Plane Wave Interactions with a Dielectric Half-Space at 60 THz

In this article, CST MICROWAVE STUDIO® (CST MWS) is used to illuminate an infinite dielectric half-space with a uniform plane wave at 60 THz and the reflection and transmission quantities are obtained. This problem has an analytical solution which serves to validate the simulation. The same procedure is then applied to a more generalized geometry which lacks a known analytical solution.

All simulations are performed using the Frequency Domain solver in combination with Periodic boundary conditions and Floquet ports. The Periodic boundary conditions are necessary to effectively create an infinite structure. The Floquet ports are used in place of the Perfectly Matched Layer (PML) absorbing boundary condition in order to obtain accurate results at very oblique angles of incidence (approaching grazing).

Pictures of the dielectric half-space and the incident plane wave with both polarizations are shown in Figs. 1 and 2.

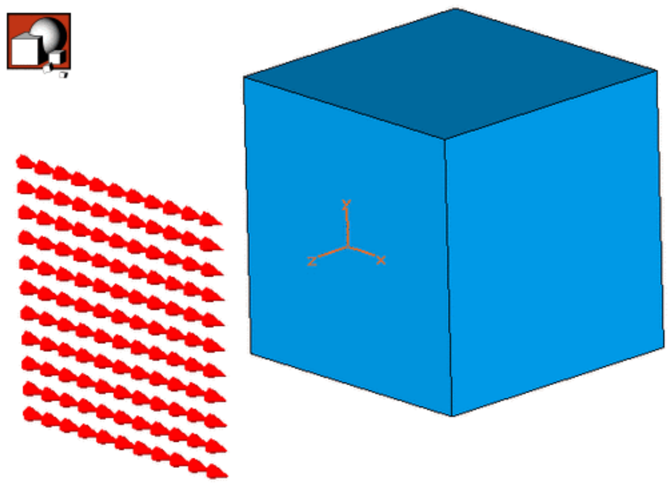

Figure 1: Uniform plane wave excitation (parallel polarization)

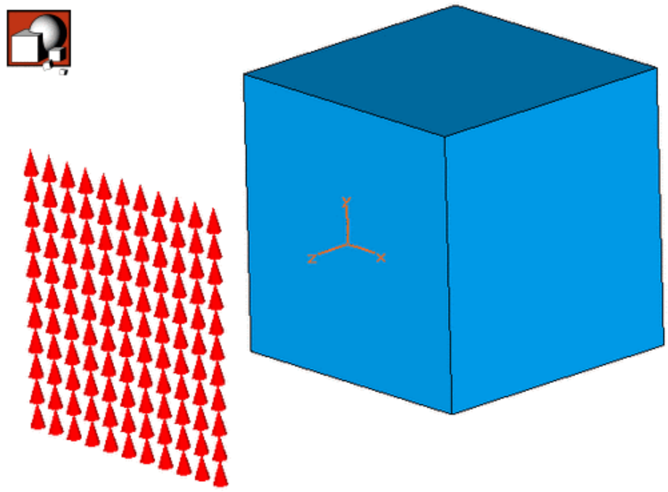

Figure 2: Uniform plane wave excitation (perpendicular polarization)

For these simulations, the dielectric was chosen to be glass with a relative permittivity of 2.25, and the elevation angle of the incident plane wave was was swept from 0 to 89.5 degrees. As mentioned, this problem has an analytical solution which is commonly referred to as the Fresnel Reflection and Transmission Coefficients. These results are easily obtained from the simulation and are compared to the theoretical results. Figures 3 and 4 show the comparison for parallel polarization whereas Figs. 5 and 6 show perpendicular polarization. All figures also show the equations for the theoretical results.

