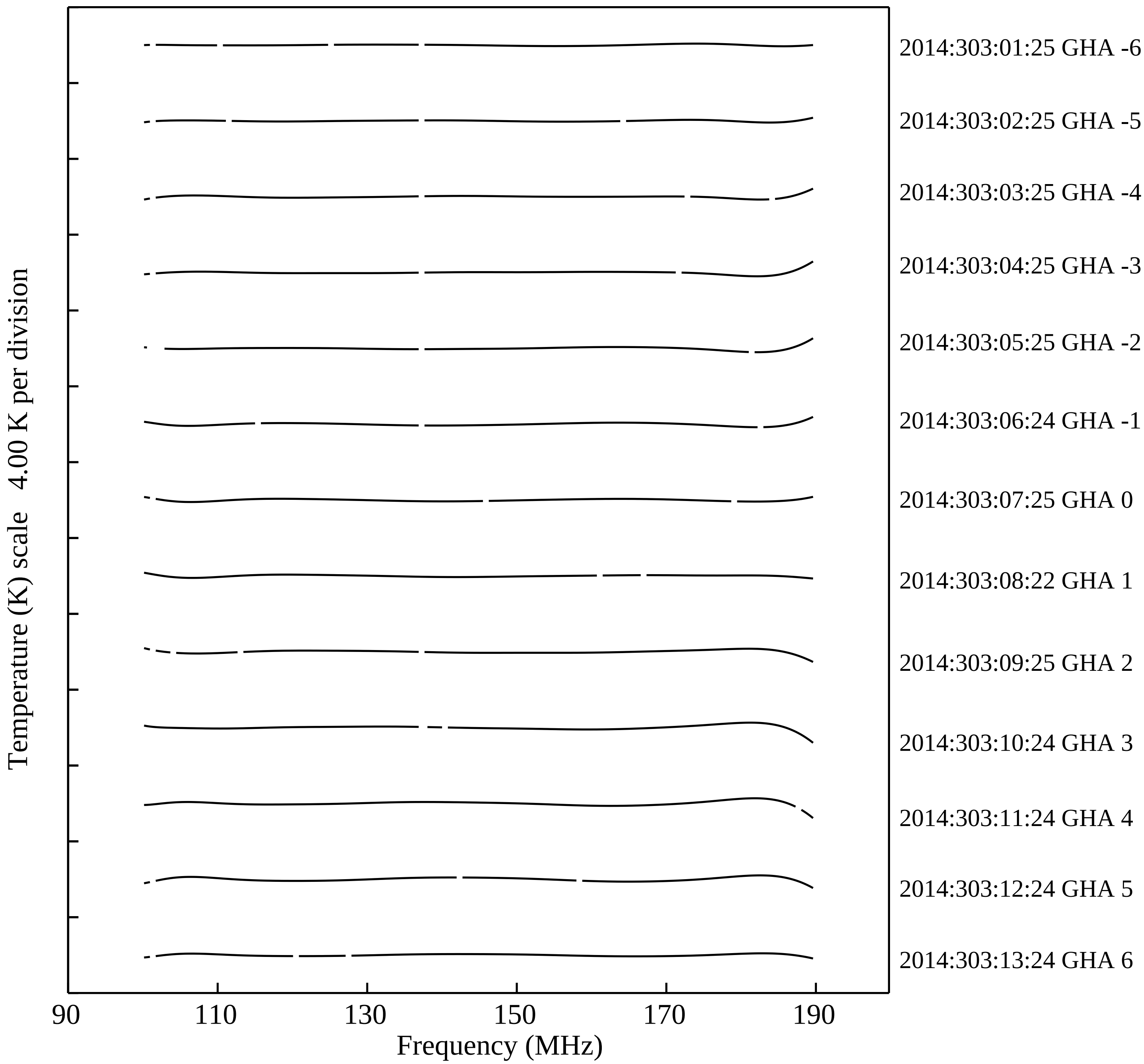

Figure 3. Simulation with tip capacitance of 1.2 pf a 5% asymmetry.

