LoCo Lab EDGES Memo 151
Comparing Antenna Simulations from FEKO, WIPL-D, and HFSS-IE

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1 Description

We compare three models for the beam directivity (or directive gain, or just gain) of the EDGES Mid-Band antenna with infinite PEC ground plane. The models were computed with (1) FEKO, (2) WIPL-D (demo version), and (3) HFSS-IE.

The models from FEKO and WIPL-D were computed every 2 MHz, spanning the range $50 - 200$ MHz. The models from HFSS-IE were computed manually at the following frequencies: 60 MHz, $65 - 75$ MHz every 1 MHz, 90 MHz, and 120 MHz. This limited sampling occurred because it was not clear how to save data at many frequencies efficiently.

We conducted three types of comparisons between the softwares:

1. Direct subtraction of directivity maps at 60, 90, and 120 MHz. This is shown below in Figures 1, 2, and 3.
2. 'Derivative' plots, where we subtract the directivity at frequency i from that at frequency i+1. This was done for $\phi = 0°$ and $\phi = 90°$. The results are shown in Figure 4 for FEKO and in Figure 5 for WIPL-D.
3. The integrated gain above the horizon at all the frequencies available, as well as the residuals to a 7-term polynomial fit over 50-150 MHz for FEKO and WIPL-D, and to a 4-term polynomial fit over 60-120 MHz for HFSS-IE. This is shown in Figure 6.

2 Discussion

1. In Figures 1, 2, and 3, we see good qualitative and quantitative agreement between the gain maps from FEKO, WIPL-D, and HFSS. The largest differences are between FEKO and WIPL-D. Specifically, the gain toward the zenith is lower for WIPL-D by up to a few percent, and the beam is wider for WIPL-D perpendicular to the excitation axis.
2. Figures 4 and 5 show good qualitative and quantitative agreement in the gain derivatives from FEKO and WIPL-D.
3. The most interesting comparison is the integrated gain above the horizon from the three softwares. This is shown in the Top panel of Figure 5. The beam is zero below the horizon when the model includes an infinite PEC ground plane. Thus, it is expected for the curves in the top panel of Figure 5 to be flat across frequency and equal to 1 (in the absence of loss). However, the FEKO curve

decreases monothonically with frequency. Currently we do not understand this behavior. The WIPL-D is relatively flat and slighly below 1 at frequencies below 125 MHz. At frequencies > 125 MHz, the curve goes above 1. At these frequencies the beam starts to bifurcate, and maybe the WIPL-D solutions are not as robust. The HFSS curve is the most flat below 120 MHz, although not as close to 1 as that from WIPL-D.

4. In Figure 5, Bottom panel, we see that the FEKO curve has the highest numerical noise. Also, the curve could have a small 'dip' at ~ 95 MHz, which has been seen (with a larger amplitude) in other FEKO models that include a realistic ground plane on top of a lossy dialectric soil. The WIPL-D curve does not show a dip at ~ 95 MHz. The HFSS curve shows the lowest numerical noise.

