LoCo Lab EDGES Memo 154
Antenna Simulations with WIPL-D Accounting for Soil

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1 Description

Here, we show results of EM simulations with WIPL-D of the EDGES Mid-Band antenna for different metal ground planes and soil properties.

The objective is to see if in the results from WIPL-D there are glitches in the integrated directive gain above the horizon. Such glitches, with an amplitude of $\sim 10^{-4}$, have been seen in the results from other EM solvers.

It was found out that WIPL-D is indeed capable of doing simulations assuming infinite soil in the bottom hemisphere ($\pm x$, $\pm y$, $z \leq 0$) characterized by a relative permittivity (ϵ_r) and a conductivty (σ).

We used the free demo version of WIPL-D, which has restrictions on the number of unknowns that can be solved for. Thus, our simulations here are limited to the frequency range $60 - 108$ MHz (with 1-MHz resolution), and a square metal ground plane (above soil) of size 10×10 m^2.

2 Results

The results are shown in Figures 1-5. In all figures, the top panel is the integrated gain, and the bottom panel is the residuals after a polynomial fit.

- **Figure 1**: Reference simulation, in which the EDGES Mid-Band blade panels were simulated in free space. The integrated gain computed over the full sphere was expected to be equal to 1 across frequency. This is satisfied to within 10^{-3}. Departures from 1 for now could be attributed to the meshing being done only at the highest frequency. This will be explored in the future. The residuals were exepcted to be smooth. For the figure, we removed a 5-term polynomial and the residuals are close to the level of the numerical noise ($\sim 10^{-6}$). *IF* some of the structure of the residuals is interpreted as glitches, they would be within 10^{-6}.

- **Figure 2**: Simulations of the blade panels above infinite soil, for different ϵ_r and σ. For the residuals, we removed 5-term polynomials. We do not see glitches above the numerical noise level.

- **Figure 3**: Simulations of the blade panels and a 1×1 m^2 square metal ground plane above infinite soil, for different ϵ_r and σ. For the residuals, we removed 7-term polynomials. We do not see glitches above the numerical noise level.

- **Figure 4**: Simulations of the blade panels and a 5×5 m^2 square metal ground plane above infinite soil, for different ϵ_r and σ. For the residuals, we removed 7-term polynomials. We do not see glitches above the numerical noise level.

- **Figure 5**: Simulations of the blade panels and a 10×10 m^2 square metal ground plane above infinite soil, for different ϵ_r and σ. For the residuals, we removed 7-term polynomials. We do not see glitches above the numerical noise level.

In all the cases with metal ground plane (Figures 3, 4, and 5), we assumed two heights for the ground plane above the soil: 10^{-7} and 10^{-2} meters. The results are practically identical (with no obvious glitches in either case). Therefore, in Figures 3, 4, and 5, we show the results for a ground plane height of 10^{-7} meters.

3 Summary

In summary, in these simulations we do not see glitches with an amplitude close to $\sim 10^{-4}$. All the sharp structure (variations within 2 MHz) is seen at the $\sim 10^{-6}$ level.

We intend to run simulations with a 30×30 m^2 ground plane once we have accesss to the unrestricted evaluation version of WIPL-D.

