Antenna Beam Properties: Gain, Loss & Solid Angle

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In this report we calculate the total radiated power of the EDGES antenna above the horizon. We use different beam simulations of the EDGES midband and low-band antennas to make the below plots. Also calculated is the solid angle of the beam above the horizon for the same models.

Normalized Total radiated power

The total gain fraction above the horizon at each frequency is calculated by integrating the gain over all viewing angles above the ground (θ > 0 deg), according to:

$$gain\,(\nu) = \frac{1}{4\pi}\int_0^{\frac{\pi}{2}}\int_0^{2\pi} G(\theta,\phi)\,sin\theta\,d\theta\,d\phi$$

The gain of the **Midband antenna model - FEKO - Nive's Simulation is looked at below:**

Mid Band - ground 30m X 30m - Soil: $\varepsilon_r = 3.5$ and $\sigma = 2e\text{-}2$ S/m

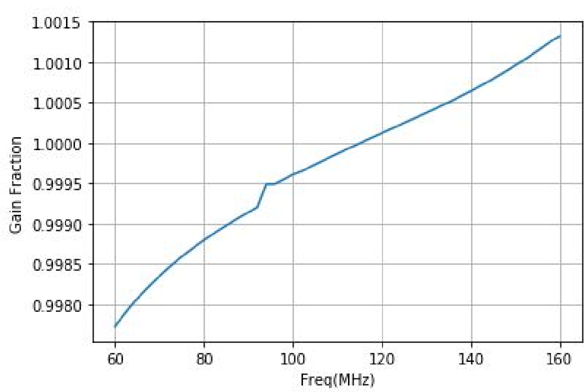


Fig1: Total gain above the horizon versus frequency for Midband antenna with a.) 1 deg Theta & Phi spacing

There is a glitch at 92 MHz and it was investigated in the following ways

1.) Different models:

Midband antenna model - FEKO - azelq_blade9perf7mid.txt

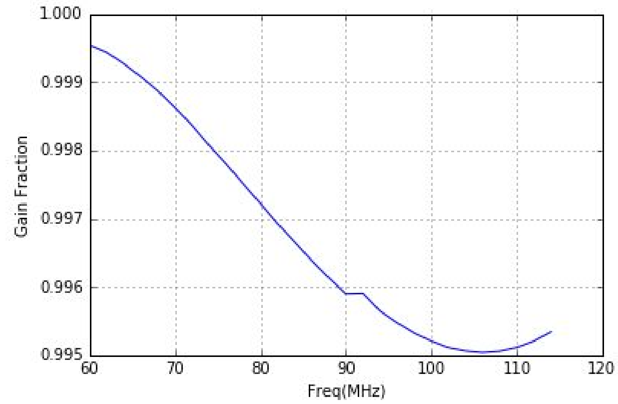


Fig2: Total gain above the horizon versus frequency for Mid-band antenna simulated by Alan. The glitch still exists

Notes:

- The calculated gain fraction in each of the above cases is different
- But in each case there is a glitch at ~ 92 MHz
- The variation of the gain fraction with frequency is seen to increase in case 1 Vs the decrease seen in case 2 & 3.

2.) Changed the Theta and Phi Spacing

Midband antenna over 30m X 30m Soil: $\varepsilon_r = 3.5$ and $\sigma = 2e\text{-}2$ S/m was resimulated with gain calculated at every 0.5 deg in theta and phi

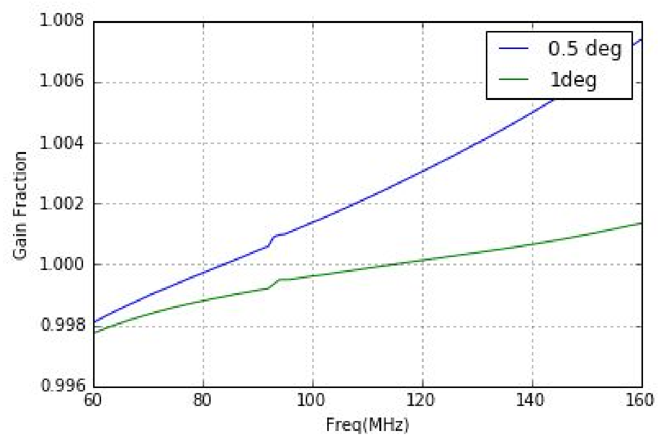


Fig3: Total gain above the horizon versus frequency for Midband antenna with 0.5 deg Theta & Phi spacing.