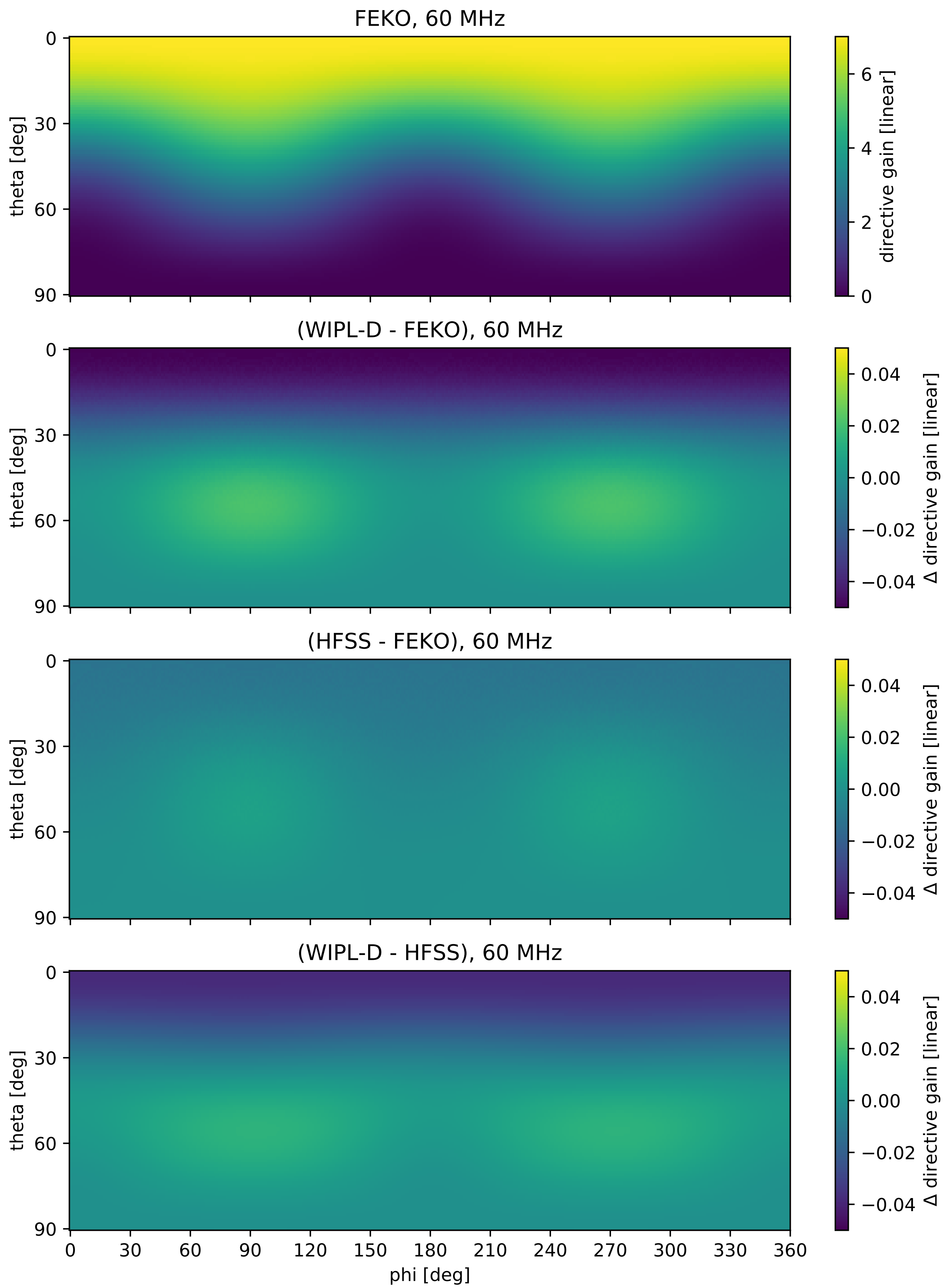

Figure 1: Comparison of the directivity models at 60 MHz from FEKO, WIPL-D, and HFSS-IE. The largest difference is between FEKO and WIPL-D. Focusing on the second panel, the WIPL-D gain is lower toward the zenith (by up to $\sim 1\%$ of the zenith gain), and wider on the axis phi=$90^\circ - 270^\circ$ (yellow blobs).

