Bench tests for EDGES-3 Ground Plane Resonance
Worklog EDGES-3 - In preparation for MRO site visit Feb 2024

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Goal: To reproduce MIT EDGES memo 435. Alan's bench tests and FEKO simulations have shown that gaps between the welds on the ground plane creates slot capacitance leading to resonances at ~60 MHz. We want to reproduce the bench tests using wire mesh.

Set up:
We used a wire mesh of mesh size ~1cmX1cm that each measures ~20cmX40cm. A crocodile clip was used to connect the two mesh grids, and a plastic bag was used to create the separation as suggested in the memo (the actual spacing between the mesh was much greater than the suggested 25 microns), refer Figure 1. The wire mesh was soldered to create a ~15cm slot, and an additional 100 pF capacitor was also soldered ~ 1 cm away from one of the joints within this slot.

Assuming the gap in the wire mesh creates a parallel plate capacitor

$$C = \epsilon \frac{A}{d}$$

Considering $\epsilon = 8.856 * 10^{-12} F/m$, $A = (20\,cm\,weld\,length) * (3\,mm\,diameter)$, $d = 25\mu m\,slot\,gap$, gives $C \approx 100\,pF$.

Fieldfox was set to the suggested values:
Resolution: 0.05 dB,
Frequency range: 40-200 MHz
No. of points: 201
Output power: -15 dBm
Cable length: ~30 cm
Additional set up: Ferrites were used on both ends of the cable
Calibration: Direct VNA calibration using SOL
Mesh was soldered at two points separated by 15 cm to create a slot capacitor, and the ends of the mesh were clamped with a plastic clip (40 cm apart). An additional 100 pF was soldered ~1 cm from one of the joints.

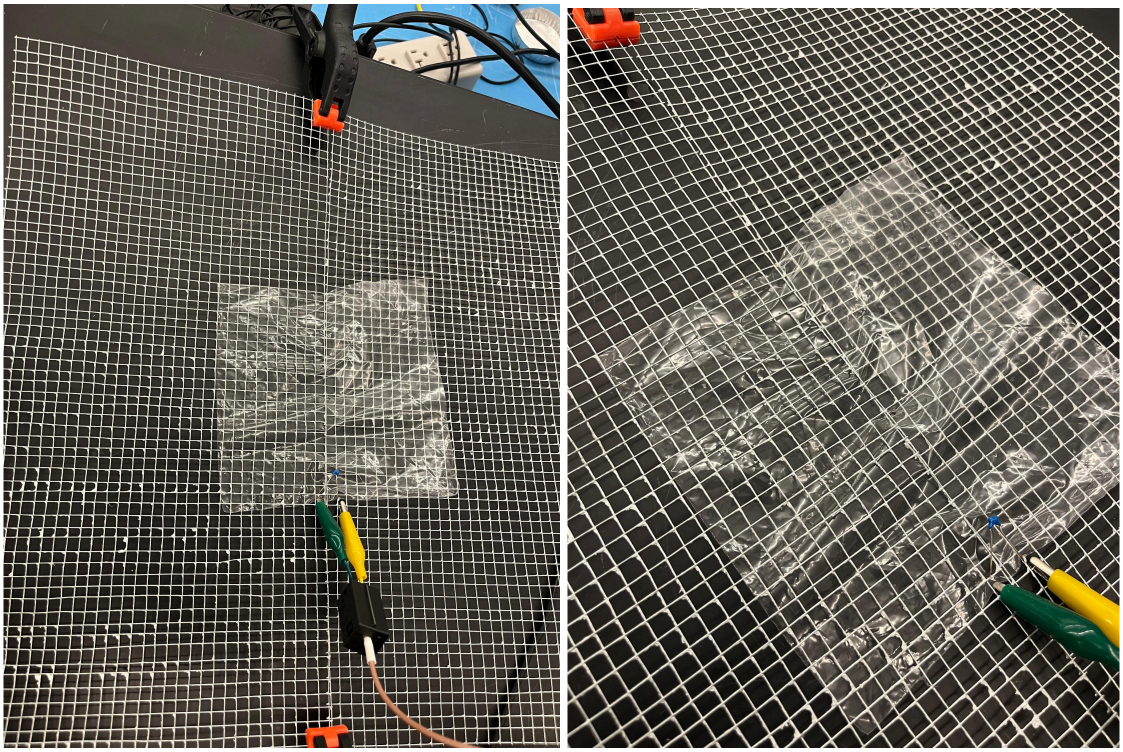


Figure 1: Set-up - Mesh soldered to create 15cm slot, 100 pF soldered in the slot, and a plastic sheet is inserted between the mesh to avoid shorting of the mesh (plastic sheet is below one of the mesh and above one of the mesh). Crocodile clip is connected to each of the mesh grids ~3 cm from the slot.