- The glitch is still at the same frequency with the same amplitude

3.) Finner frequency sampling

Midband antenna over 30m X 30m Soil: $\varepsilon_r = 3.5$ and $\sigma = 2e\text{-}2$ S/m was resimulated with gain calculated at every 0.5 deg in theta and phi and at every 0.25 MHz instead of 1 MHz

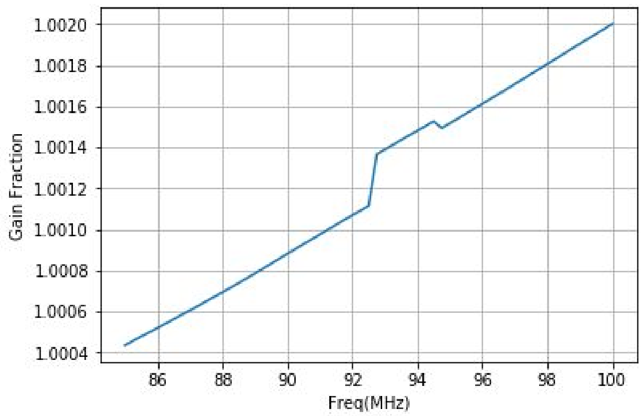


Fig4: Total gain above the horizon versus frequency for Midband antenna with 0.5 deg Theta and Phi spacing and 0.25 MHz freq resolution.

- The gain transitions occurs suddenly at 92.25 MHz and extends till 94.25 MHz.

4.) Change the radius of the port

Midband antenna over 30m X 30m Soil: $\varepsilon_r = 3.5$ and $\sigma = 2e\text{-}2$ S/m was resimulated with gain calculated at every 0.5 deg in theta and phi and at every 1 MHz

Radius changed from 1.5 mm to 0.75 mm

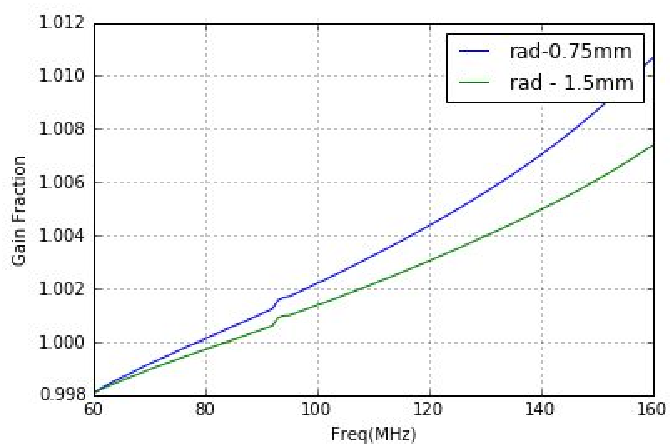


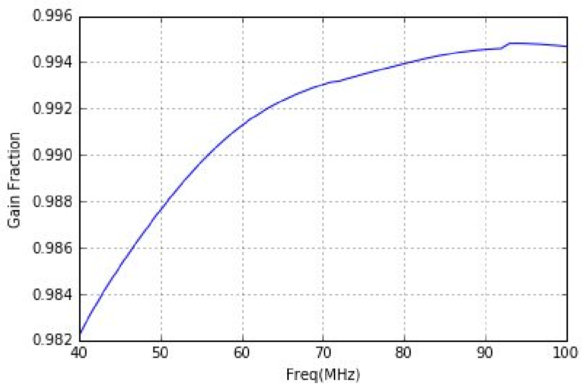
Fig5: Total gain above the horizon versus frequency for Midband antenna with Same as fig3 but changed the radius from 1.5mm to 0.75 mm.

- The glitch is found to be at the same frequency and is of the same amplitude.

5.) Different Antennas

Lowband ground 10m X 10m - Soil: $\varepsilon_r = 3.5$ and $\sigma = 2e\text{-}2$

Lowband - PEC



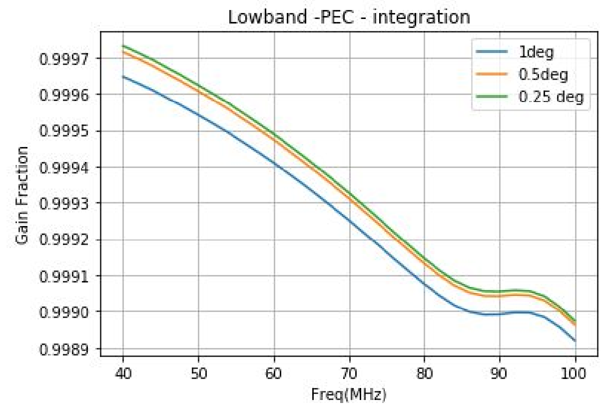


Fig6: Total gain above the horizon versus frequency for lowband antenna a.) over real ground (old GP) with 1 deg Theta & Phi spacing, b.) PEC ground with 1 deg Theta & Phi spacing.