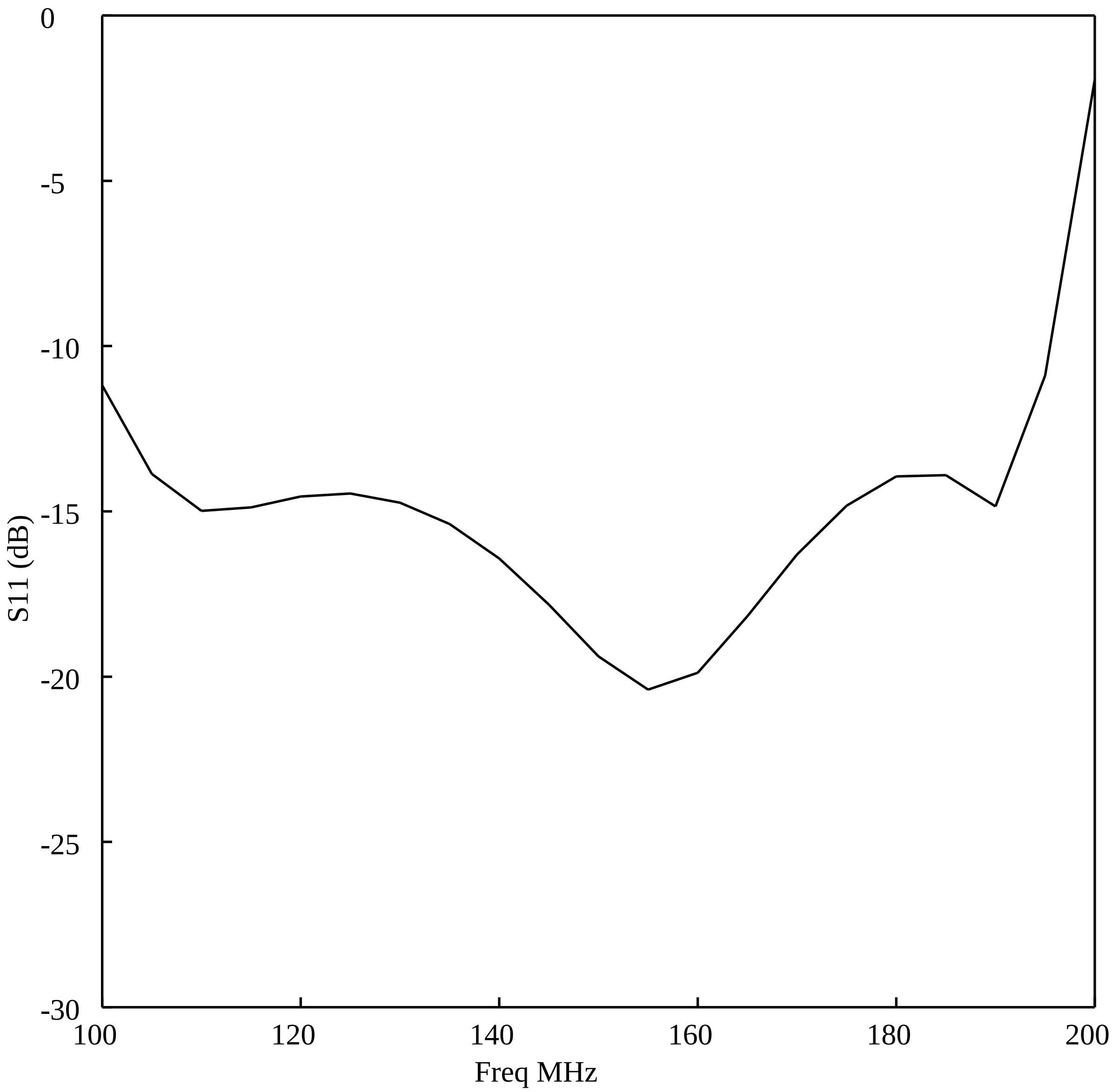

Figure 4. S11 with tip, tuner and topcap capacitance of 1.4, 3.4 and 5.8 pf.