Observations:

Figure 2: No connection – both ports are open, after calibration

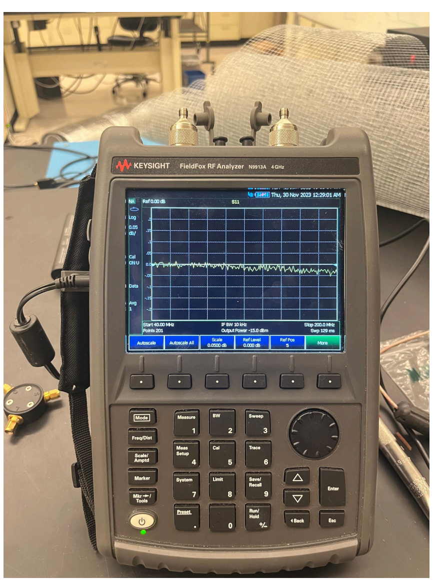


Figure 3: Cable connected, crocodile clip open. Scale: 0.05 dB, Ref: -0.250 dB

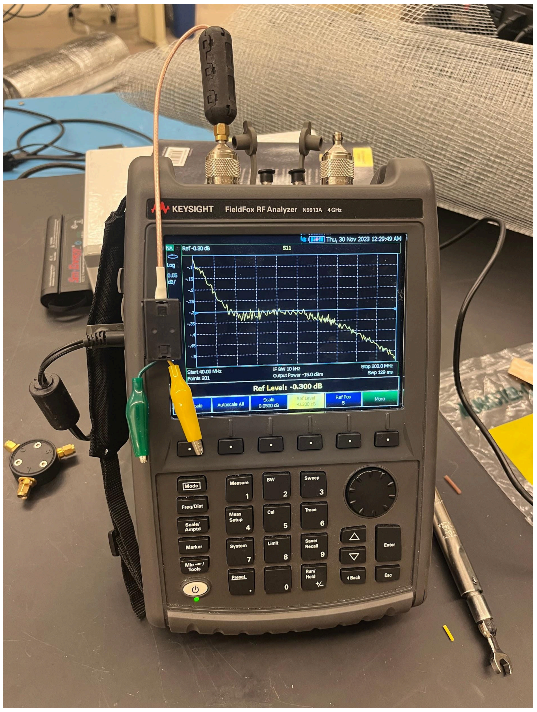


Figure 4: Cable connected, crocodile clips connected to each other. scale: 0.05 dB, Ref: -0.35 dB

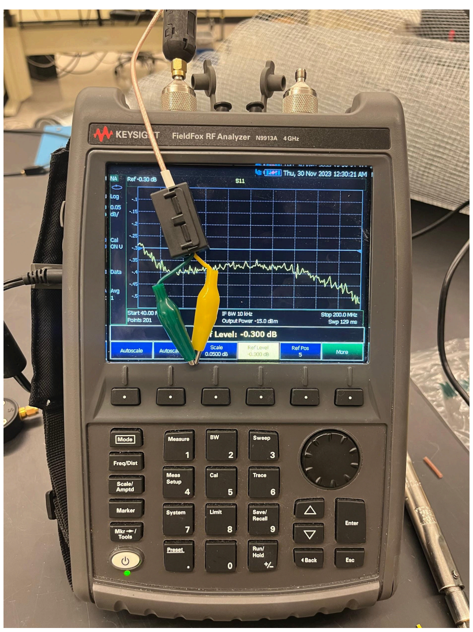


Figure 5: Cable connected to the mesh, scale: 0.5 dB, reference: -1.5 dB, resonance seen at 87.5 MHz

