EDGES MEMO #435

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To: EDGES group
From: Alan E.E. Rogers and John Barrett
Subject: FEKO simulations of close contact of wires in welded mesh ground planes

Welded wire grid mesh ground planes have been used for all the EDGES data taken at the Inyarrimanha Ilgari Bundara observatory in Murchison Western Australia. Concerns over potential resonances are examined in memo 209 using analytic expressions for estimates of the capacitance between wires in the mesh which come in close contact with each other. However it is found that modeling close contact at the level of a few microns with FEKO is very difficult and consequently the modeling of slot resonances in memos 168, 209 and 407 used added capacitance. For example the slots in memo 429 and 431 have 100 pf capacitance added across the slot to obtain the resonance at about 60 MHz.

FEKO simulations have now been made using wire mesh. Figure 1 shows an example of 2 pieces of mesh joined with connections between the top and bottom three horizontal wires and only capacitance between the three horizontal wires in the center. A 25 cm long dipole antenna is placed 3.4 cm above the center and is oriented across the slot. Figure 2 is a test case in which the 2 pieces of mesh are joined with the piece of the right on top of the piece of the left with the same connections between the horizontal wires. In both cases a 110 pf capacitance has been added to produce a resonance at about 100 MHz and in both cases the FEKO model is on soil with dielectric 3.5 and 1e-2 S/m conductivity.

The following tests were done on the FEKO models in preparation for a bench test with a VNA to see if resonances can be detected with a loop or dipole antenna close the slot which results from close contact.

The resonance is only detected when the dipole is oriented perpendicular to the gap between panels.

1] For the same height of the dipole above the mesh there is little difference in whether the panels are connected without or with overlap as in figures 1 and 2.
2] Soil is needed for a significant detection of the resonance with either the loop or the dipole and there is no significant detection with the mesh in free space or over an infinite PEC ground.
3] A dipole with ferrite “clamp on” filter as a balun is more sensitive than the loop in memo 431
4] The sensitivity of the dipole and loop drop off rapidly with distance of more than about 5 cm above the mesh.

In order to get a high capacitance between wires high density bag made by www.plasticmill.com with 6-micron thickness were obtained. The thickness was checked by comparing the volume of the 2 50 bag rolls and I get 5e-4 cubic meters for the size of the packaged rolls with the estimate of the volume of 200 24x24 inch sheets of 6 micron thickness.

It was hoped that a test of a resonance using 2 20x40 cm pieces of mesh set-up with a 15cm long slot with gap of 6 microns might be provided by using pieces of a density bag. For 3.15 mm diameter wires separated by 6 microns the capacitance is about 13.5 pf/cm is estimated assuming a dielectric constant of 3 using the analytic expression and calculator at https://www.et.

However when the mesh was set-up on the bench as shown in the photo (Figure 3) it was found that in practice a connection of the VNA with crocodile clips (as shown in Figure 4) is needed to observe the resonances. In addition, it was found that the sections of mesh used on the bench were not uniform enough to make use of the 6 micron thick bag plastic to get a 6 micron separation of the wires of a distance of more than about 3 to 4 cm so that only about 50 pf could be obtained so a 100 pf capacitor was soldered between the wires to get the resonance down to about 60 MHz.

A suggested procedure for tests of potential resonances and fixes of resonances if found in the 48x48m ground plane at the WA is as follows:

1] Examine all mesh joints within 5m of the antenna

If there are no gaps less than 0.001 inches (25 microns) between welds based on an insertion check with 0.001 inch (25 micron) feeler gauge between the closely spaced parallel wires then there is no problem but if there is a possibility of closer contact then proceed to test with a VNA as follows:

In order to get good contact of the VNA to mesh wires add 1/8 Inch M3 Stainless Steel Wire Rope Cable Clip Clamps to the wires perpendicular to the closely wires on each side of the close contact. Then check for electrical contact between clamps with an ohmmeter and if no contact tighten the clamps until contact is achieved. Then attach the VNA to the clamps using crocodile clips and observe the S11 from 40 to 120 MHz with resolution of 0.05 dB to check for any resonances. Without a resonance the S11 should be smooth at the 0.01 dB level and not change if the gap is shorted.

