# 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. The threat of weaponized electromagnetic pulse (EMP) is a serious factor in defining power system resilience. This work studies the EM shielding effects provided by reinforced concrete structures considering the following:

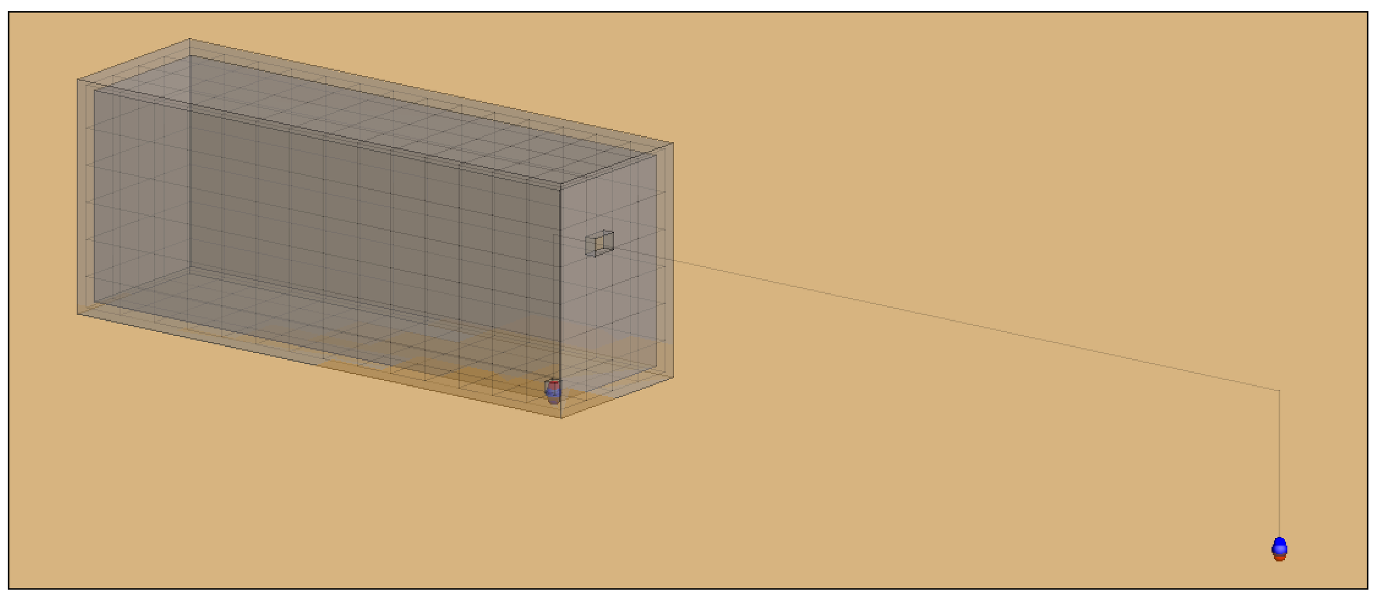
- Plane wave excitation at HEMP early time component (E1) frequencies.
- Various parameters associated with penetrating cables and lines including length, diameter, height above ground, and terminations.

Computational methods are used to calculate field values inside a modeled reinforced structure and a attenuation transfer function is developed. Additionally, induced normalized current values and voltage transients are calculated and compared.