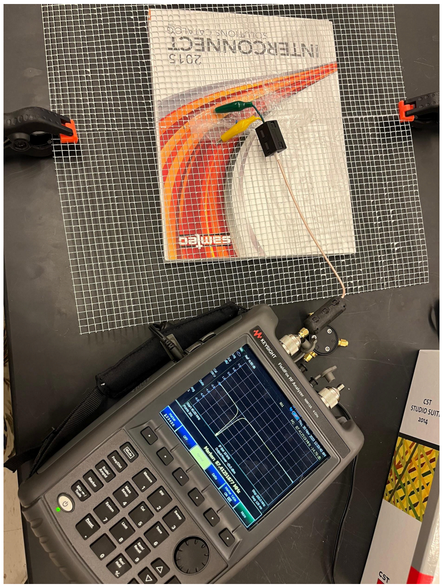
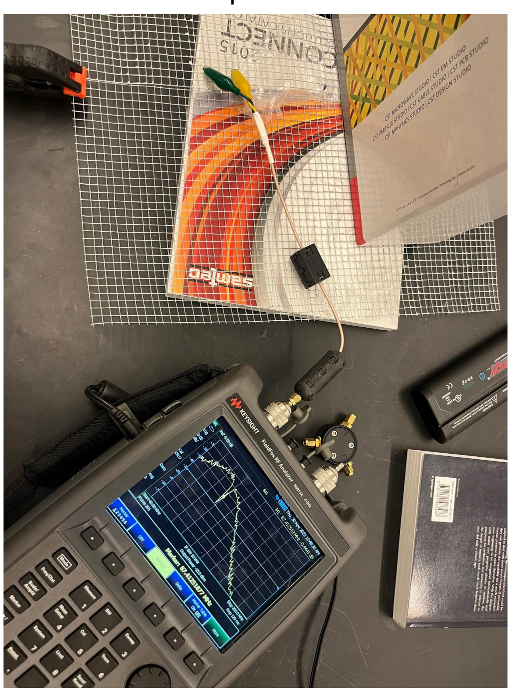


Figure 6: We notice that the resonance continues to appear in the vicinity of the capacitor, even when the probes are connected to the same side of the mesh – suggesting that it is within the field where the capacitor has it's interacting field.



Tests with metal plates:

To check if we can reproduce the similar resonance effects without using the capacitor, we used metal sheets that measured 18 cm X 38 cm each. The two sheets were used and a 20cm slot was established using wires. Electrical contact for the crocodile clips was established using a screw approximately at the center of the 20 cm slot, 5.5 cm away from the end of the plate.

Figure 7: Set up using metal plates. A slot capacitance is established using two wires connecting the plates at a 20 cm separation. An insulator tape is used to avoid shorting of the plates between the slot. Crocodile clips are connected using screws. Wires were used over clamps for the ease of moving plates to achieve various separation.

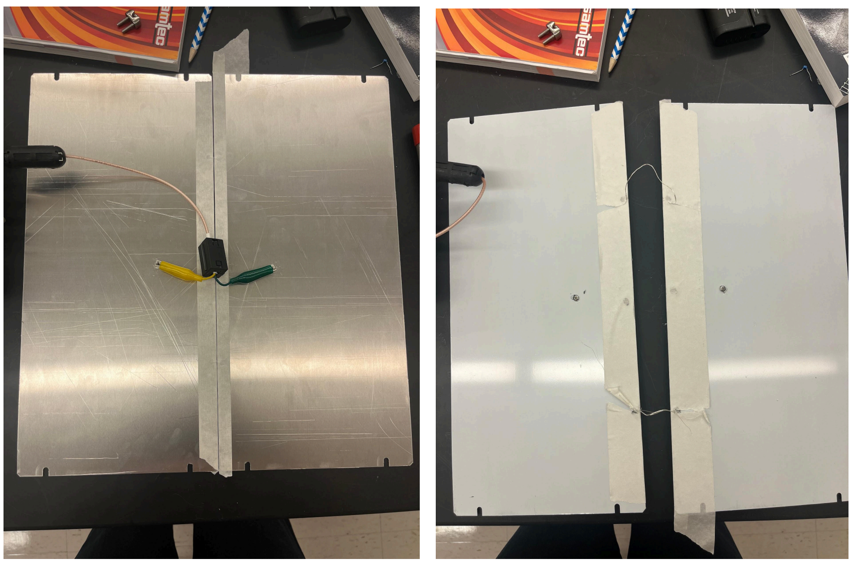


Figure 8: Resonance was seen with the initial set-up that involved a separation of <0.25mm (twice the thickness of the tape) at 144 MHz.