If no resonance is detected remove clamps and move to next potential case.

If a resonance is observed then add a clamp across the closely space wires and tighten until resonance has gone away and then remove the clamps used to connect to the VNA or leave them in place for another check later and move to the next potential case.

It may be possible to get good contact to the crocodile clips without the clamps. This can be checked with the crocodile clips connected and the coaxial connector to the VNA disconnected as depending on the particular VNA and its setting the ohmmeter will be disturbed by the signals from the VNA.

A comparison of the resonances seen in the EDGES-3 data shown in memo 421 are compared with FEKO simulations in memo 429 suggest that the most likely location for resonant slots in the welds is to the northeast of the baseplate which is an area where an examination of the welds shows potential contact of the parallel wires between welds.

A FEKO model, which is shown in figure 5, is used to show the effects of a resonance on the beam of EDGES-3 at the WA. The resonance in the model is produced by the wire grid mesh which has 4 5x5 cm squares that have loss of contact between parallel wires. Each of the 3 locations of lost contact are loaded with 199 pf capacitance achieve a resonance at about 60 MHz. The results of the effects on the beam vs GHA are shown in Figure 6 and the S11 that is expected to be observed with a VNA connected with crocodile clips across the center gap is plotted in Figure 7.

In summary understanding and fixing resonances is needed to avoid the instrumental artifacts that arise from these resonances. Richard Bradley of NRAO pointed out in 2019 that slot resonances could possibly explain the 2018 EDGES result although it seems unlikely that slot resonances on different

ground planes would produce the same absorption profile which has now been observed on many different ground planes and orientations of the EDGES antennas.

References:

Bradley, R.F., Tauscher, K., Rapetti, D. and Burns, J.O., 2019. A ground plane artifact that induces an absorption profile in averaged spectra from global 21 cm measurements, with possible application to EDGES. *The Astrophysical Journal*, *874*(2), p.153.