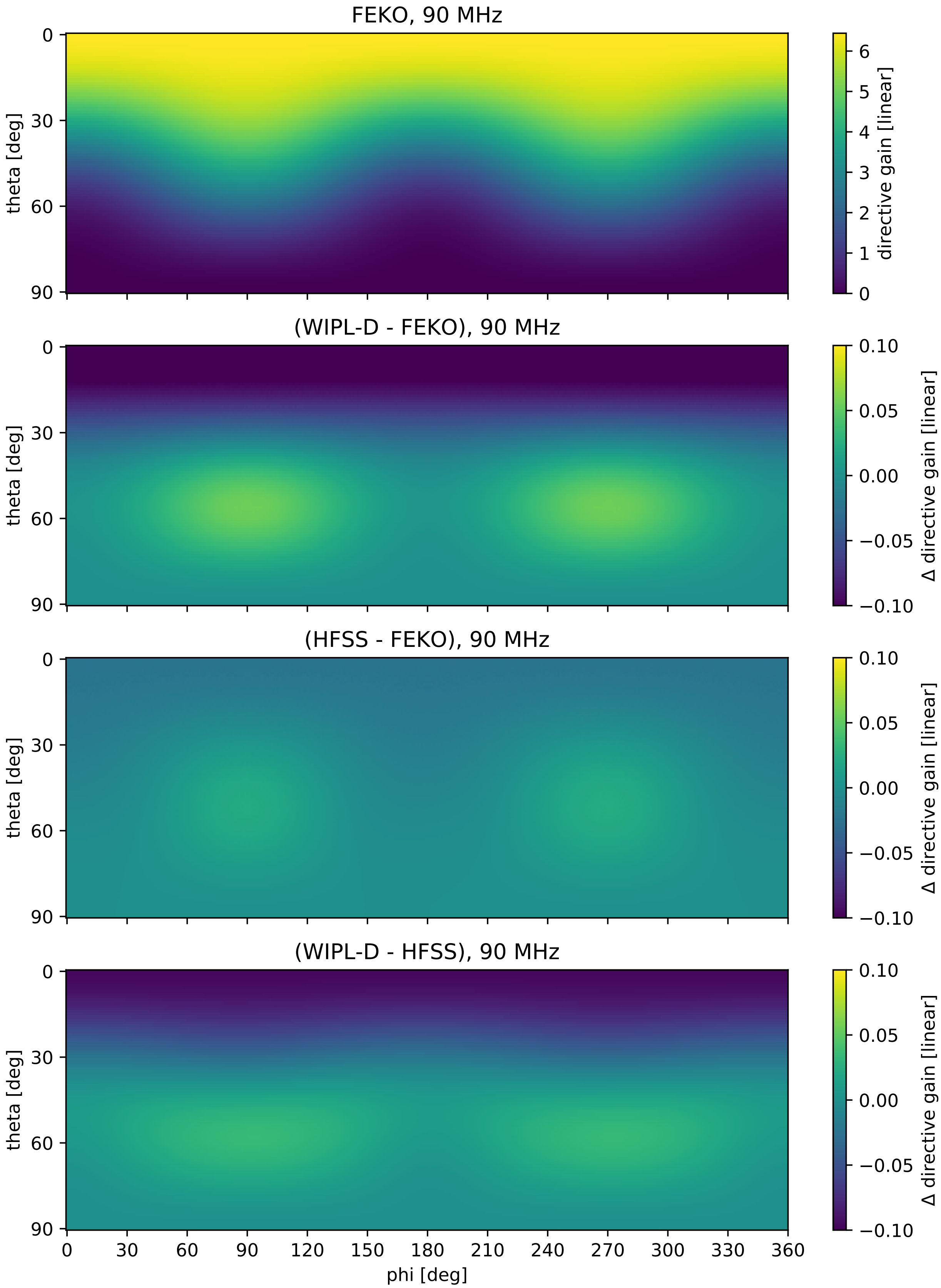

Figure 2: Comparison of the directivity models at 90 MHz from FEKO, WIPL-D, and HFSS-IE. The largest difference is between FEKO and WIPL-D. Focusing on the second panel, the WIPL-D beam is lower toward the zenith (by up to $\sim 2\%$ of the zenith gain), and wider on the axis phi=$90^\circ - 270^\circ$ (yellow blobs).