Lowband ground 30m X 30m - Soil: $\varepsilon_r = 3.5$ and $\sigma = 2e\text{-}2$ S/m

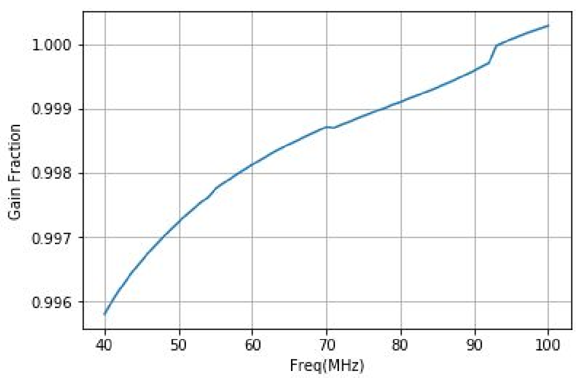


Fig7: Total gain above the horizon versus frequency for lowband antenna over real ground (New GP) with 1 deg Theta & Phi spacing.

Notes:

- In the lowband real ground - There is a glitch at ~72 MHz & 92 MHz (for both the ground plane designs)
- With the PEC ground - no glitch

6.) Changing Mesh Sizes

The configuration that was used in this study is the Lowband New ground plane.

Meshing type	Panel Mesh length	Ground plane mesh length
Standard	λ/12	λ/6
Fine	λ/16	λ/8
Coarse	λ/8	λ/4

Where λ is taken to be 3m.

Lowband ground 30m X 30m - Soil: ε_r = **3.5 and** σ = **2e-2 S/m**

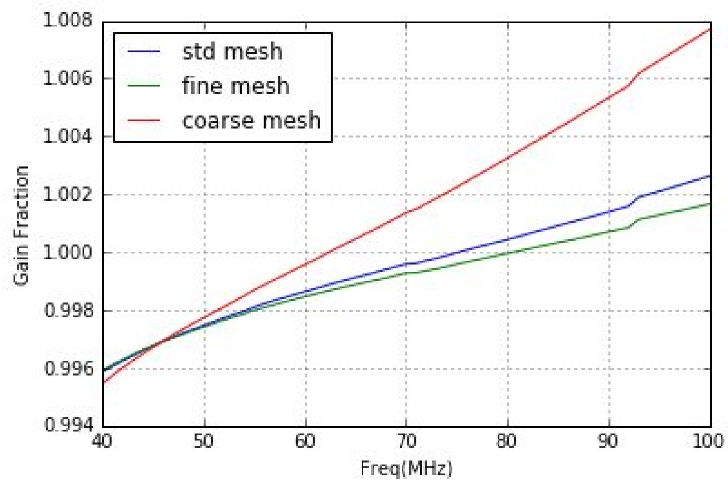


Fig8: Gain Fraction Versus Frequency for different beam solutions of the Lowband New ground plane model. The variations are due to the meshing variations

- The glitch is seen to be independent of the mesh sizes

7.) Thickness of the Blade

The configuration that was used in this study is the Lowband old ground plane.

Lowband ground 10m X 10m - Soil: ε_r = **3.5 and** σ = **2e-2 S/m**

The blade was simulated to have a thickness of 3mm. Unlike the previous cases where it was just a flat rectangle with no thickness.

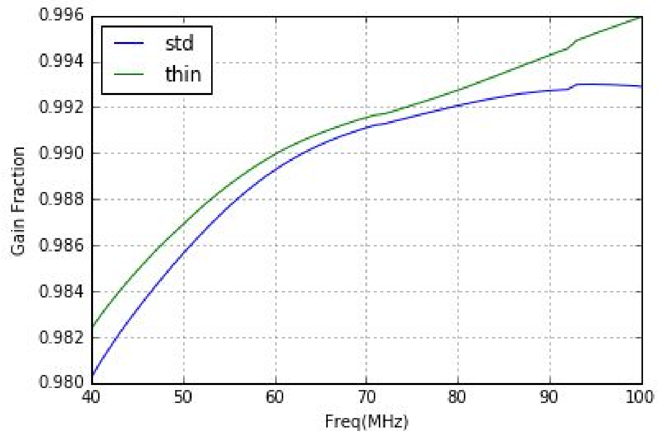


Fig9: Gain Fraction Versus Frequency for the beam solutions lowband old ground plane with the panels having a thickness of 3mm.