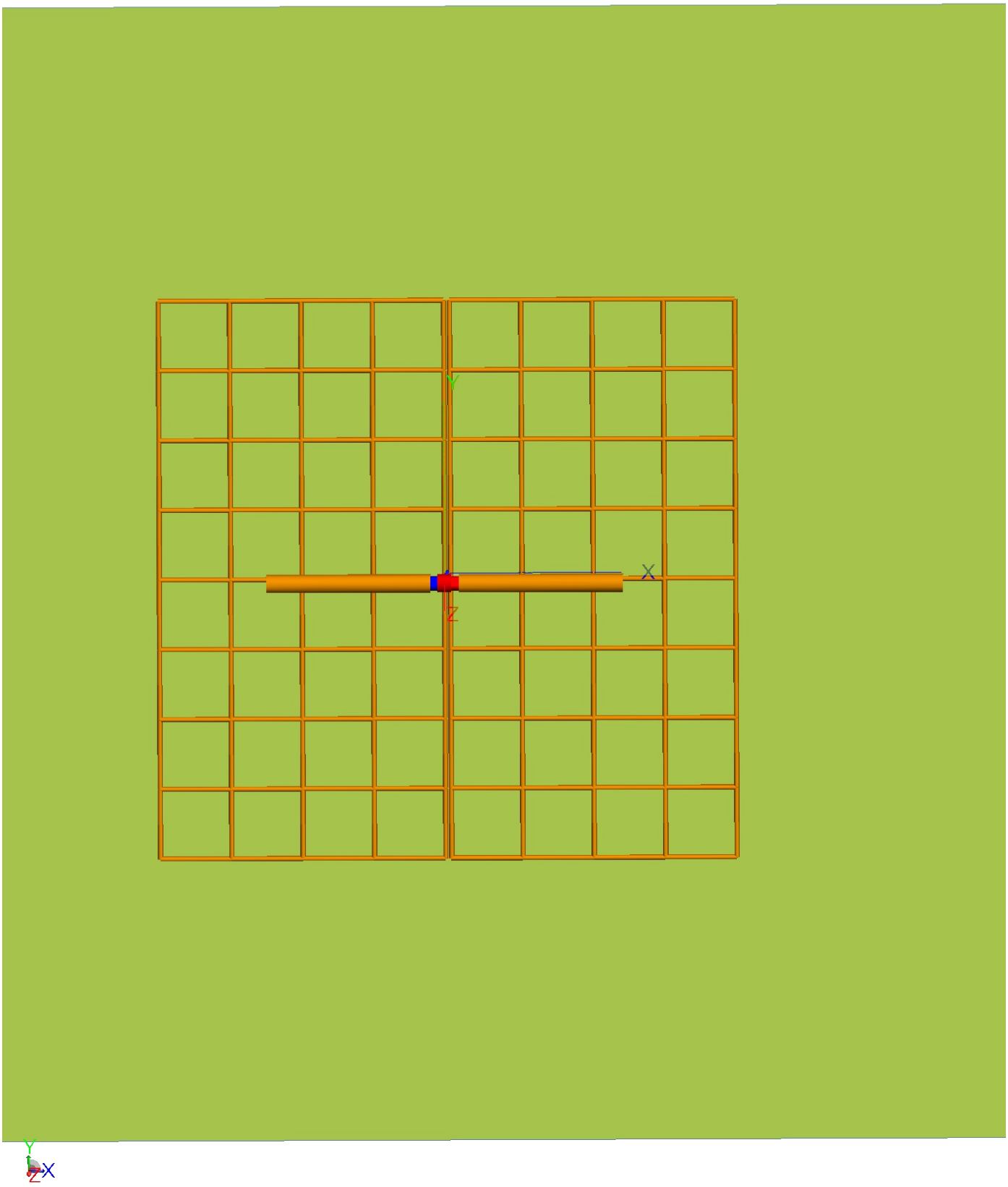

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Figure 1. FEKO simulation of dipole over mesh panels with 3.5mm diameter wires spaced 5 cm apart

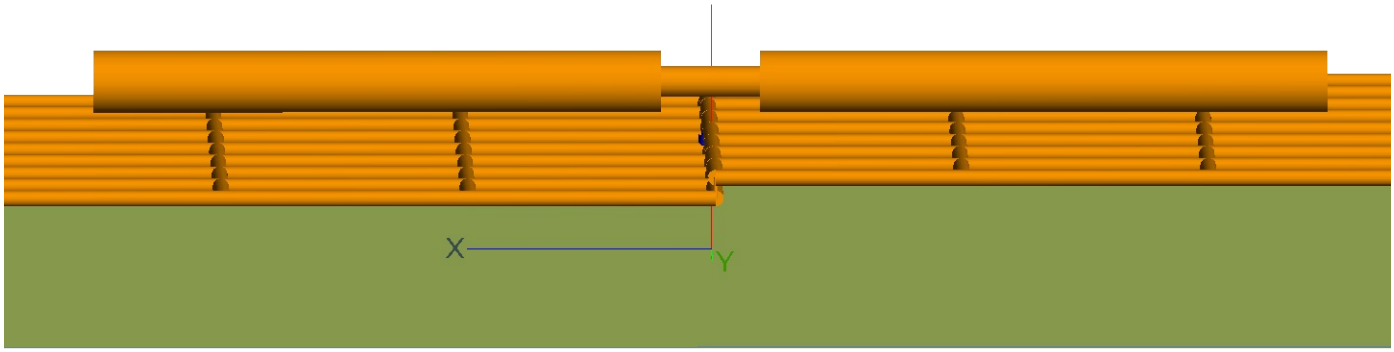

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Figure 2. Low angle view of dipole over mesh for simulation with vertical overlap of panels