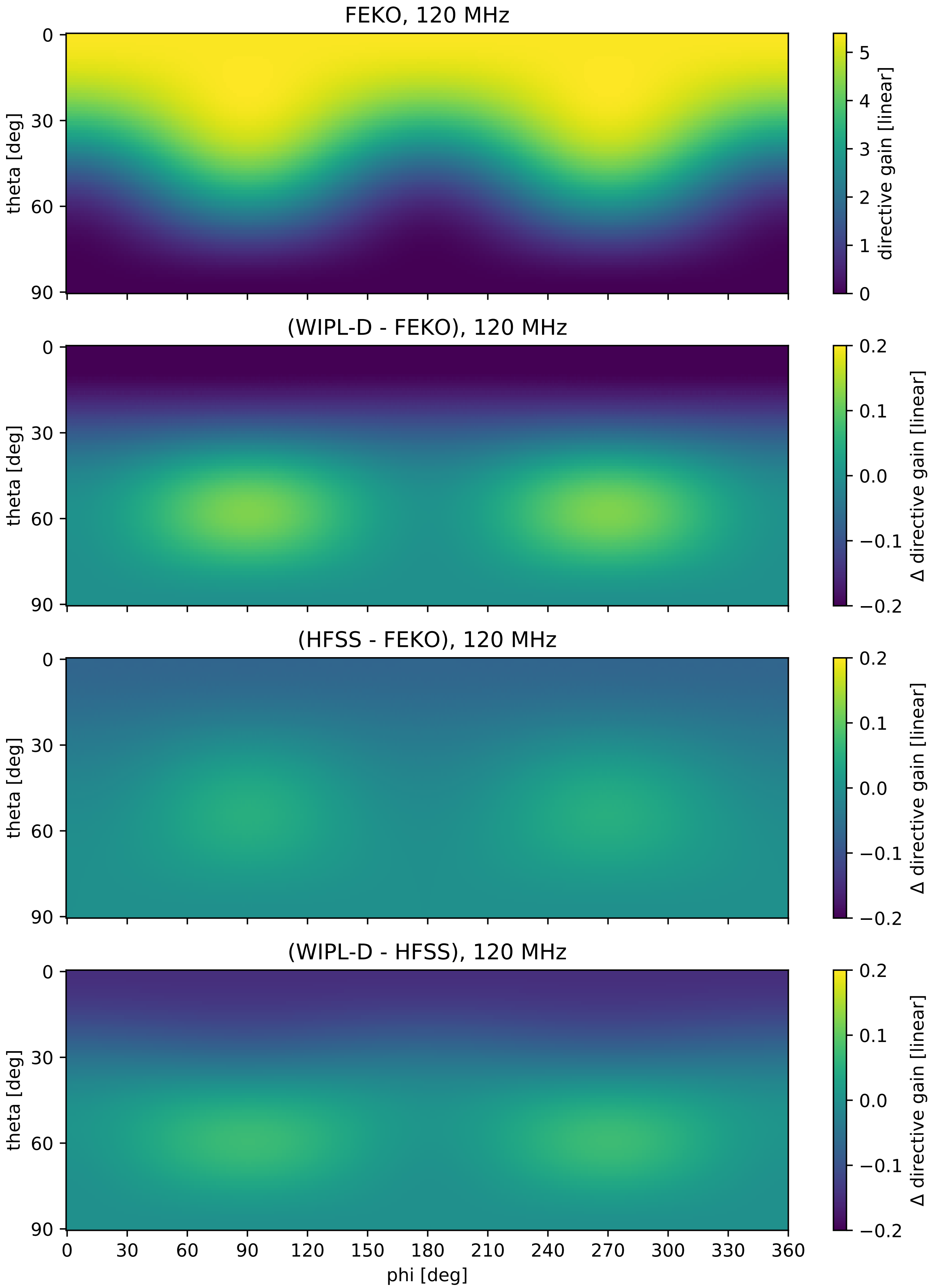

Figure 3: Comparison of the directivity models at 120 MHz from FEKO, WIPL-D, and HFSS-IE. The largest difference is between FEKO and WIPL-D. Focusing on the second panel, the WIPL-D beam is lower toward the zenith (by up to $\sim 5\%$ of the zenith gain), and wider on the axis phi=$90^\circ - 270^\circ$ (yellow blobs).

