Electromagnetic Penetration of Structures with Applications in Vulnerability Assessment

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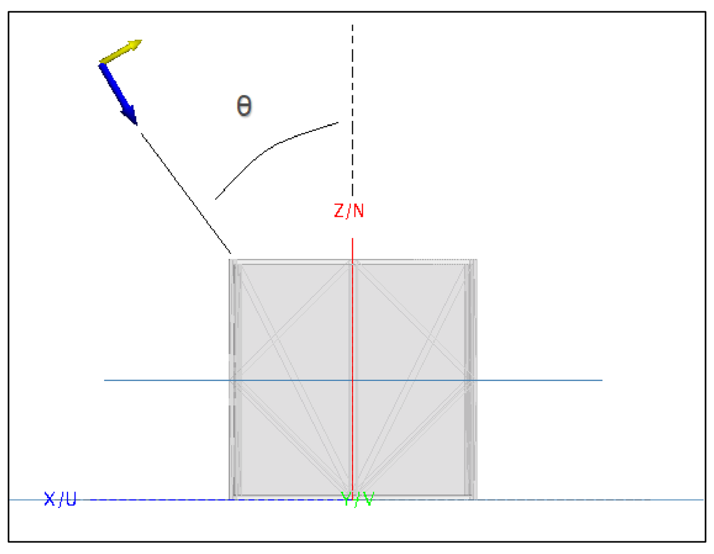
INTRODUCTION AND SCOPE OF STUDY

High-altitude electromagnetic pulse (HEMP) is an intense electromagnetic signal generated from interactions between high energy particles, produced in a nuclear detonation, and molecules in the atmosphere. Due to recent escalated threats of weaponized EMP, further understanding of the potential effects from HEMP is of concern. This study aims to develop a foundational understanding of the electromagnetic penetration of structures.

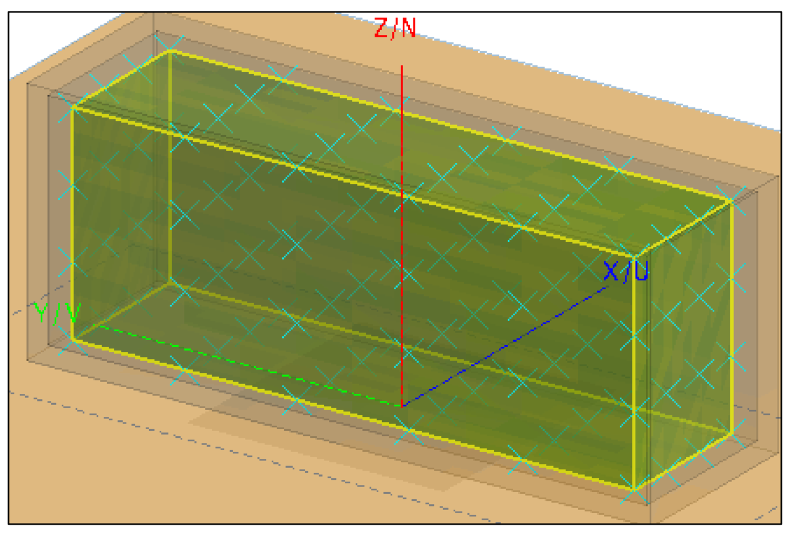
By comparing computationally solved electric and magnetic field data inside modeled three dimensional concrete structures with the incident plane wave field values, a transfer function can be obtained. The transfer functions defined by equations 1 and 2 exemplify the attenuation provided by the structure. Several variables of interest including angle of incidence, polarization angle, frequency dependence of wall material, and effect of dielectric ground plane were analyzed to determine critically and develop a ‘worst case’ scenario.