- Changing the thickness of the blade did not affect the glitch locations and amplitude.

8.) Changed Gap between the panels

The configuration that was used in this study is the Lowband old ground plane.

Lowband ground 10m X 10m - Soil: $\varepsilon_r = $ **3.5 and** $\sigma =$ **2e-2 S/m**

The gap for the low band was changed from 0.013m to 0.022m

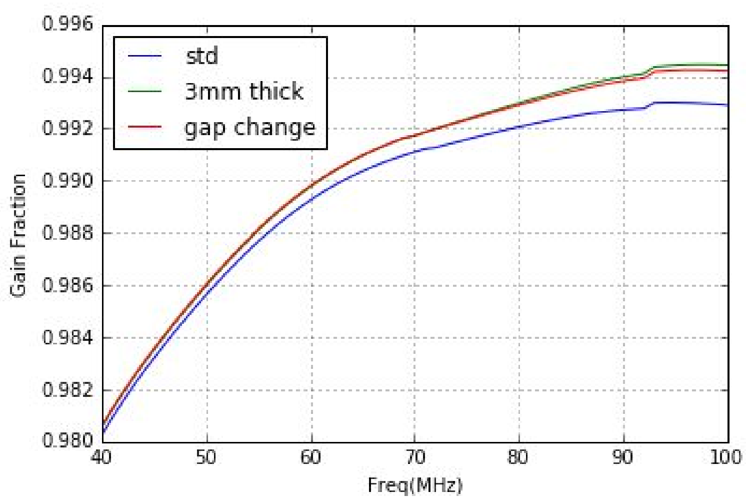


Fig10: Gain Fraction Versus Frequency for the beam solutions lowband old ground plane the gap between the panels being 0.022mm instead of 0.013mm.

- Changing the thickness of the blade did not affect the glitch locations and amplitude.

9.) Soil Characteristics

a.) Conductivity

The configuration that was used in this study is the Lowband old ground plane.