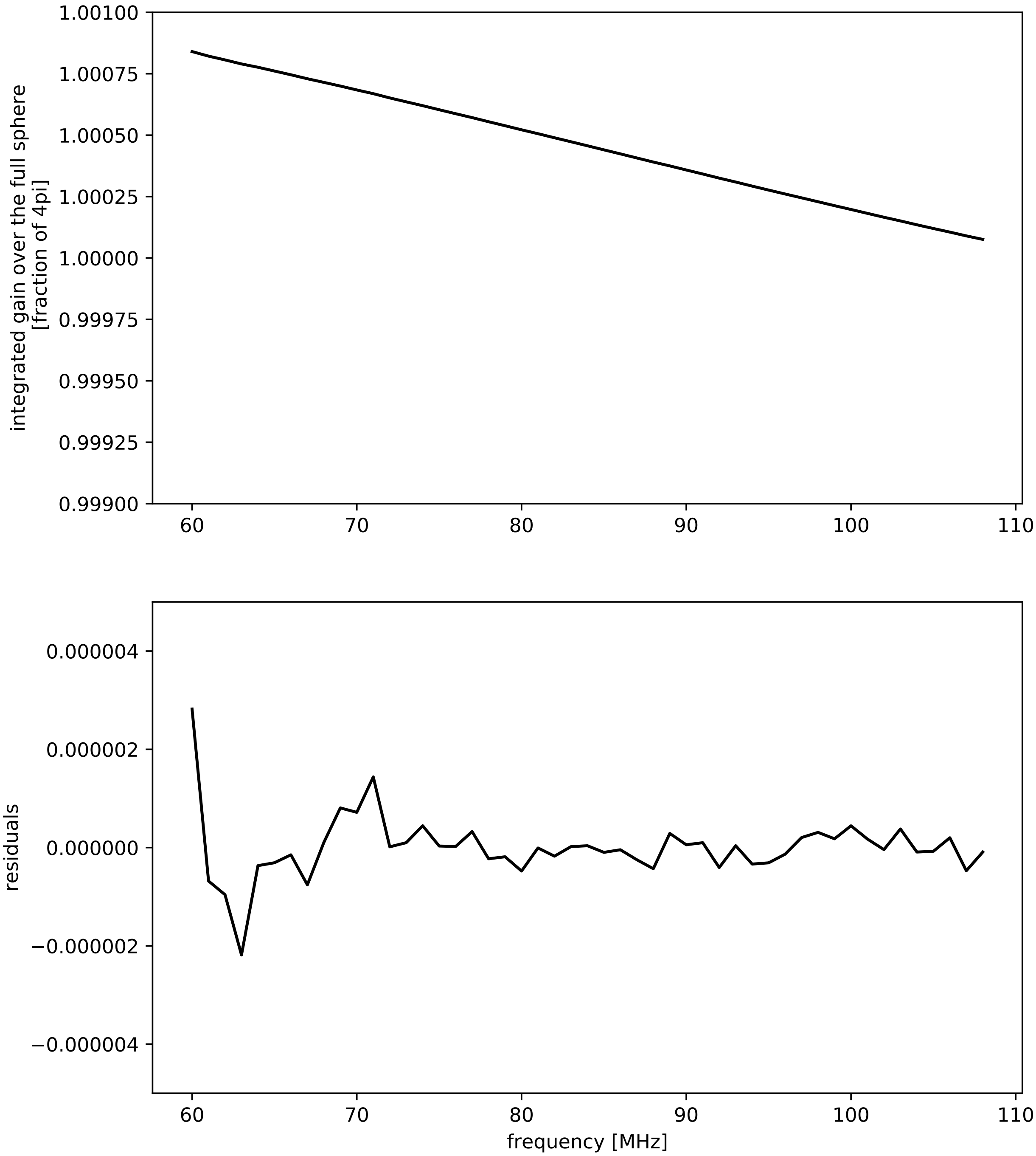

Figure 1: Reference simulation. Here, the EDGES Mid-Band blade panels were simulated in free space. Across frequency, the integrated gain (in this case computed over the full sphere) departs from 1 by $< 10^{-3}$. After removing a 5-term polynomial, the residuals are close to the level of the numerical noise ($\sim 10^{-6}$).

