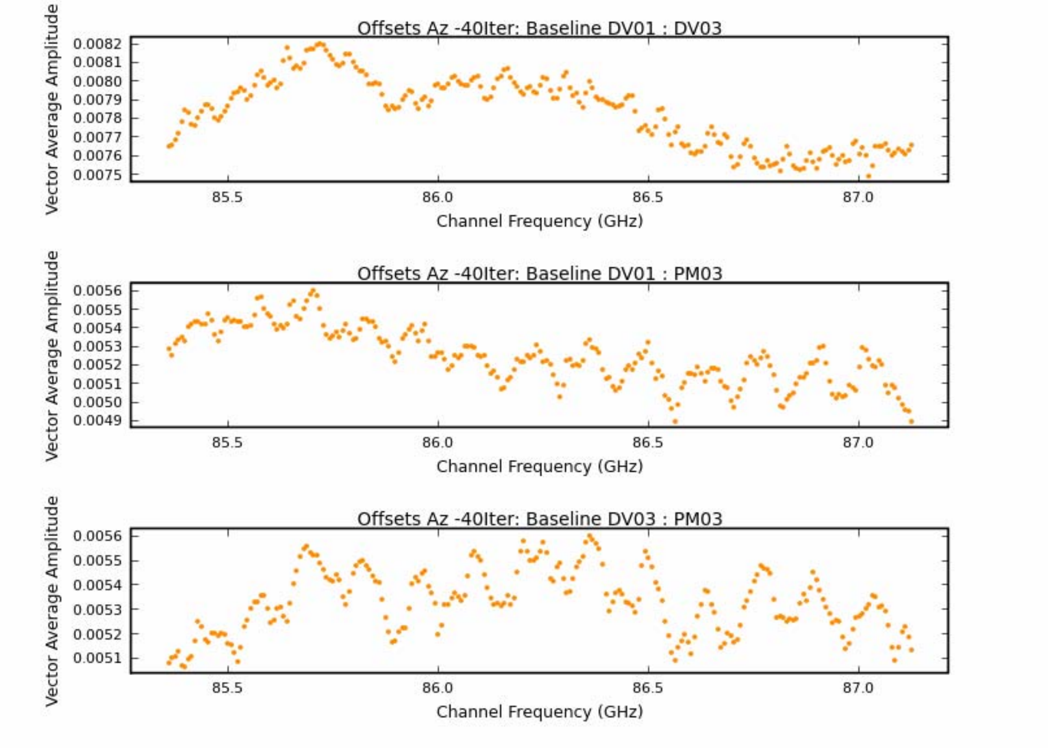
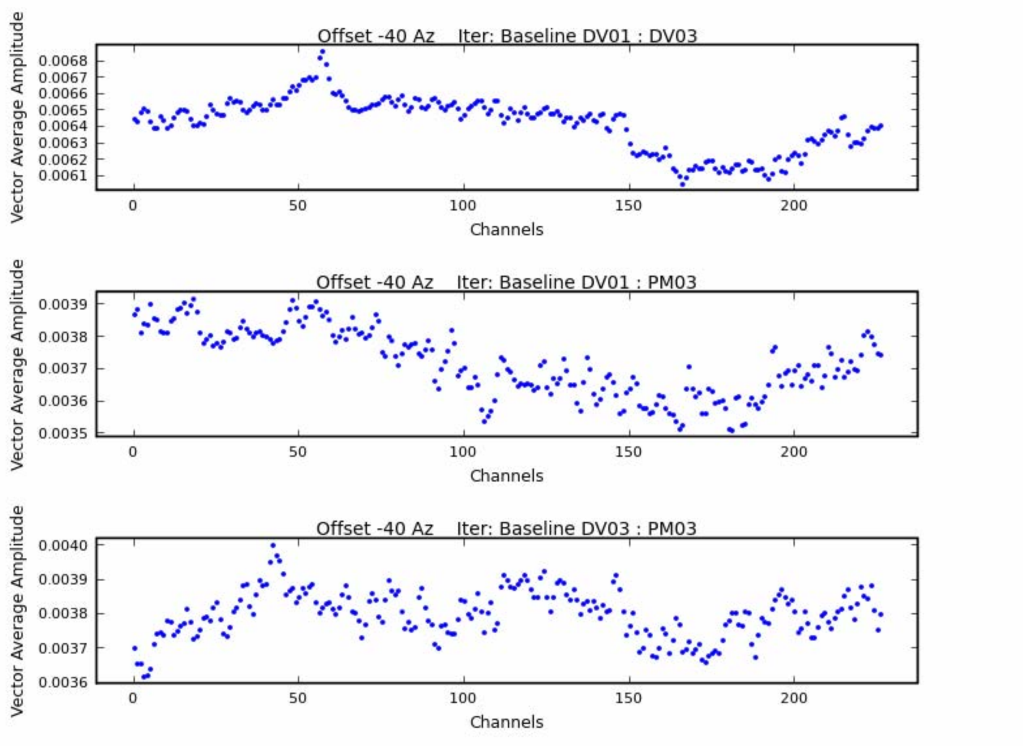
Membrane Reflections