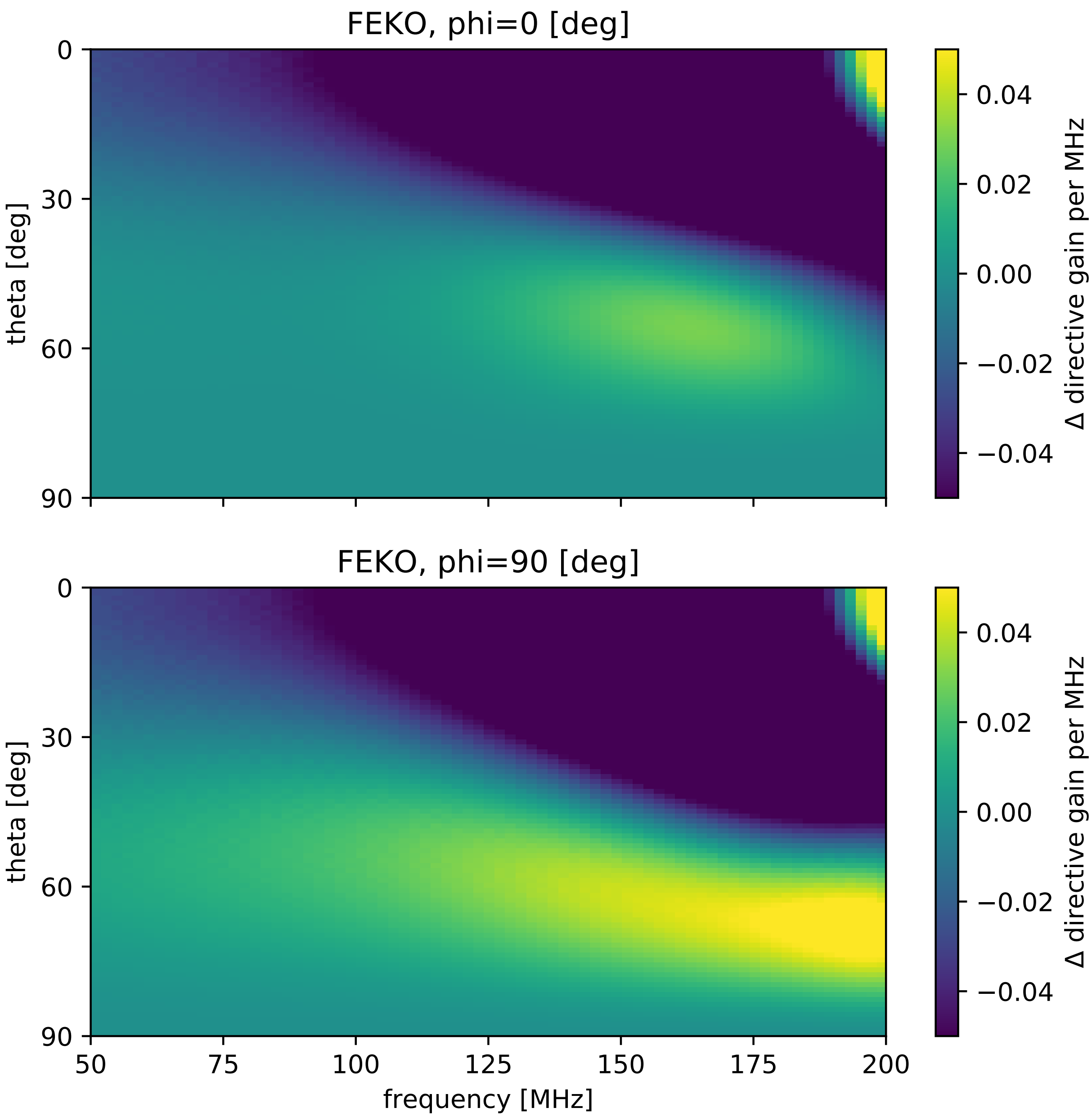

Figure 4: Using the FEKO model, here we show the derivative of the directivity as a function of frequency (i.e., per MHz), for $\phi = 0^\circ$ (top) and $\phi = 90^\circ$ (bottom).