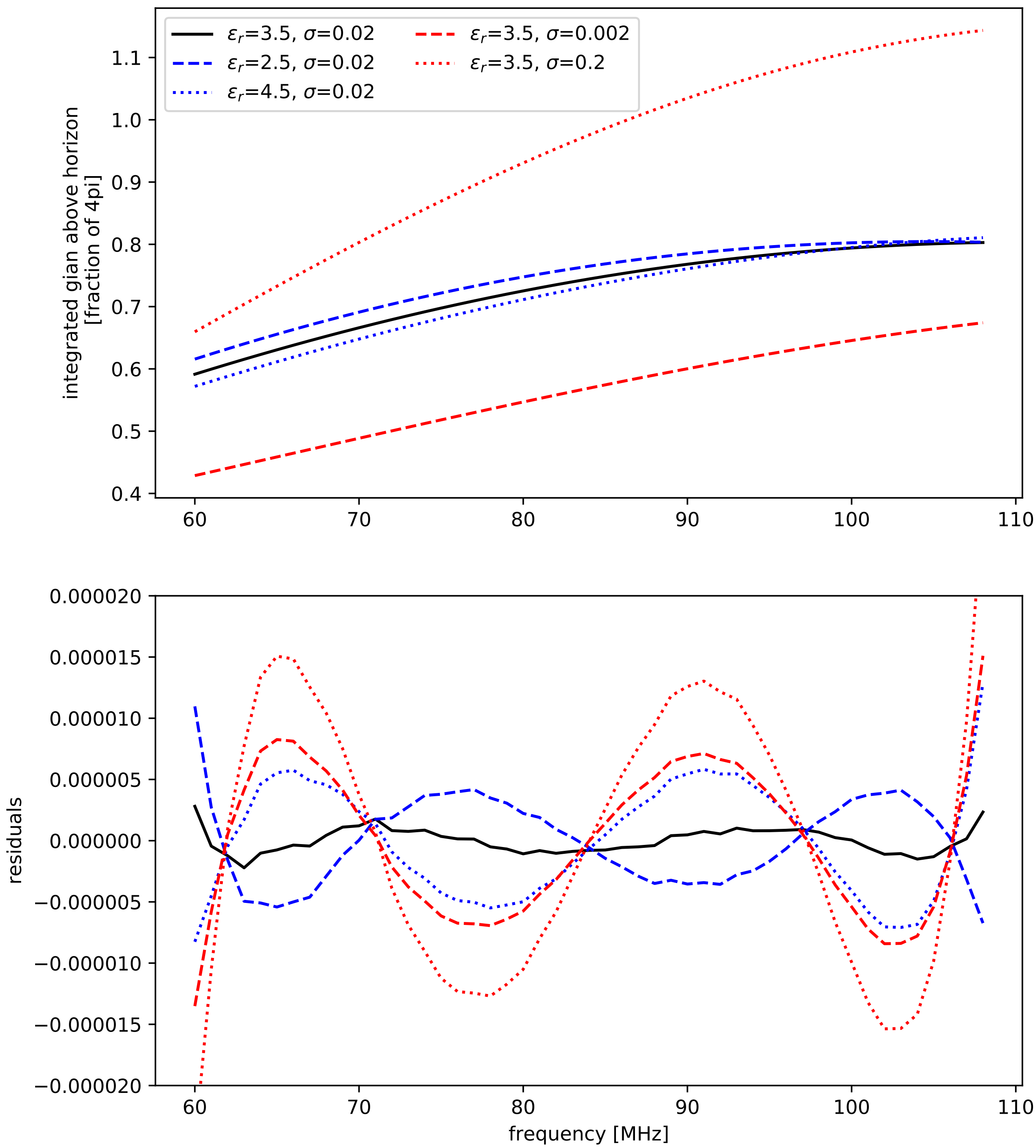

Figure 2: Simulations of the blade panels above infinite soil, for different ϵ_r and σ. For the residuals, we removed 5-term polynomials. We do not see glitches above the numerical noise level. We note in the top panel that in the case with $\epsilon_r = 3.5$ and $\sigma = 0.2$ (red dashed line) the integrated gain goes above 1 at higher frequencies. This might indicate an unreasonable combination of parameters, but we intend to explore further.