$$E_f = 20\log\left(\frac{E_p}{E}\right) \qquad (1)$$

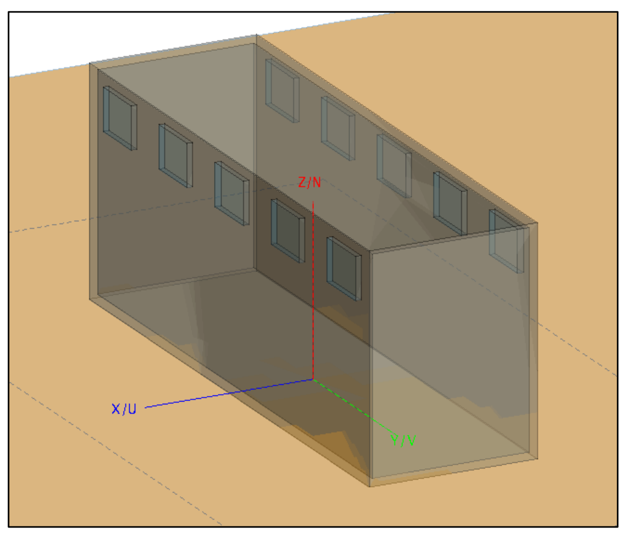
$$H_f = 20\log\left(\frac{H_p}{H}\right) \qquad (2)$$



Angle of incidence θ.



Points of field result calculation.



Structure including apertures.

PROCEDURE AND RESULTS

Angle of Incidence

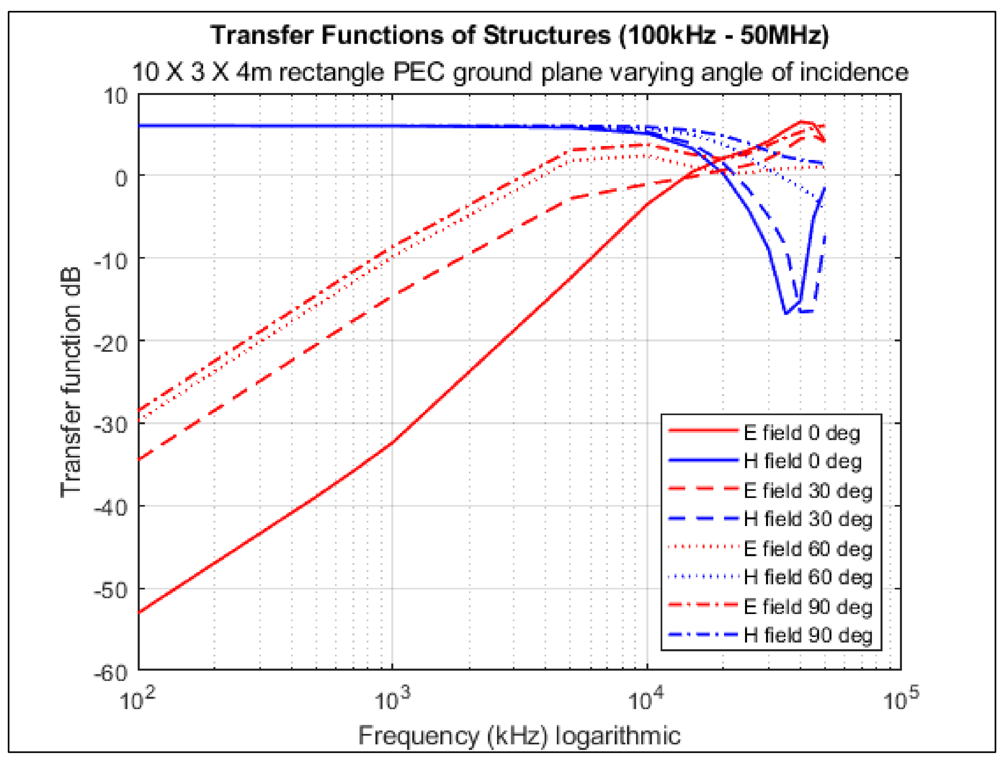
By Varying the angle of incidence of the incoming radiation we observe different excitation behavior within the structure. As the angle in relation to the vertical axis grows, we observe a reduction in attenuation. Angles between 60° and 90° display similar results and can be deemed as a worst case scenario.