Lowband ground 30m X 30m - Soil: ε_r = **3.5 and** σ = **2e-2 S/m**

The conductivity of the soil was varied to study its effect

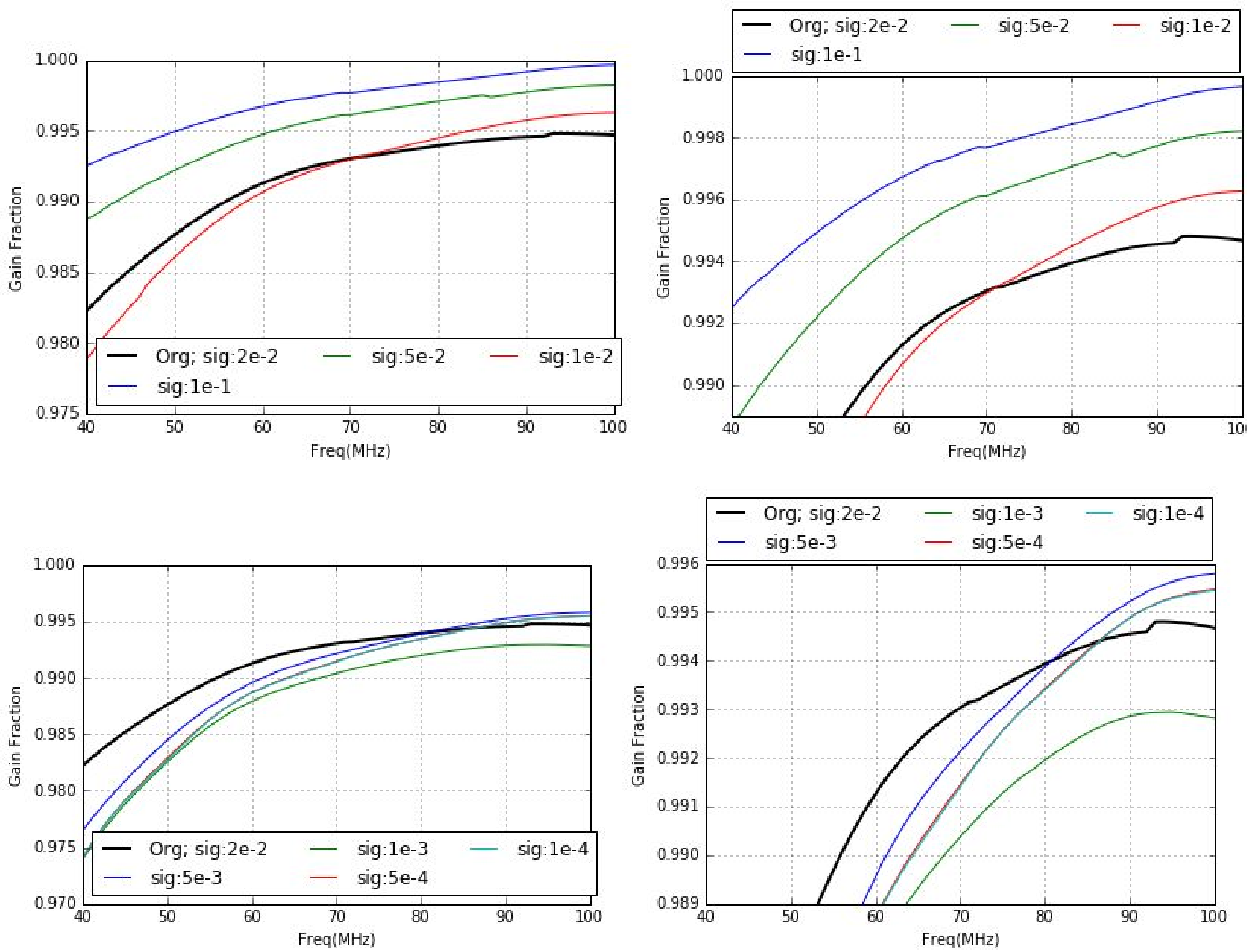


Fig11: Total gain above the horizon versus frequency for low-band antenna with the old GP over different soil conductivities.

- The glitch is seen to move in frequency with the change in conductivity
- The glitch disappears at the conductivities below 1e-2 (<1e-2).

b.) Dielectric constant

The configuration that was used in this study is the Lowband old ground plane.

Lowband ground 10m X 10m - Soil: $\varepsilon_r = 3.5$ and $\sigma = 2e\text{-}2$ S/m