The attached note was written when we first realized that there was a problem with the design of the membrane. This has now been confirmed. Here is a plot of the ripple on a bright source with a 40 arcsecond pointing offset. (The pointing offset increases the reflection from the receiver making the effect clearer.)

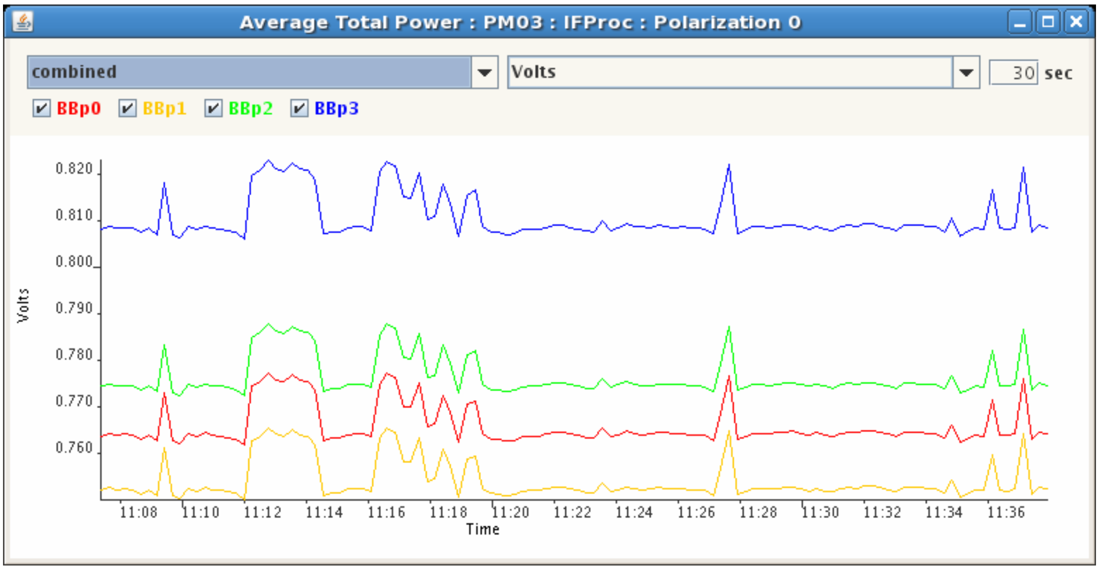


Here is an equivalent observation after installing the "damper" (see below for details)