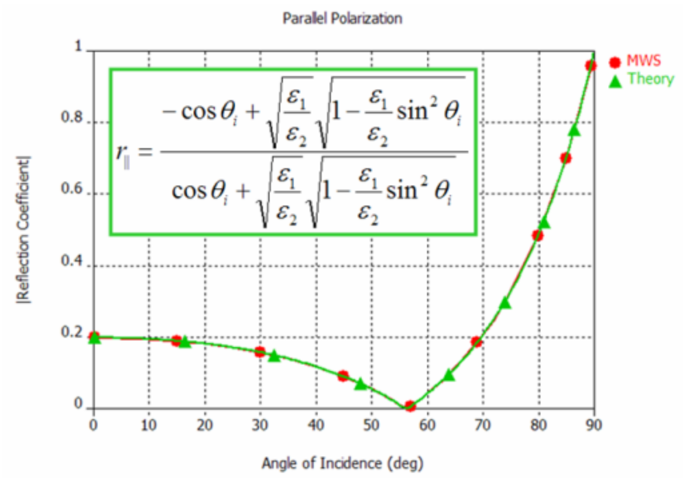

Figure 3: Overlay of theoretical and simulated reflection coefficient v. angle of incidence for parallel polarization

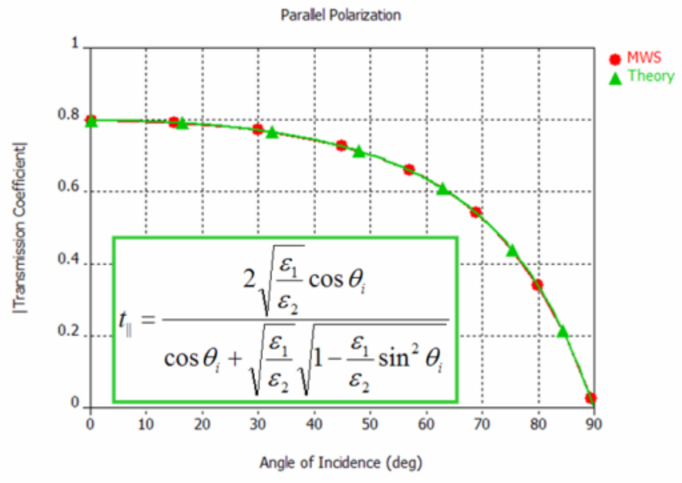

Figure 4: Overlay of theoretical and simulated transmission coefficient v. angle of incidence for parallel polarization

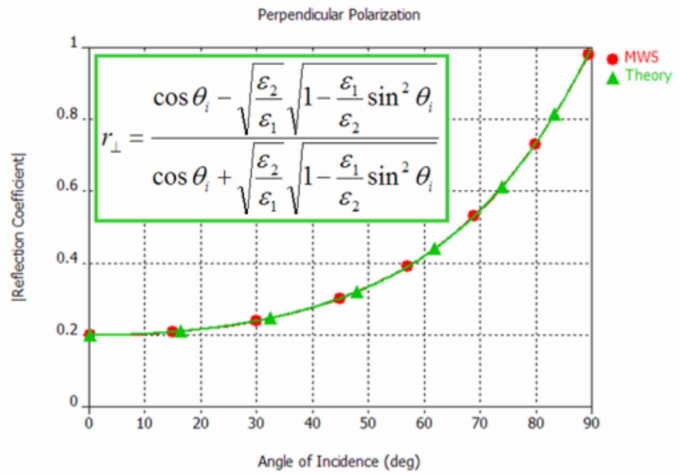

Figure 5: Overlay of theoretical and simulated reflection coefficient v. angle of incidence for perpendicular polarization