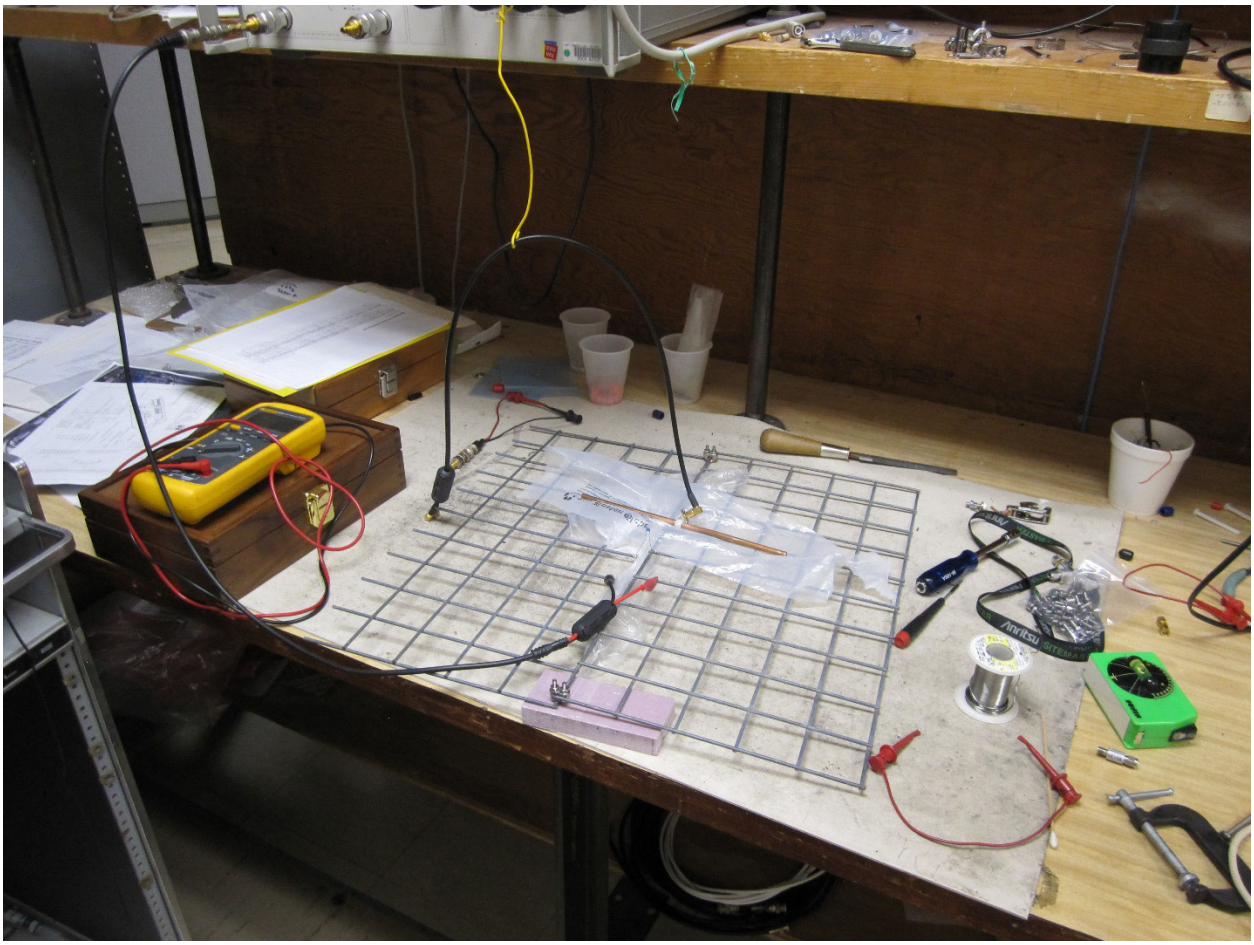

Figure 3. View of bench set-up for tests of resonances

Figure 4. Photo of connections to mesh using crocodile clips