The dielectric constant of the soil was varied to study its effect

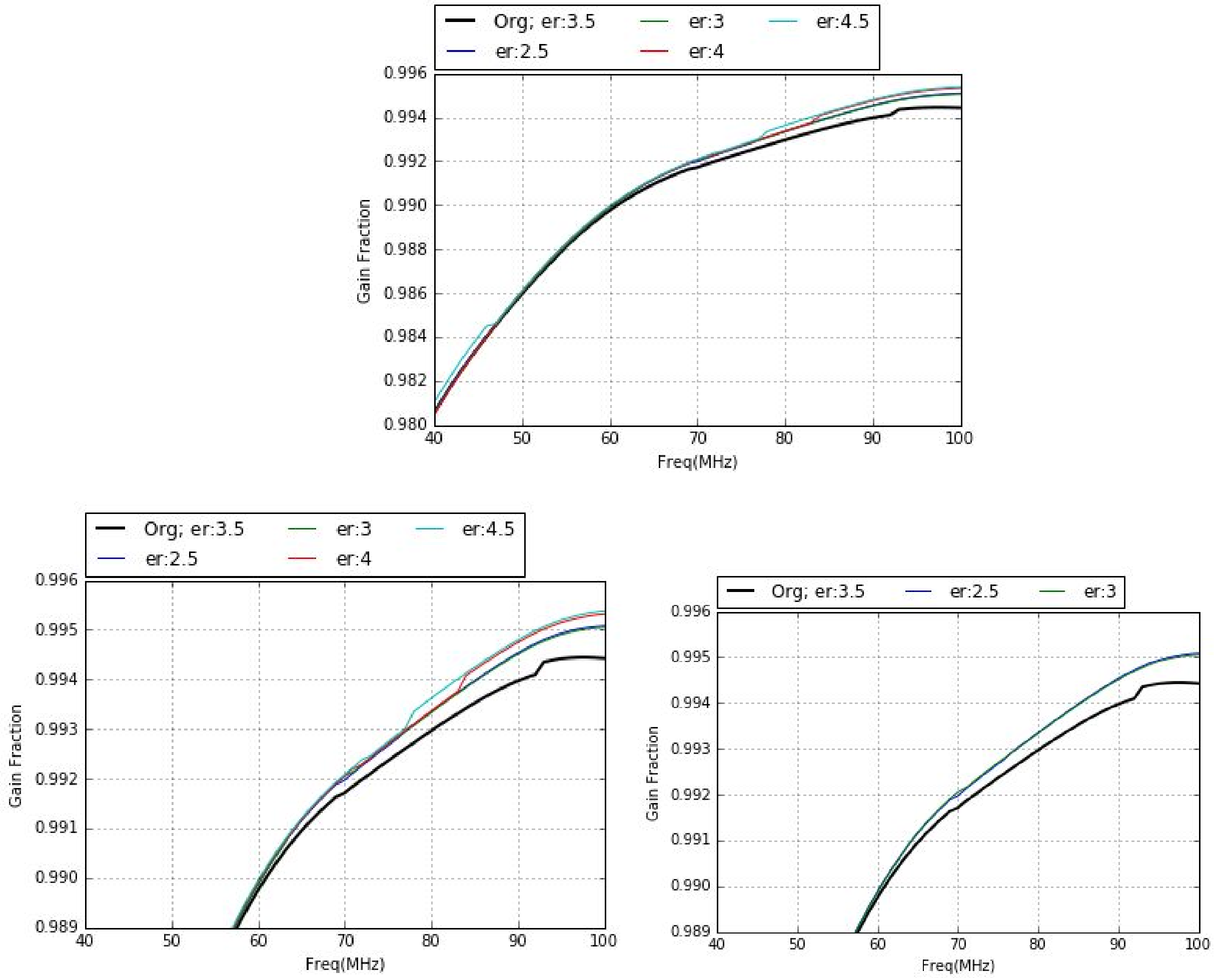


Fig12: Total gain above the horizon versus frequency for low-band antenna with the old GP over different soil permittivities.

- The glitch is seen to move in frequency with the change in permittivity.
- Unlike the change in conductivity, the overall gain seems to be constant.
- With increasing permittivity, from 3.5 to 4.5, the upper frequency glitch moves to higher frequencies
- For 2.5,3 almost no glitch is seen

FEKO Support Suggestions:

10.) Mesh the port finer

Lowband old ground

So far the port was modelled and meshed as a single element. Here I mesh into 3 individual segments as suggested by FEKO support.

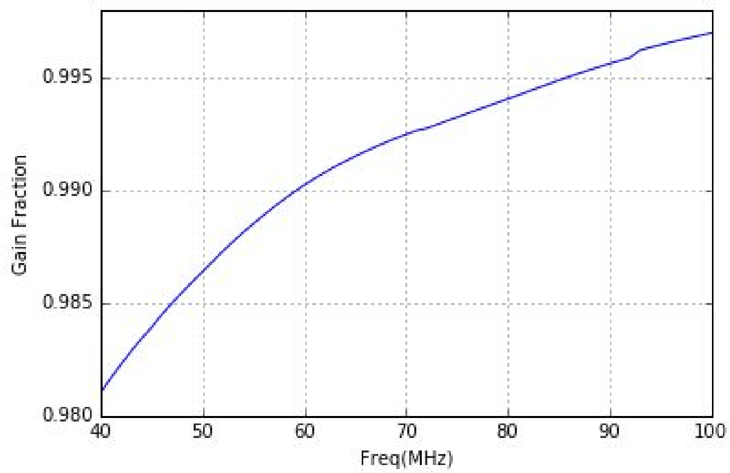


Fig13: Gain Fraction Versus Frequency for the beam solutions of the lowband old ground plane where the port segment is meshed into 3 smaller segments.

11.) Change the port type.

Lowband old ground

For all the simulations so far, wire port was used. Here I change it to an edge port.

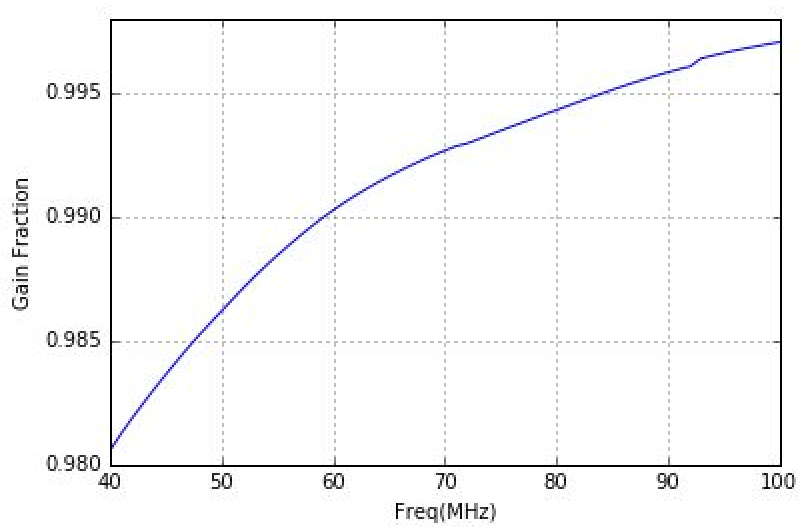


Fig14: Gain Fraction Versus Frequency for the beam solutions of the lowband old ground plane where the port was changed to an edge port.