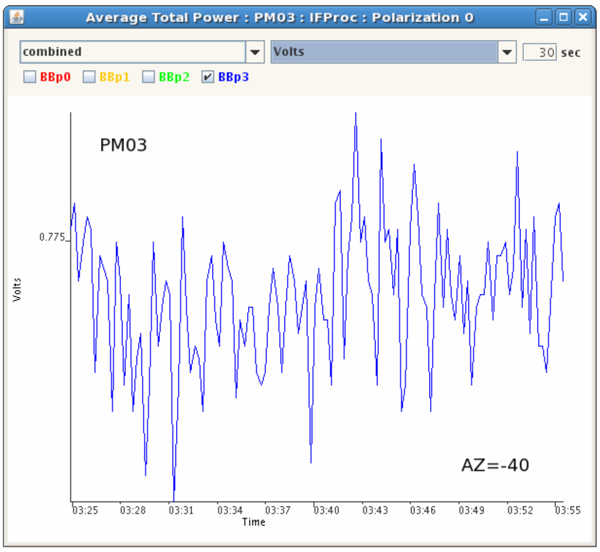


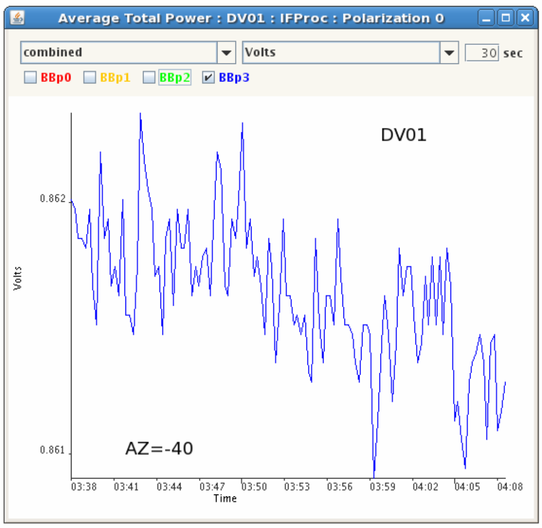
There is still a lot of structure on the bandpass but the very obvious ripple with a period of ~130 MHz on the baselines involving PM03 is largely gone.

The total power stability was also improved markedly. Here is an example of what we were seeing back in March. It turned out that this effect depended on the orientation of the dish with respect to the wind.



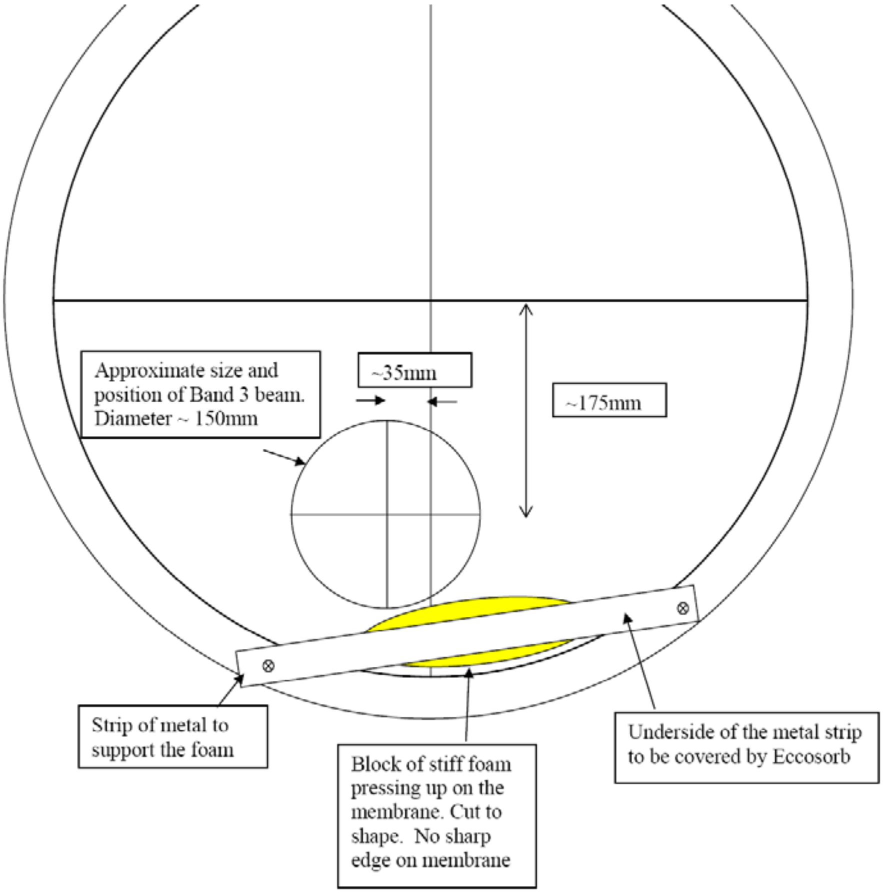
Here is recent measurement (with DV01 for comparison). The scales are not quite clear but it is obvious that the gross instability is not present. This one of many examples taken at different orientations, none of which showed the large excursions seen above.