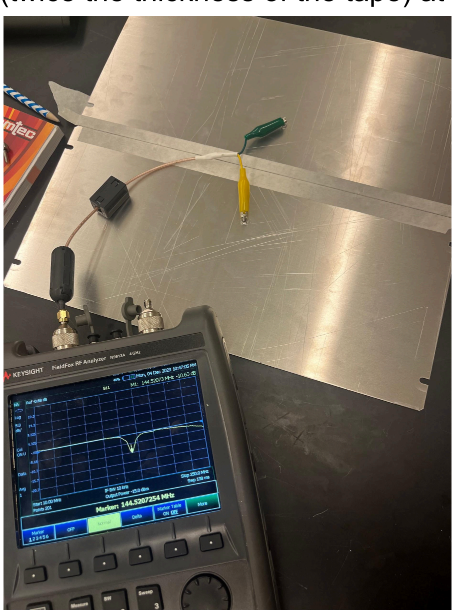
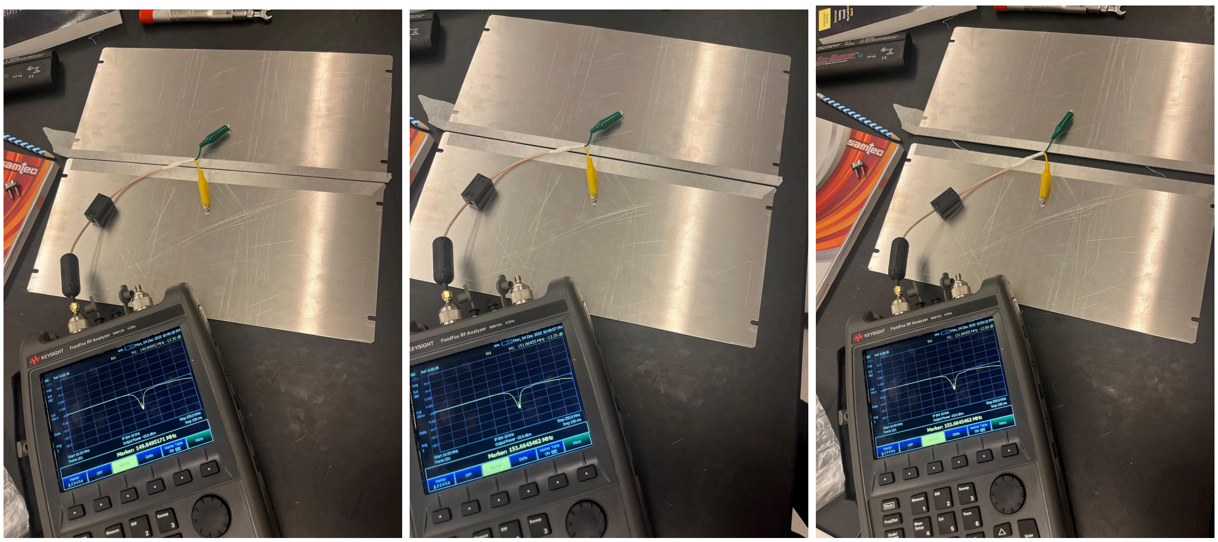


Figure 9: Increasing the separation increases the resonant frequency as expected. Capacitance decreases with increasing separation, and thus resonant frequency increases (capacitance and resonant frequency are inversely related). In the figure, the separation increases from 1mm, 2mm and 1cm, while the resonant frequency changes from 149 MHz to 152 MHz, measuring ~-13 dB. (Not captured in picture) Furthermore, we note that if the plates are overlapping (so effective area of the capacitor being 20cm X overlapping width of 2 cm), capacitance increases and the resonant frequency can be as low as 70 MHz with the separation of <0.1mm (thickness of insulating tape).



Conclusion:

1. We used ferrites and directly calibrated using SOL
2. S11 is flat after calibration, however, when the cable is connected some structures at the scale of ~1 dB. We are currently using a cable of length ~30cm.
3. After soldering the mesh to create a 15cm slot capacitor and an additional 100pF capacitor, we see resonance at 96.8 MHz.
4. Resonance disappears upon removing the 100 pF capacitor, suggesting it is necessary in this test to recreate the resonance using a small wire mesh set up.
5. Resonance continues to appear within ~5cm of the capacitor, even when the crocodile clips are connected to the same side of the mesh.
6. Resonance disappears when the crocodile clips are moved to the end of the mesh, away from the interacting field of the capacitor.
7. In the tests with metal plates without the capacitor, we do see resonance at 145 MHz.
8. Resonant frequency increases with increasing gap → indicating adding plastic shims in the gaps should push the resonance to higher frequencies if present. Equivalently, clamping and shorting the mesh grids should push the resonance to lower frequencies if present.

In the field for the EDGES-3 ground plane, this test will be performed following the steps outlined in EDGES memo 435 to determine the presence of resonance in the ground plane before clamping/ adding plastic shims to move the possible resonance out of the observing band.