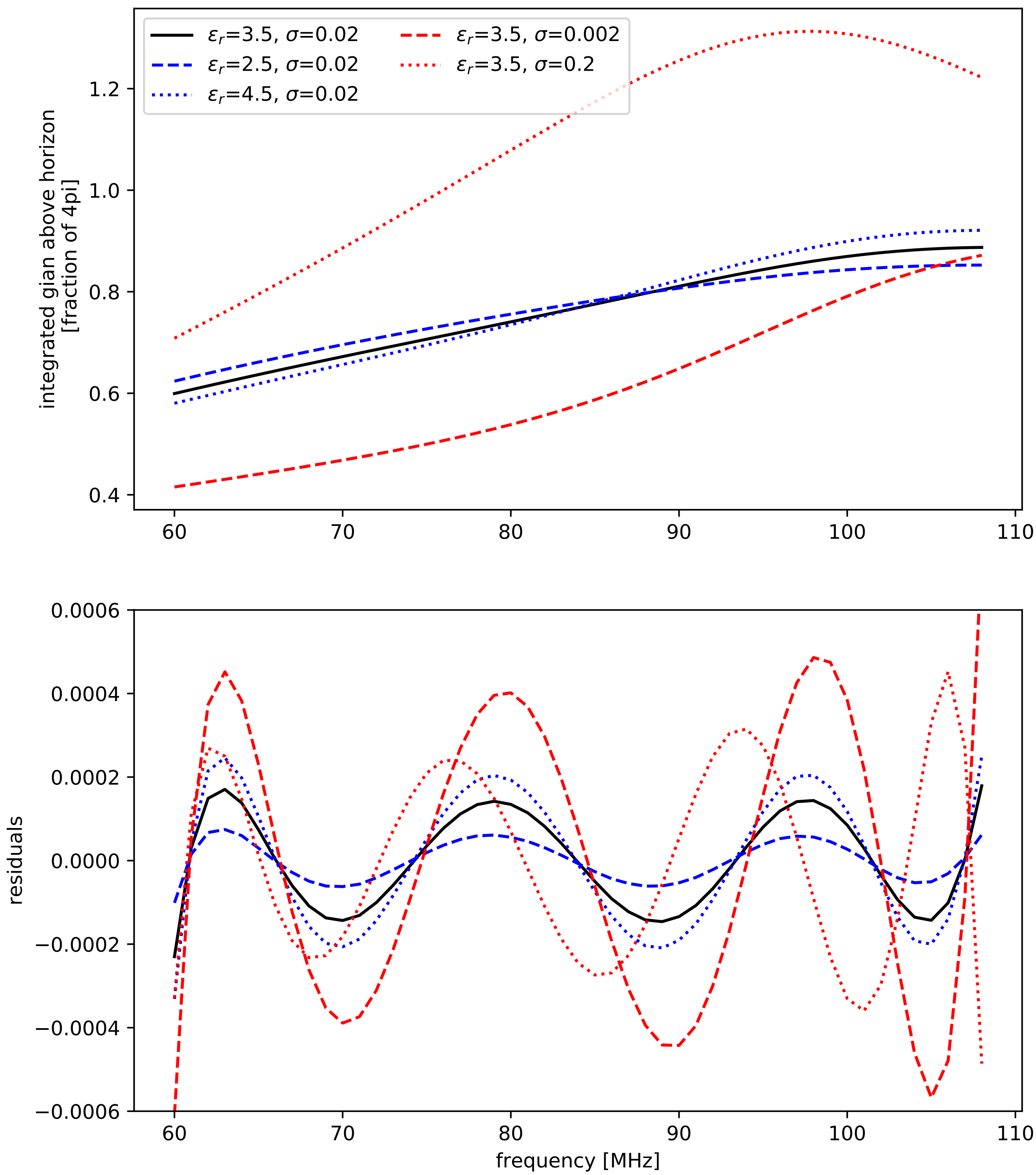

Figure 3: Simulations of the blade panels and a 1×1 m^2 square metal ground plane above infinite soil, for different ϵ_r and σ. For the residuals, we removed 7-term polynomials. We do not see glitches above the numerical noise level. We note in the top panel that in the case with $\epsilon_r = 3.5$ and $\sigma = 0.2$ (red dashed line) the integrated gain goes above 1 at higher frequencies. This might indicate an unreasonable combination of parameters, but we intend to explore further.