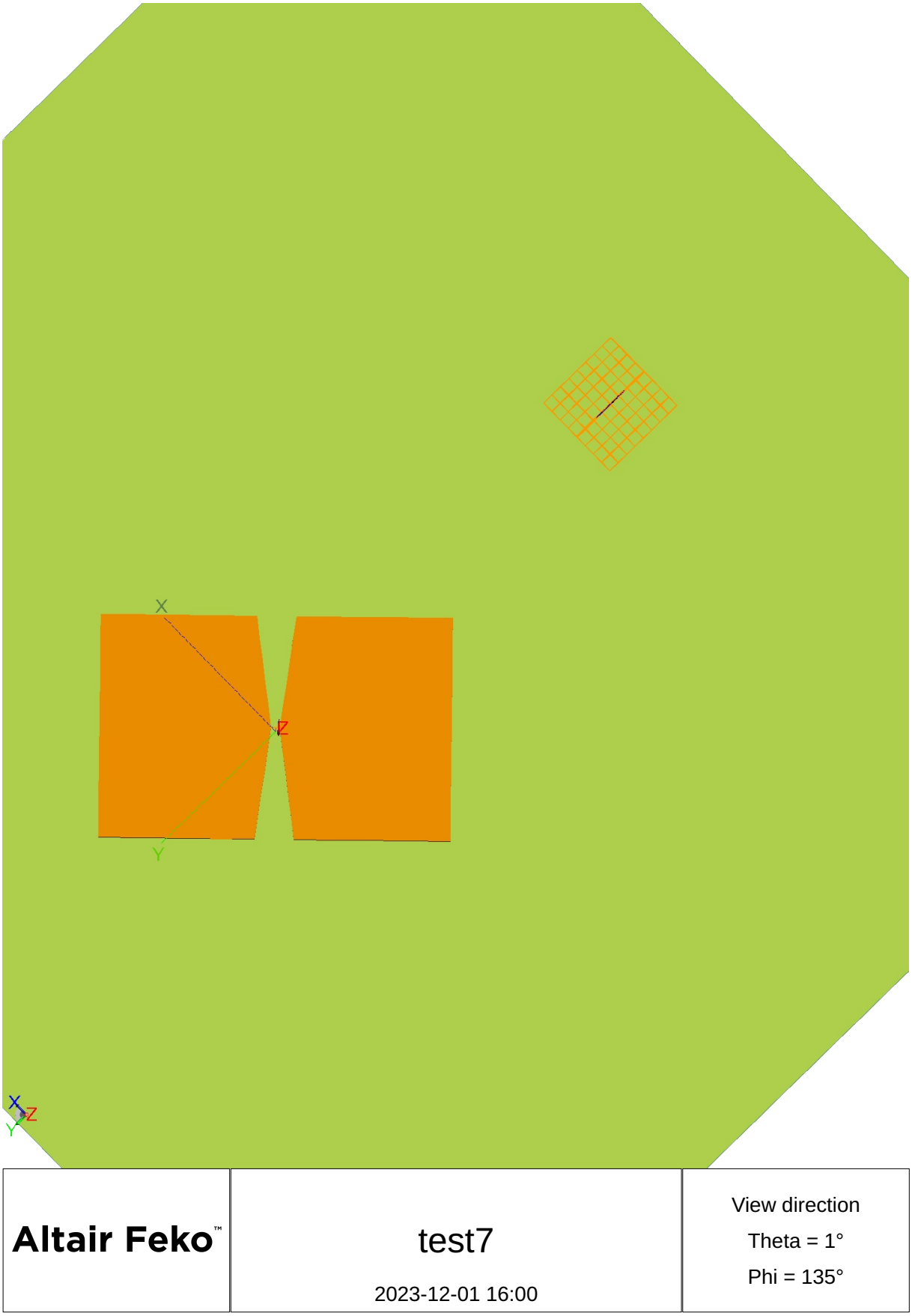

Figure 5. FEKO model of wire grid 2 meters from EDGES-3 on soil dielectric 3.5 and 1e-2 S/m.