12.) Different Softwares

CST Models:

Lowband old ground

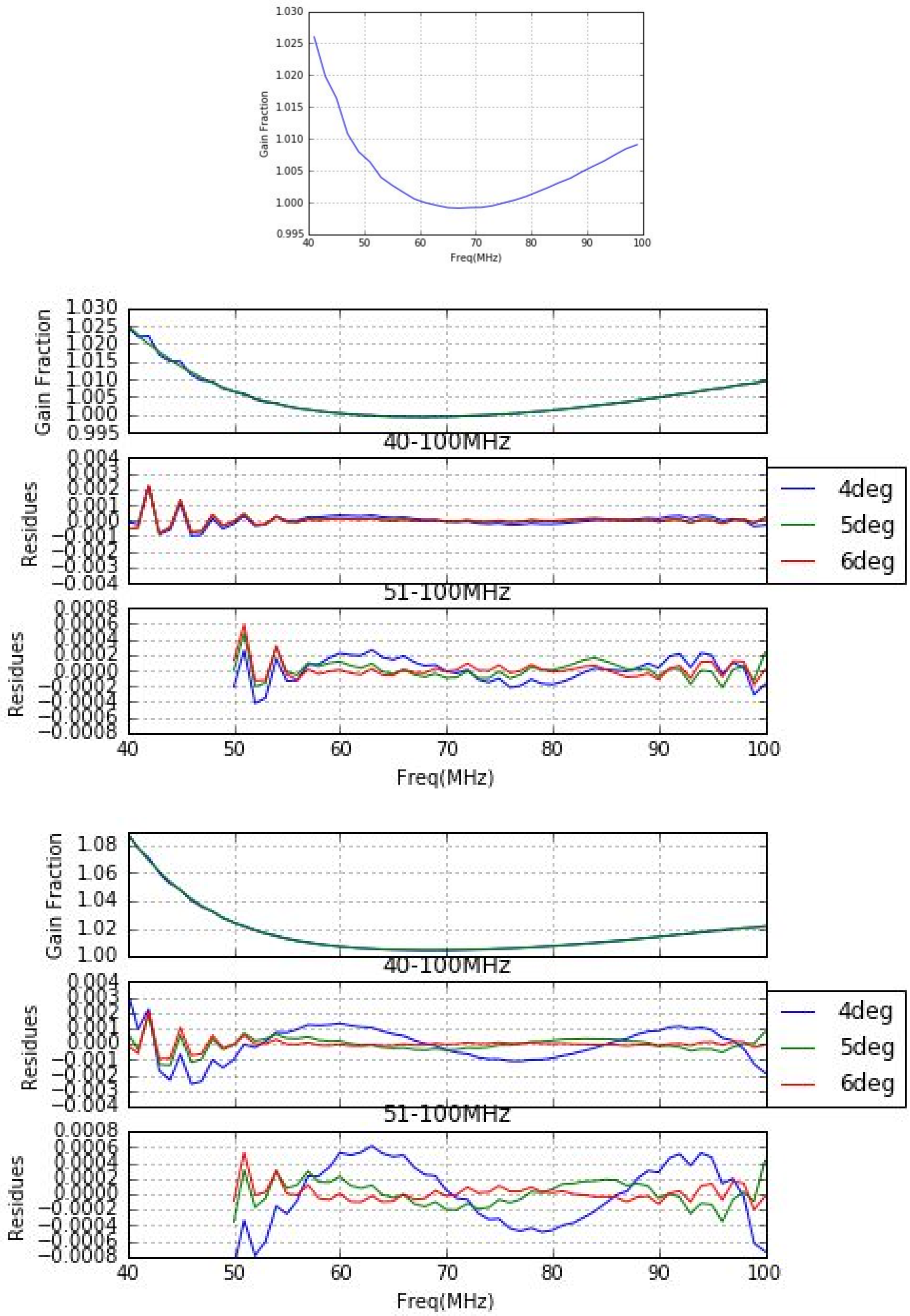


Fig15: Total gain above the horizon versus frequency for low-band antenna over real ground (Old GP) with 1 deg Theta & Phi spacing and 2 MHz freq resolution. b) ACA 2nd order solver accuracy c.) MOM Solver (2nd order accuracy)