Polarization Angle

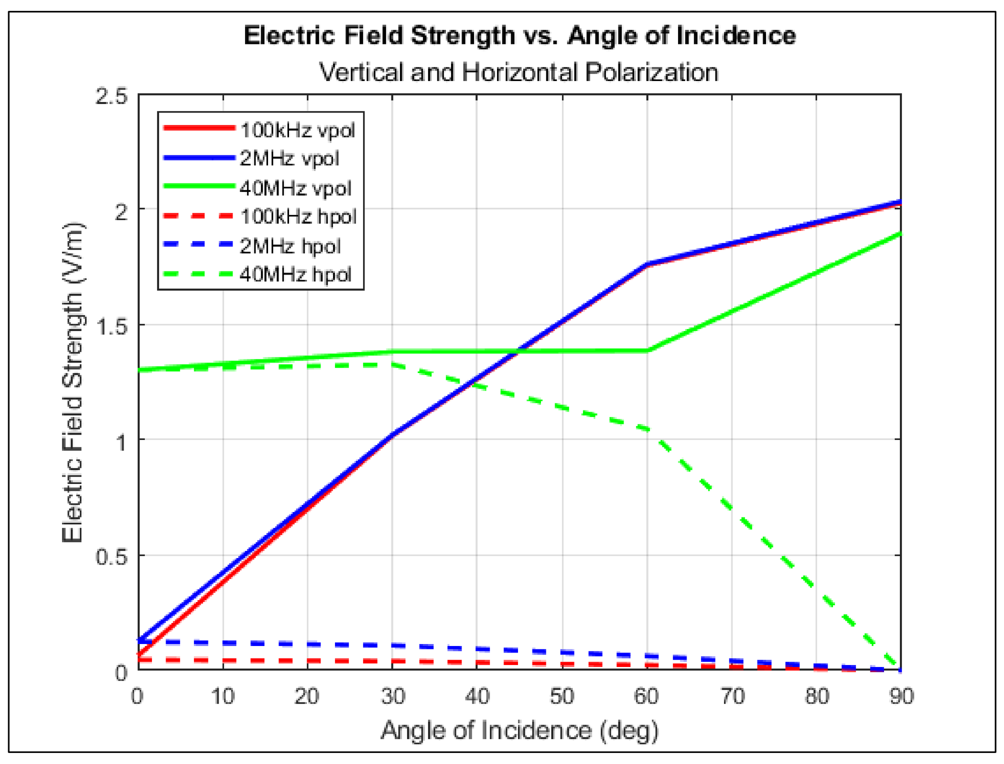
Studying the cases of vertical and horizontal polarization of the incoming radiation reveals a more intense response for the vertically polarized case. Therefore vertical polarization can be applied to the worst case scenario.

Frequency Dependence of Dielectrics

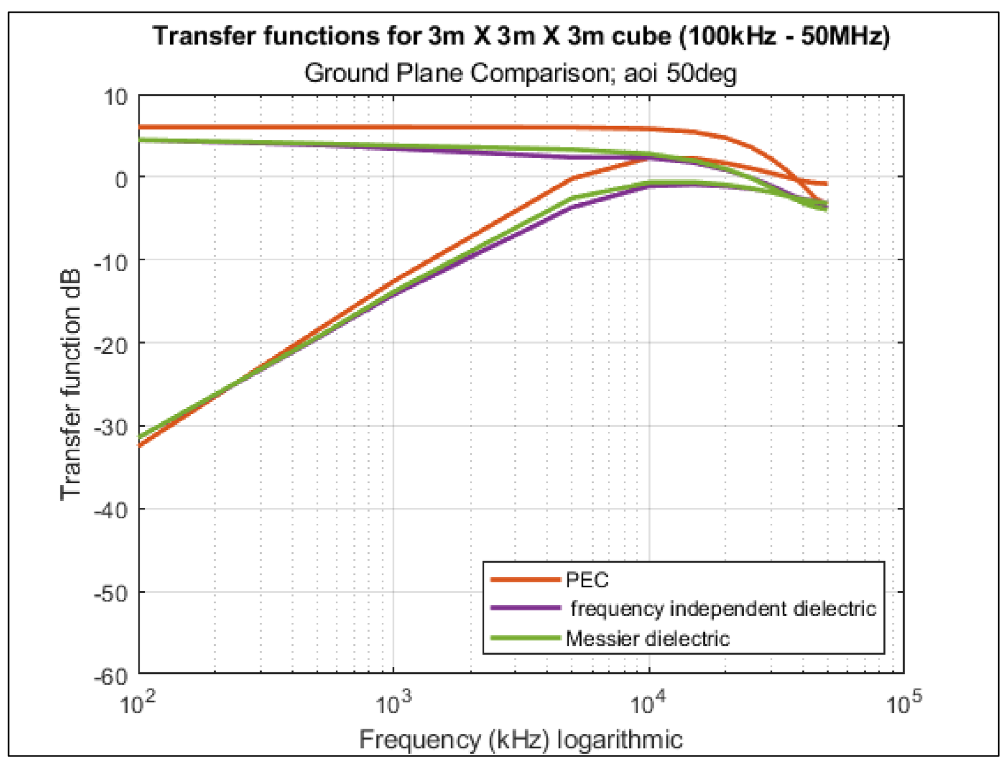
The wall material of the structure was modeled with both a frequency independent and dependent dielectric. Similarly the ground plane was modeled as a perfect conductor and dielectric. Regardless of frequency dependence, the transfer function constitutes fairly similar attenuation. If computational resources were of concern, using a perfect conducting ground plane and a frequency independent wall material would be sufficient.