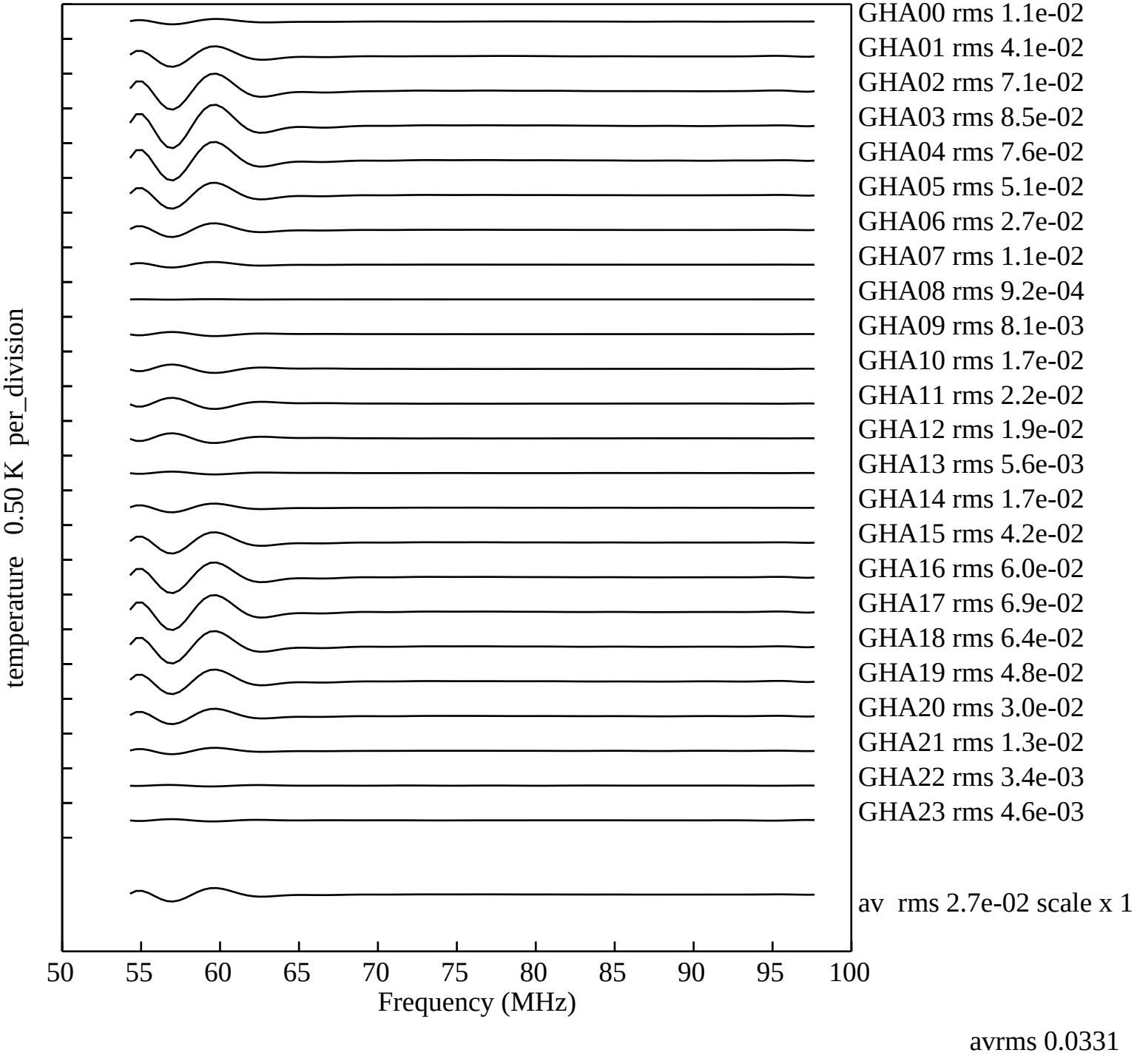

Figure 6. Plots of residuals to FEKO model in figure 5 with 5-terms removed