The basic point is that from the focal plane subreflector subtends an angle of +/-3.6 degrees so the receivers have a significant response 5 degrees off-axis. Tilting the membrane by 5 degrees was clearly not enough. The problem is made worse by the fact that the receiver beams are titled by 1 to 2 degrees due to the fact that the feeds are off-axis. On PM03 the direction of tilt is such that band 3 is most affected. On the Vertex antennas the direction of tilt was chosen to be along the elevation axis, which means that the main effect will be different bands.

The diagnosis was confirmed by installing a “damper” on PM03.   Here is the design sketch:



And here are pictures of it in place:

The bulk of it is made of stiff packing foam with a layer of softer foam in contact with the membrane. (Unfortunately we couldn’t find a use for duct tape in this effort!)

We think the foam is clear of the band 3 beam but there is not much space. The damper lifted the membrane by about 20 mm, which should increase the tilt by nearly 2 degrees as well as making it tighter.

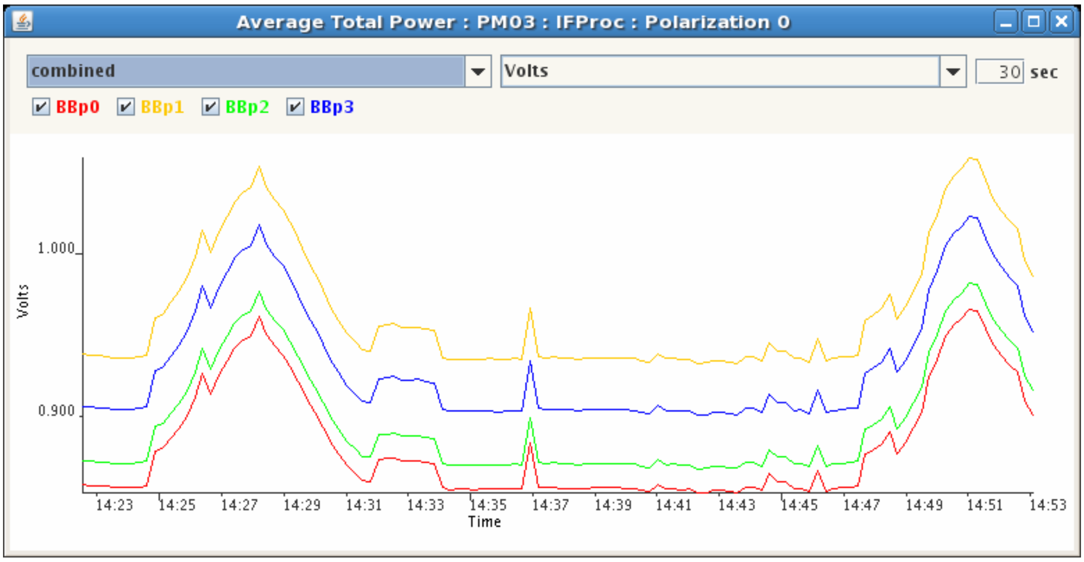
We plan to leave this in place for now and we will probably install something similar on PM02. Suggestions for improvements please?

A final solution may involve a change in the mounting arrangements of the membrane to increase the tilt and change the orientation, and/or a change in the material. Clearly the much thinner FEP membrane that we have been wanted to use for quite some time will have much lower reflections, at least at the lower frequencies. Maintaining a positive pressure in the receiver cabin is also worth considering. That would prevent flapping but might make it harder to achieve the necessary tilt.

Richard Hills 18th May 2010

Total Power Instabilities in Band 3 on PM03

We have been plagued by this instability for quite some time. Here is an example of what we see: a "spiky" fluctuation on all 4 basebands and both polarizations. The change in power level is 1 to 2% and there is a suggestion that it is bimodal, i.e. on and off states. The current ticket for this is AIV-2173 although several other tickets are probably reporting the same thing.