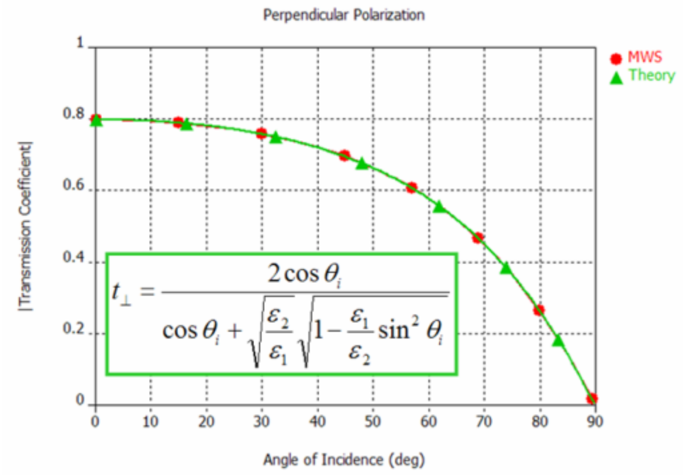

Figure 6: Overlay of theoretical and simulated transmission coefficient v. angle of incidence for perpendicular polarization

Figure 7 shows the phase animation of the incident and transmitted electric field magnitude (perpendicular polarization) at 60 THz and an incident angle of 45 degrees. One can easily see the altered propagation direction and field magnitude decrease within the glass region as expected from the transmission parameter described above.

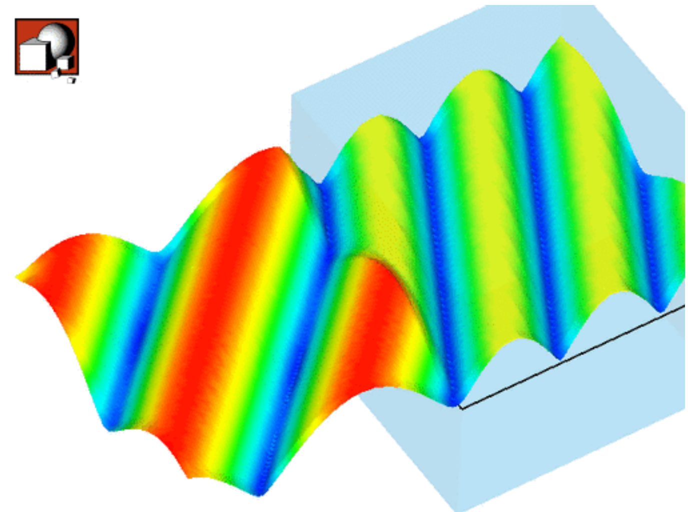

Figure 7: Phase animation of incident electric field magnitude at 45 degrees

Having validated the simulation, we can apply the same procedures and techniques to a problem lacking a known solution. However, since the aforementioned reflection and transmission coefficients are defined at the air-dielectric boundary, it would be convenient to use a notation similar to that of s-parameters, especially in the event that the interface is not an infinite plane, but rather an arbitrary shaped profile. The second advantage is that CST MWS automatically returns these s-parameter type of results since which are commonly referred to as reflectance and transmittance. For the previous simulation, some simple post-processing steps were required to convert the reflectance and transmittance to the Fresnel reflection and transmission coefficients. The geometry used for the next simulation is show in Figure 8, however, in this case the dielectric material was chosen to be silicon with a relative permittivity of 11.56.

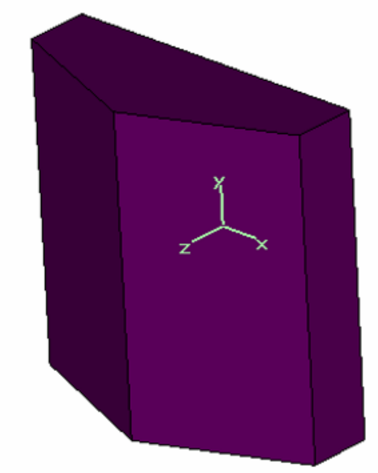

Figure 8: Second geometry for dielectric half-space simulations

This structure was excited in the same fashion as the previous simulation. Figures 9 and 10 show the reflectance and transmittance parameters for both polarizations that resulted from the CST MWS simulation. We can see that the modified geometry prevents the existence of the Brewster angle which would have appeared near 73.6 degrees if the interface were flat.