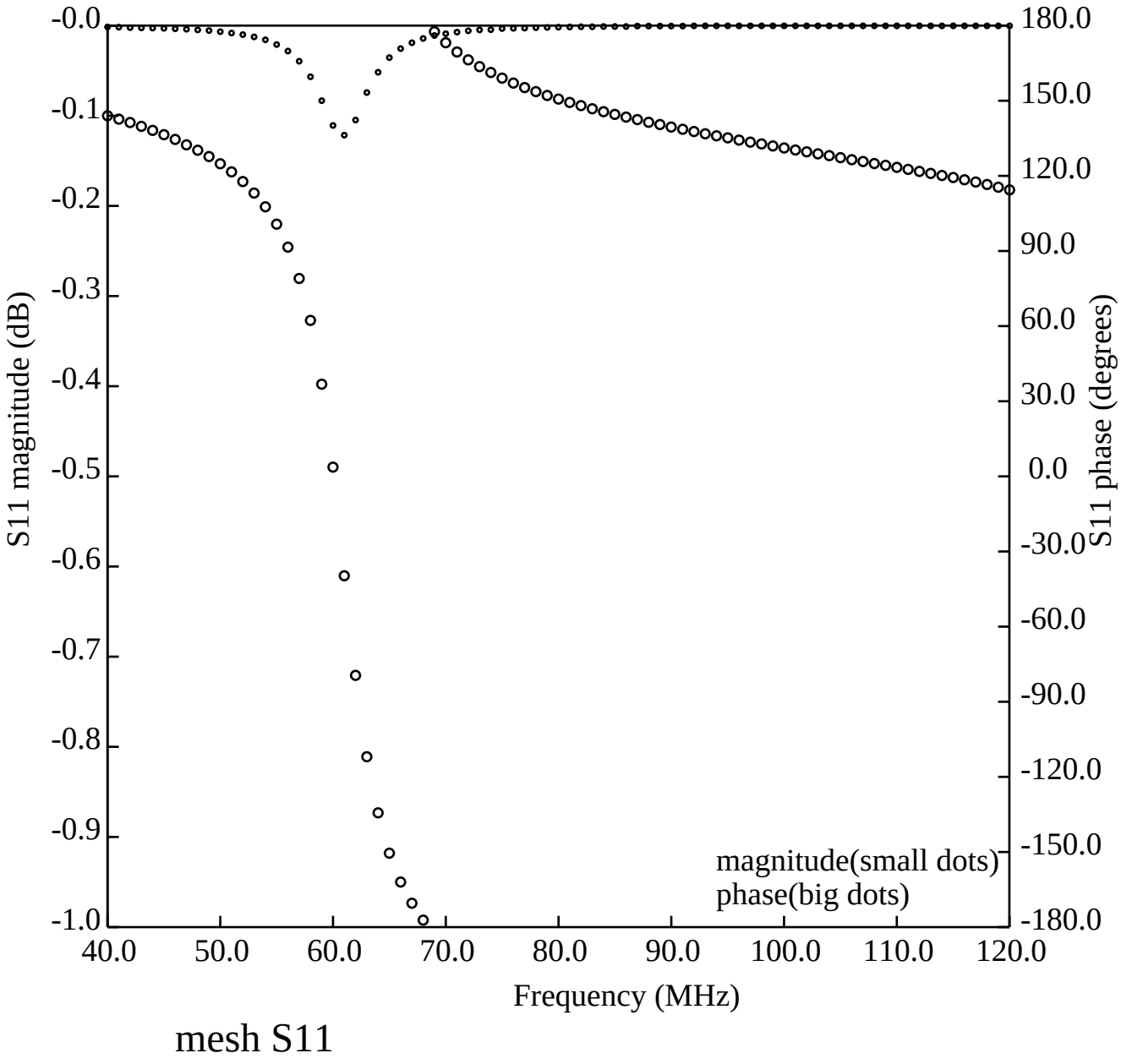

Figure 7. S11 from FEKO model in figure 5 for VNA connected via crocodile clips