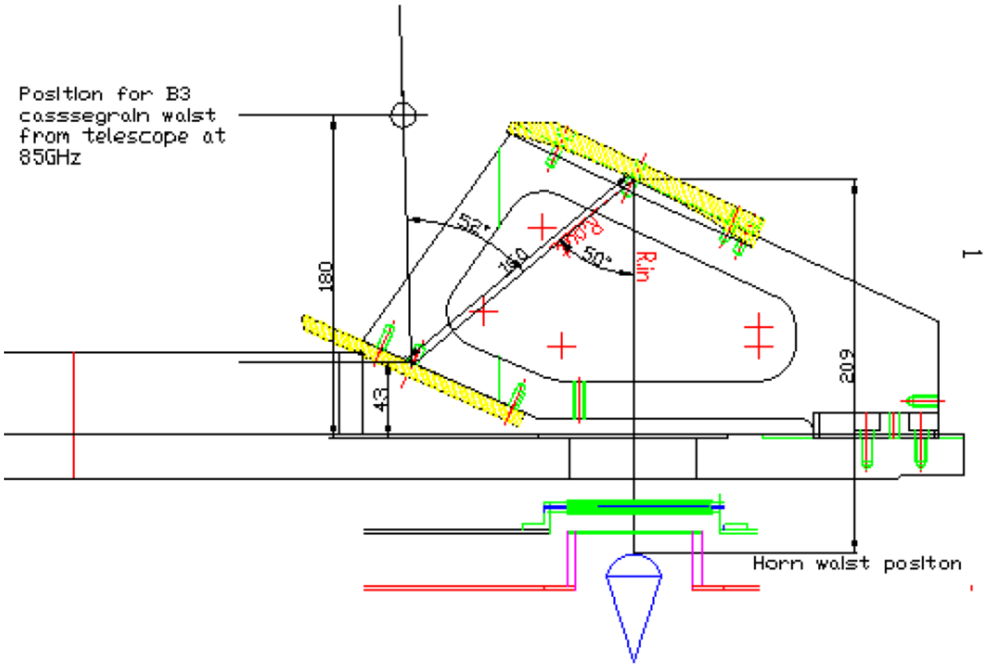
The key diagnostic points are that

1) it is definitely <u>not</u> present when the calibration loads are in the beam (I think this was reported previously, but recent tests by Nick Whyborn forced us to focus on this), and
2) the effect depends strongly on the antenna Azimuth and Elevation. It is strongest at elevations of around 70 and azimuth around 270. This Azimuth is where the wind was coming from all the time recently. Since we have had no low wind conditions, we cannot directly confirm that the effect is associated with the wind, but this seems the obvious conclusion.

The possibility that something was hanging loose and getting in the beam was eliminated by an inspection of the "widget space". This leaves a reflection off the membrane as by far the most likely explanation.

The membrane is designed to be tilted by 5 degrees with respect to the antenna axis. We checked that it is tilted by about this amount and confirmed that the tilt is downwards towards the side of the antenna that is at the bottom when the antenna points at the horizon.

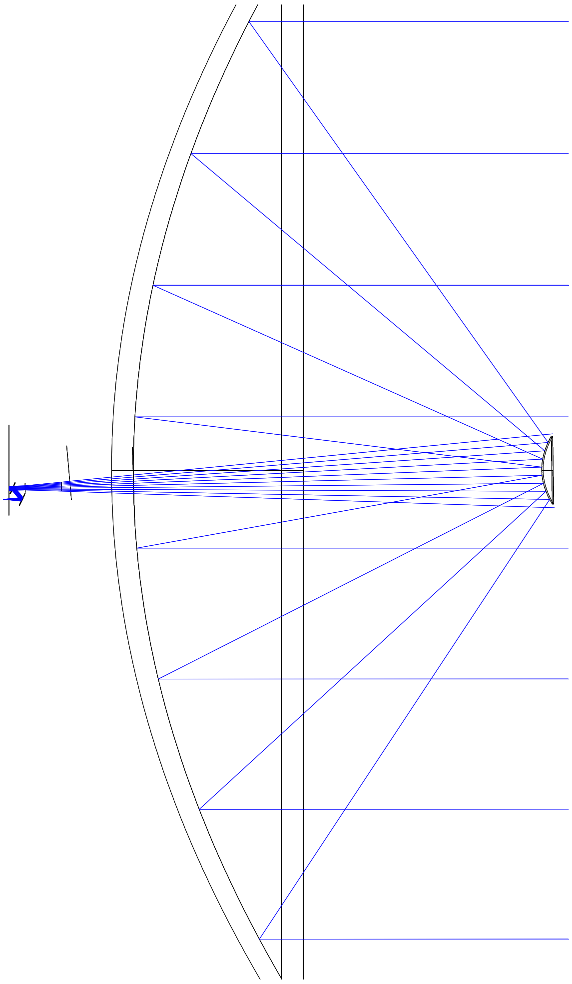
The tilt is supposed to ensure that any reflections from the membrane do not go back into the receiver. The Band 3 optics looks like this.