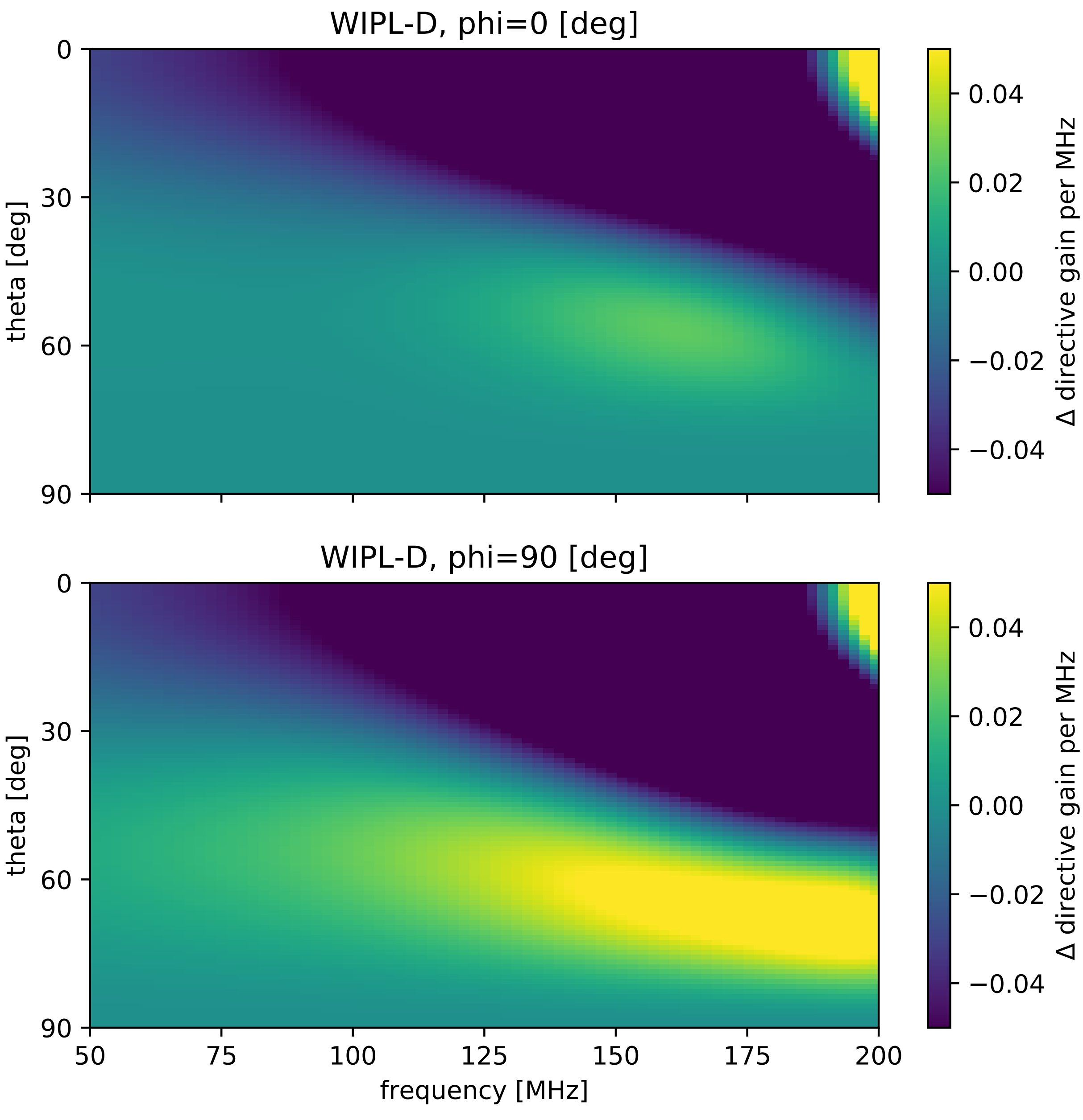

Figure 5: Using the WIPL-D model, here we show the derivative of the directivity as a function of frequency (i.e., per MHz), for $\phi = 0^{\circ}$ (top) and $\phi = 90^{\circ}$ (bottom).