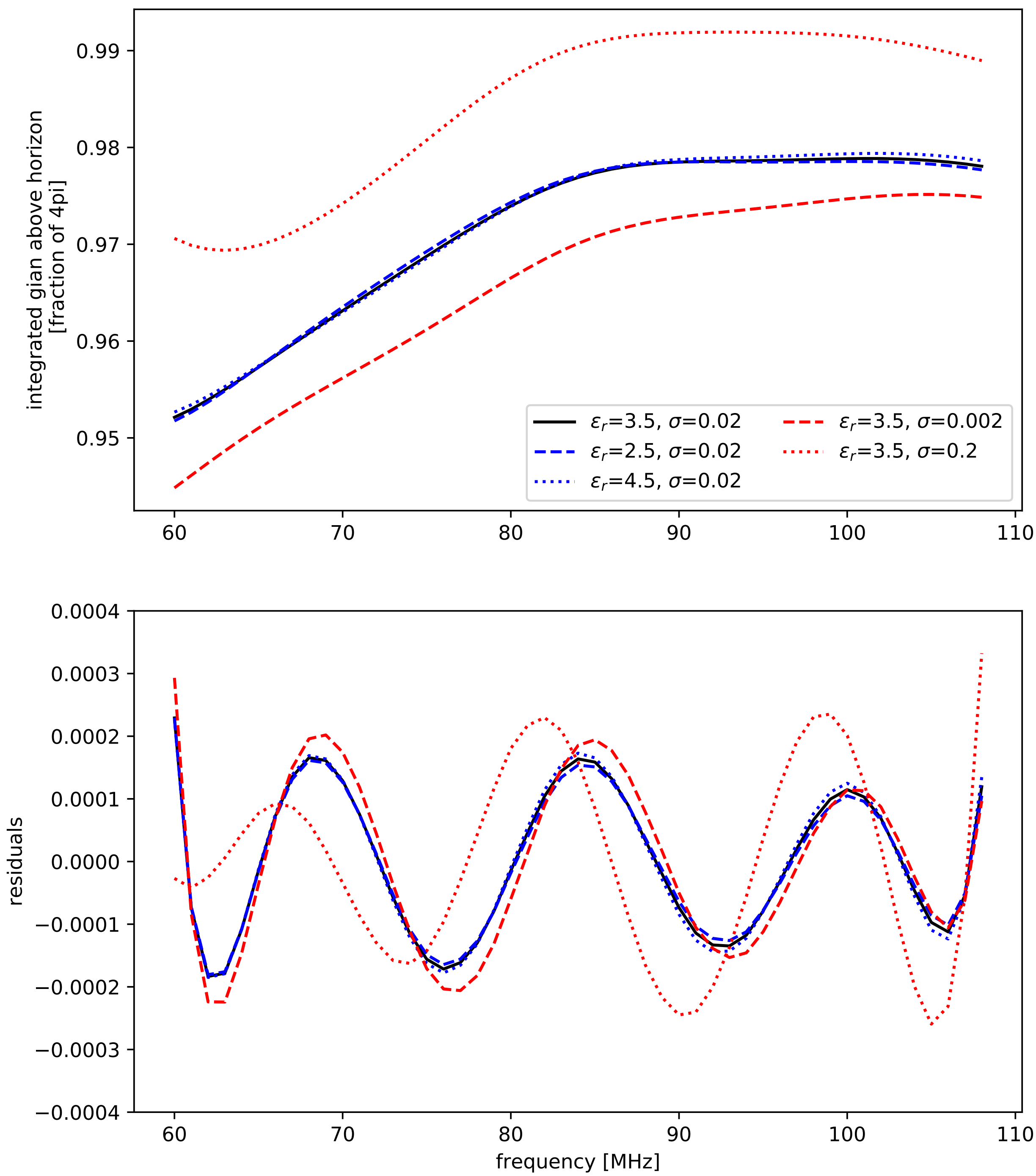

Figure 4: Simulations of the blade panels and a 5×5 m^2 square metal ground plane above infinite soil, for different ϵ_r and σ. For the residuals, we removed 7-term polynomials. We do not see glitches above the numerical noise level.