Lowband new Ground

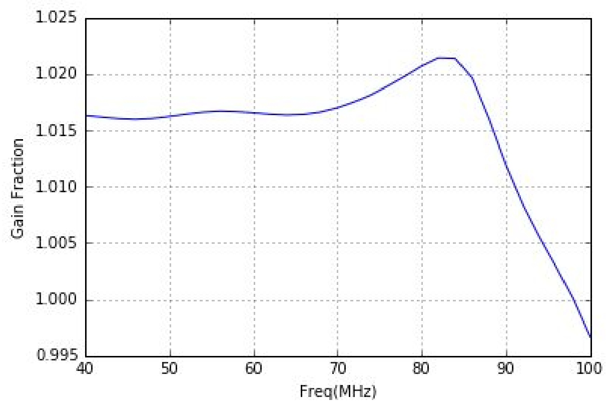
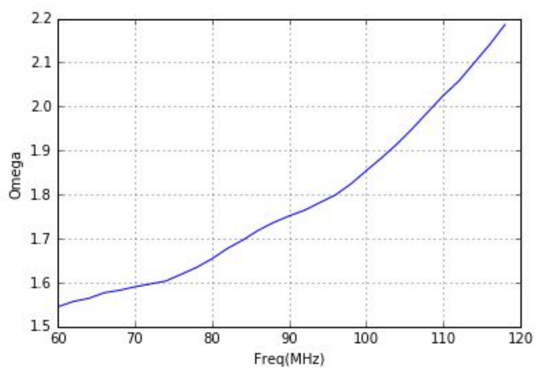


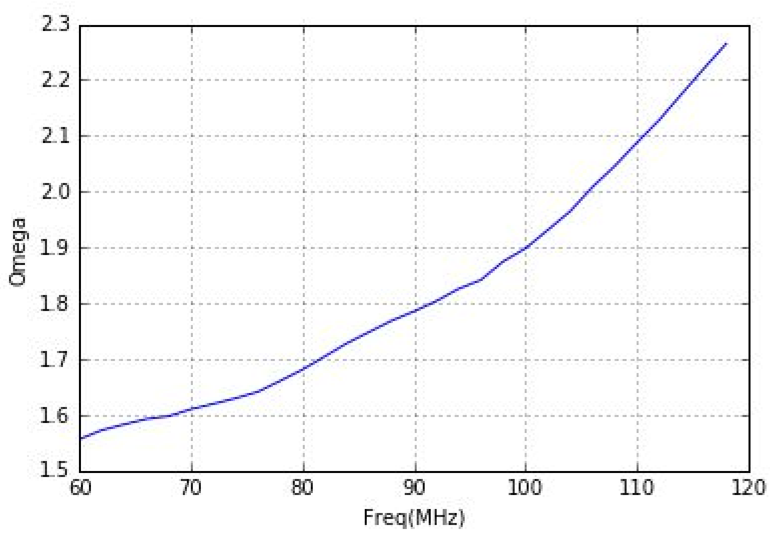
Fig16: Total gain above the horizon versus frequency for lowband antenna over real ground (New GP) with 1 deg Theta & Phi spacing and 2 MHz freq resolution.

Solid Angle

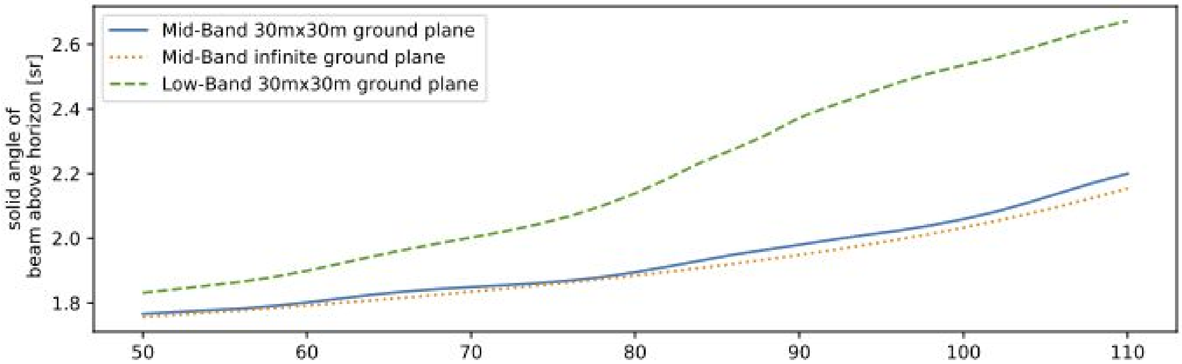
1.) Midband antenna model - FEKO - Nive's Simulation



2.) Midband antenna model - FEKO - azelq_blade9perf7mid.txt



3.) Plot from Raul's email



Notes:

- The solid angle calculated from all three cases are similar.