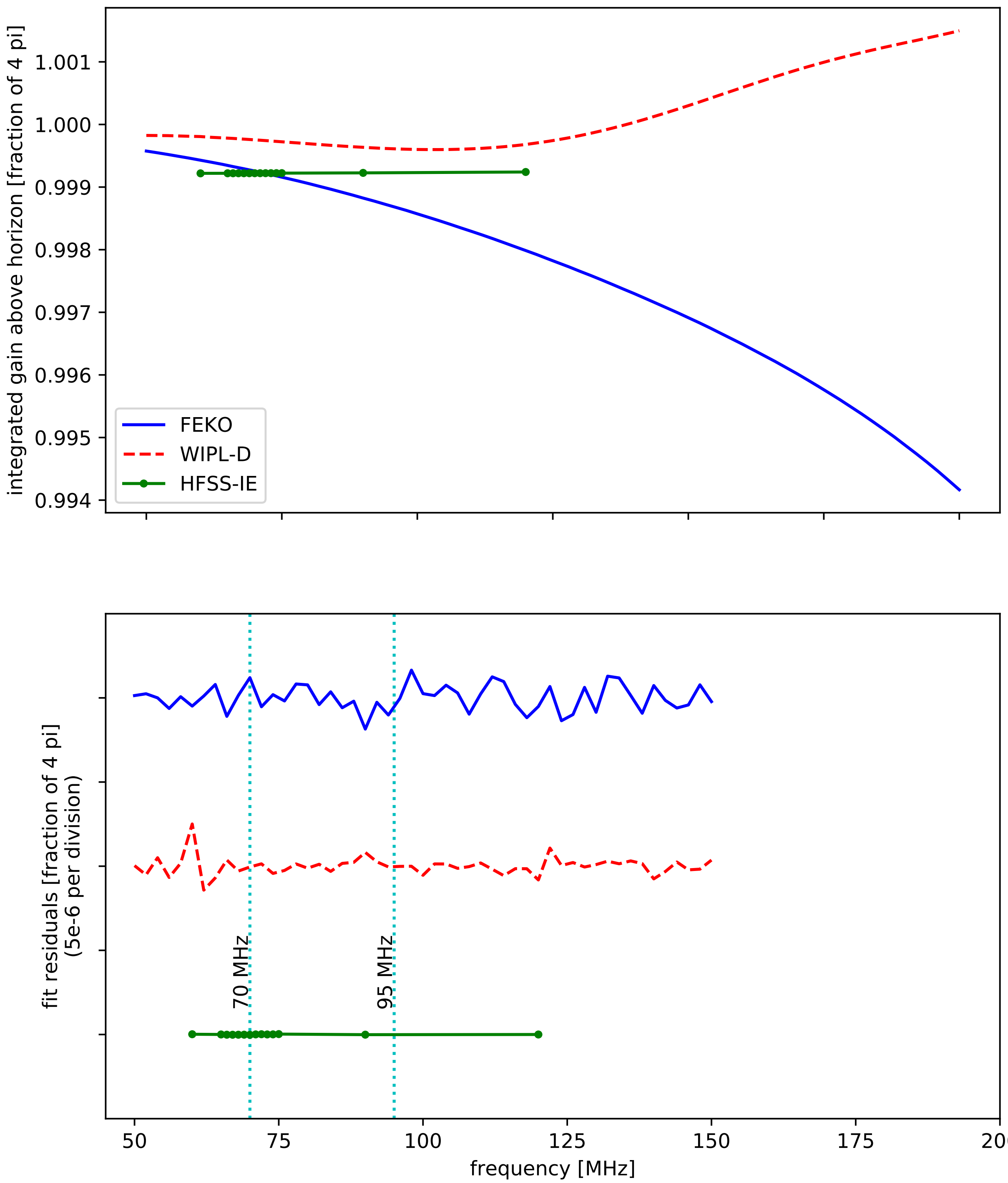

Figure 6: (Top) Integrated gain above the horizon for the three models compared. The FEKO curve decreases monothonically with frequency. The WIPL-D curve is more flat and closer to 1 below ~ 125 MHz, and increases to values above 1 for > 125 MHz. The HFSS-IE curve is the most flat. (Bottom) Residuals after fitting and removing polynomial models for the curves in the top panel. The FEKO residuals might contain a low-level dip at ~ 95 MHz, barely distinguishable above the noise. The WIPL-D residuals do not show a dip at ~ 95 MHz, and in general have lower numerical noise. The HFSS-IE residuals show the lowest numerical noise.