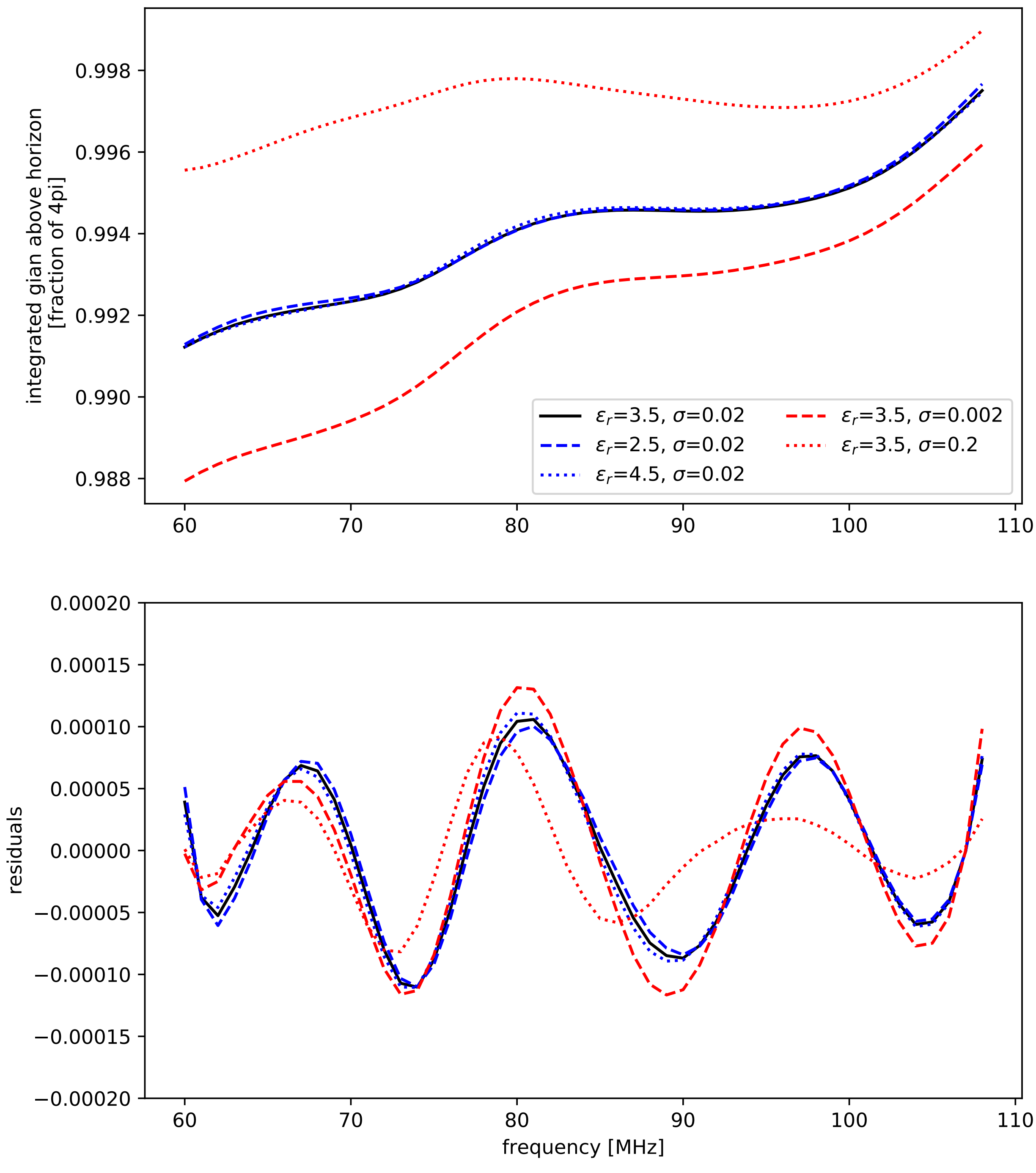

Figure 5: Simulations of the blade panels and a 10×10 m^2 square metal ground plane above infinite soil, for different ϵ_r and σ. For the residuals, we removed 7-term polynomials. We do not see glitches above the numerical noise level.