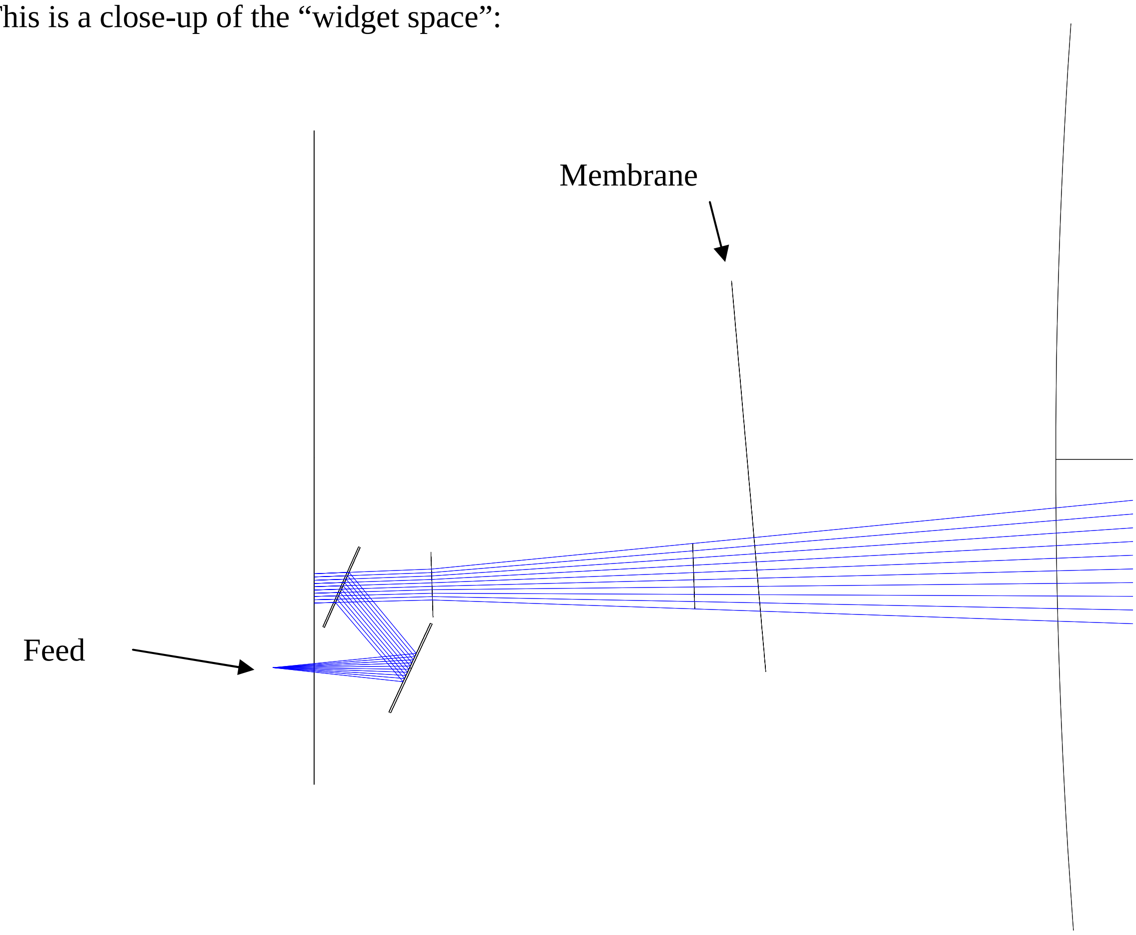
Note that the incoming beam from the subreflector is at an angle of about 2 degrees to the axis (nominally 1.84 degrees).