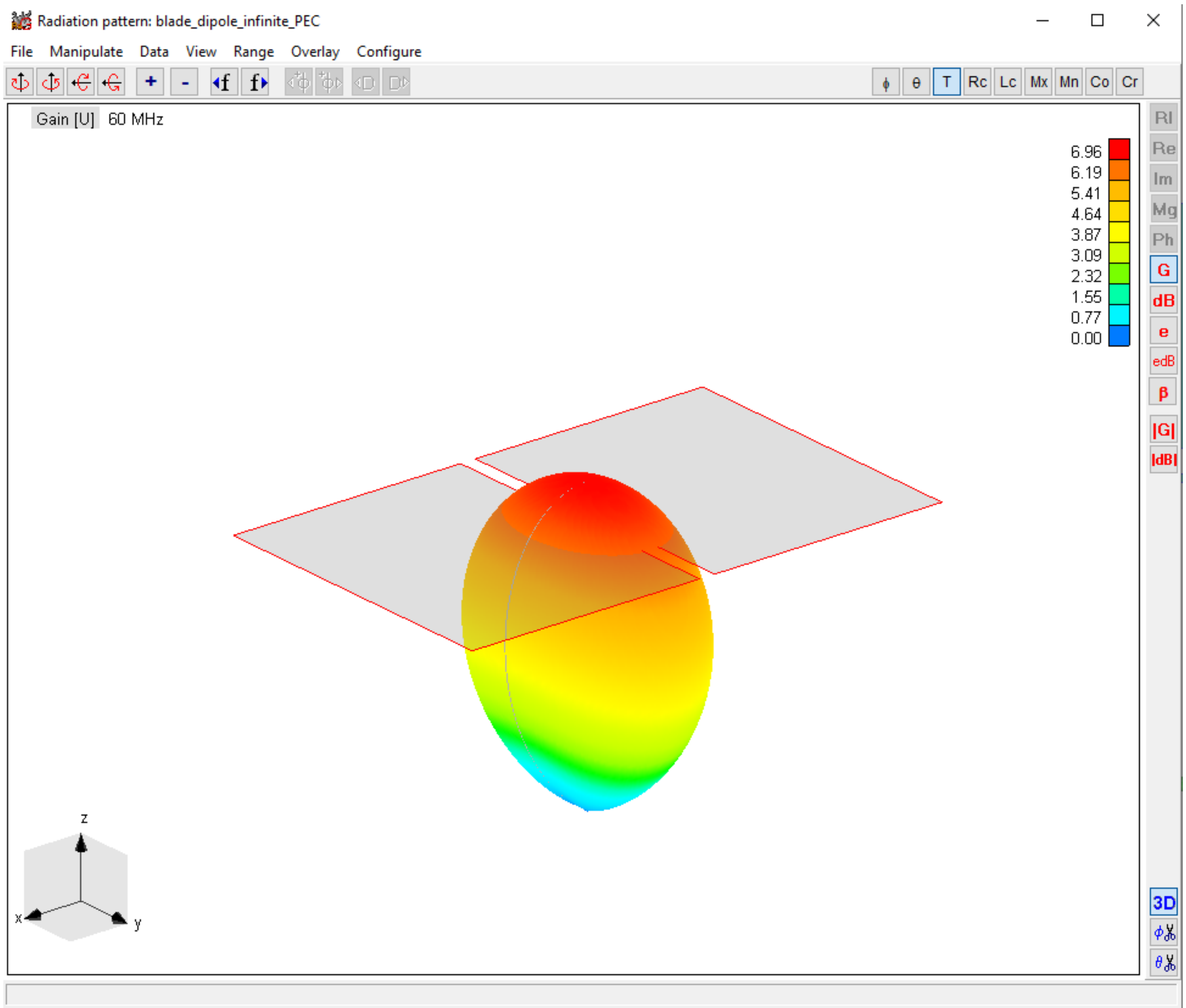

Figure 7: Screenshot of the simulation of the EDGES Mid-Band antenna with WIPL-D.