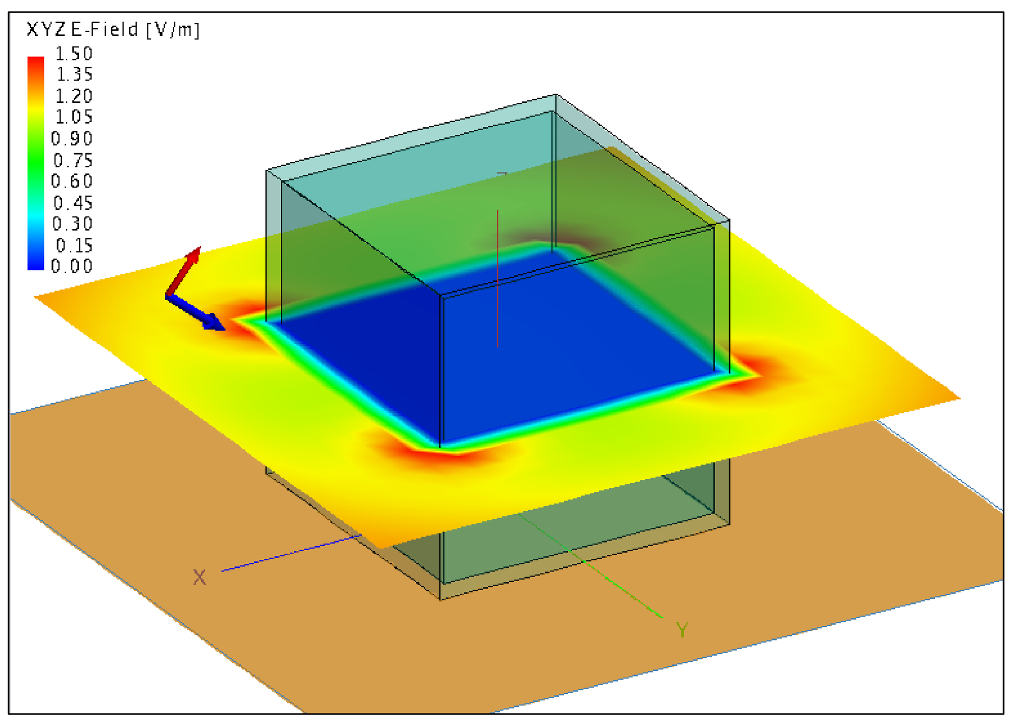
Comparison of transfer functions with varying angle of incidence.



Electric field inside the structure.



Comparison of transfer functions for different ground planes.



Electric field inside structure for perfect conducting ground plane (100kHz).

Concluding Remarks

This work has studied several variables and their influence on electromagnetic penetration of structures associated with high-altitude electromagnetic pulse. It is worthy to note the magnetic field remains roughly constant throughout the low frequency region. However, the electric field attenuation decreases quadratically as a function of frequency. Overall, these results provide reasonable assumptions which can be applied as simplifications when studying more complex cases.