Here is a picture with the "focal plane stop" installed as an experiment for holography. Note that no instabilities were visible with this stop in place.

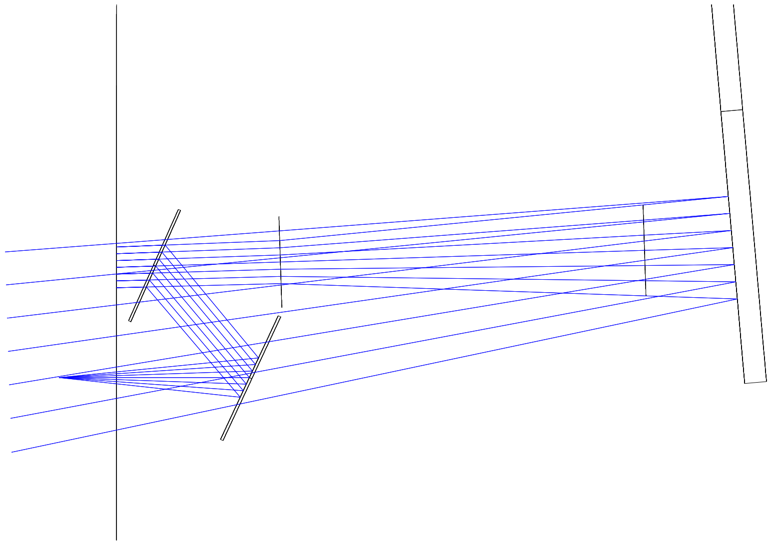
To see how a reflection could get back into the receiver, I constructed a Zemax model of the band 3 optics on the antenna.



This is a close-up of the “widget space”:



I then made the membrane into a flat mirror:



It is clear that anything being emitted by the receiver goes straight back into the area of the optics and that some of it goes back along the beam. In retrospect the 1.84 degree tilt of the beam plus the roughly +/- 3.5 degree width of the beam obviously means that the 5 degree slope produces a reflection from the membrane at normal incidence at one side of the beam.

Not all of the power reflected from the membrane (which is a little over 1% at this frequency) will go back into the feed because it only gets to normal incidence towards the edge of the beam and but a significant fraction of it will. Because at least part of what is emitted by the receiver will be coherent with the signal going into IF, however, it is the amplitude of the reflected field that is important here, not the power, and this is easily large enough to explain the observed magnitude of effect. The fluctuations are presumably due to the membrane flopping between convex and concave depending on whether the difference in air pressure between the cabin and the outside world produced by the wind is positive or negative.

The same reflection mechanism is almost certainly responsible for the amplitude ripples as a function of frequency seen when we are on the side of a strong source (CSV-208). The period of about 133 MHz is roughly consistent with the path involved here. (I need a more accurate drawing showing the distance between the optics and the membrane to confirm this.)

The instability was very probably contributing to the poor pointing, e.g. CSV-195, as well.

In principle we should be able to fix the problem by rotating the membrane so that the slope is in a different direction. The specification says,

"The orientation of the 5 degrees inclination shall be settable in steps of 45 degrees in relation to the elevation axis. The change in orientation may be achieved by unbolting and refastening the mechanism from inside the receiver cabin."

It isn't clear from the photo above how this unbolting and refastening is supposed to be done, but I fear that it will probably be quite tricky with the receiver in place.

Obviously we should have thought about which orientation ought to be used before we got to this point. Since all the receiver beams do have some tilts and similar beam-widths it will be a compromise as to where we put it. Changing to the new FEP membrane should largely solve this problem for the lower frequencies because the reflection will be far smaller.

The fact that we don't see this on the Vertex antennas may mean that a different orientation was used or that there is some more subtle difference in the geometry.

Richard Hills 26th April 2010