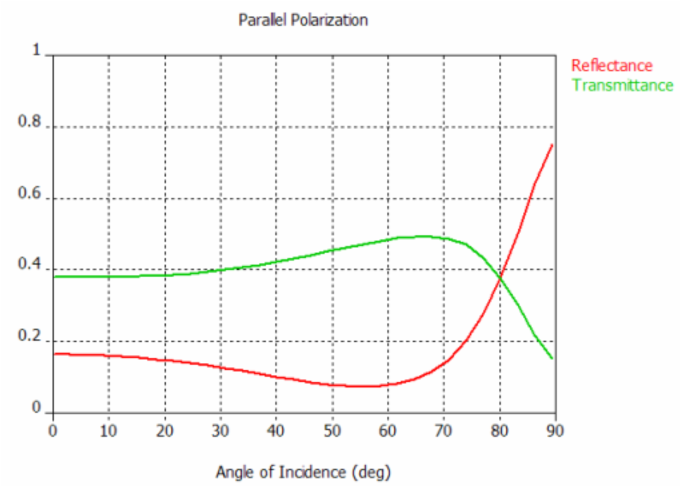

Figure 9: Reflectance and Transmittance v. angle of incidence for parallel polarization

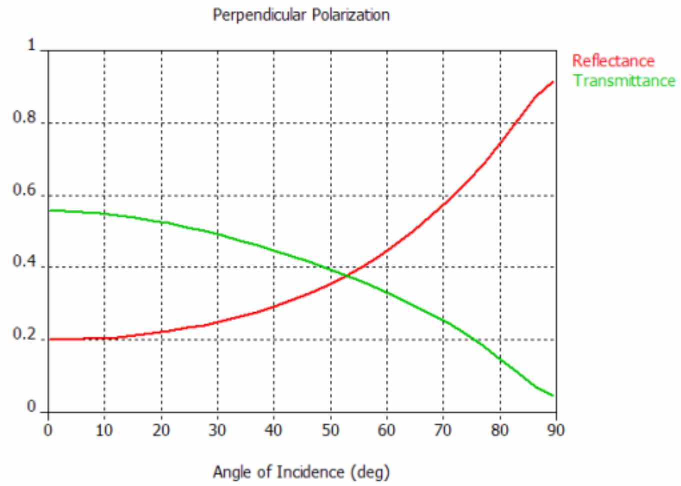

Figure 10: Reflectance and Transmittance v. angle of incidence for perpendicular polarization

A phase animation of the electric field magnitude (parallel polarization) at an incident angle of 30 degrees is shown in Fig. 11. Note the structure was expanded to three "ridges" to better show how the transmitted field changes.

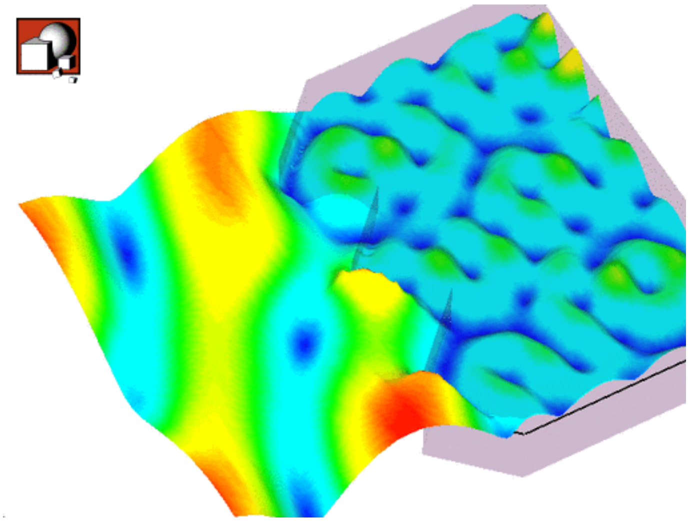

Figure 11: Phase animation of the electric field magnitude at 60 THz