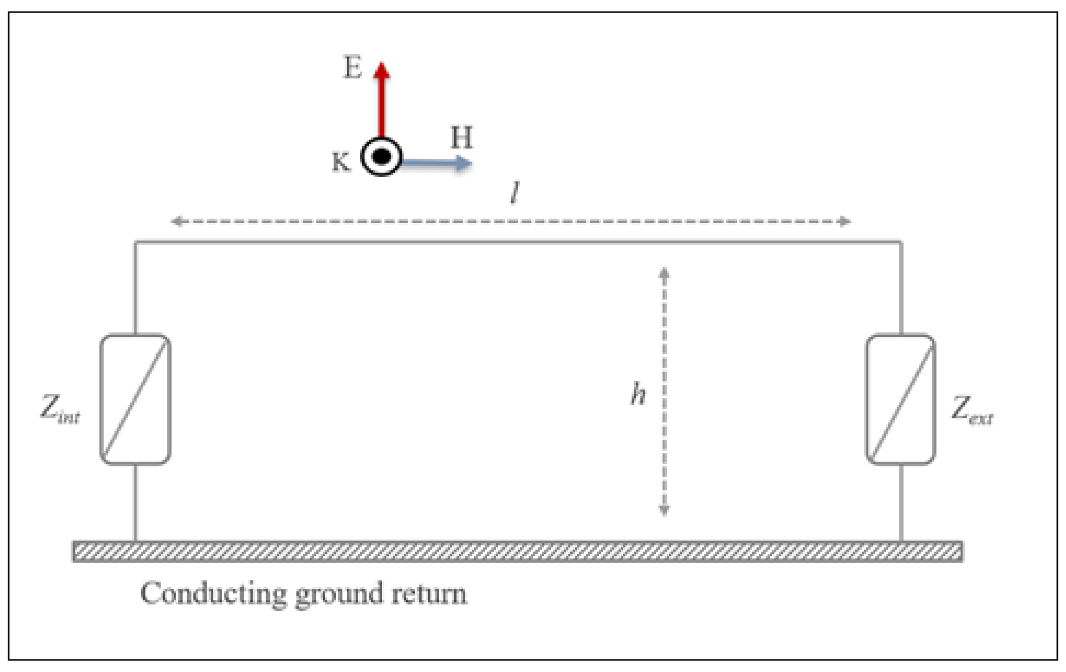
## PROCEDURE AND METHODOLOGY

The simulation approach begins with creating the three-dimensional model of the structure. Subsequently, a penetrating transmission line is modeled and incorporated. Discretization of the line and structure enable the calculation of induced currents and field values. Also, loads can be placed and monitored at the terminations of the line.

Running electromagnetic simulations and identifying critical parameters → Developing transfer function to illustrate structure attenuation results → Analysis of over voltage and resonance effects



10 by 3 by 4 m reinforced concrete structure and penetrating line



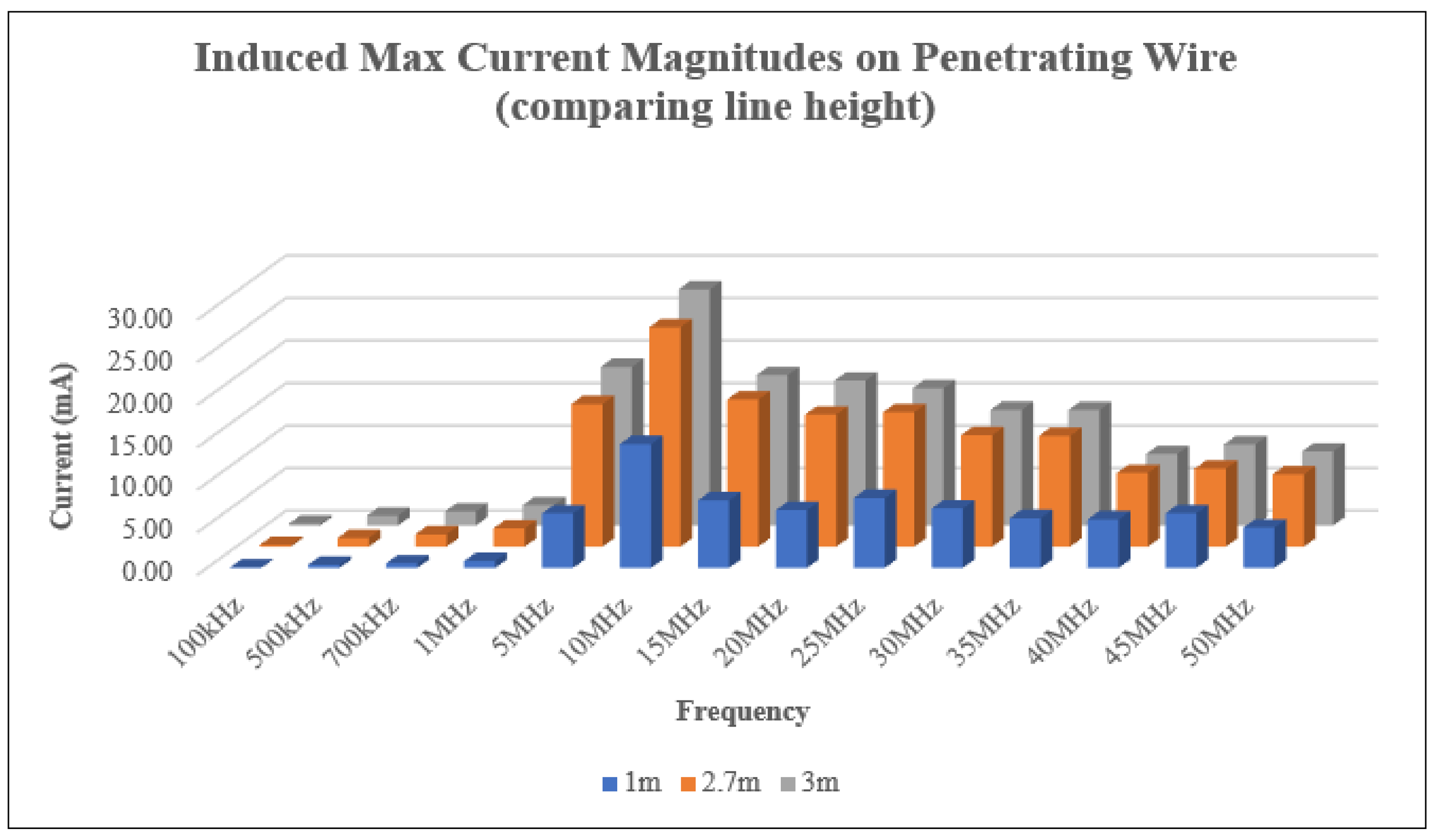

Single conductor earth return transmission line illuminated by plane wave excitation

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

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

Electric and magnetic field transfer functions

## Results and Observations

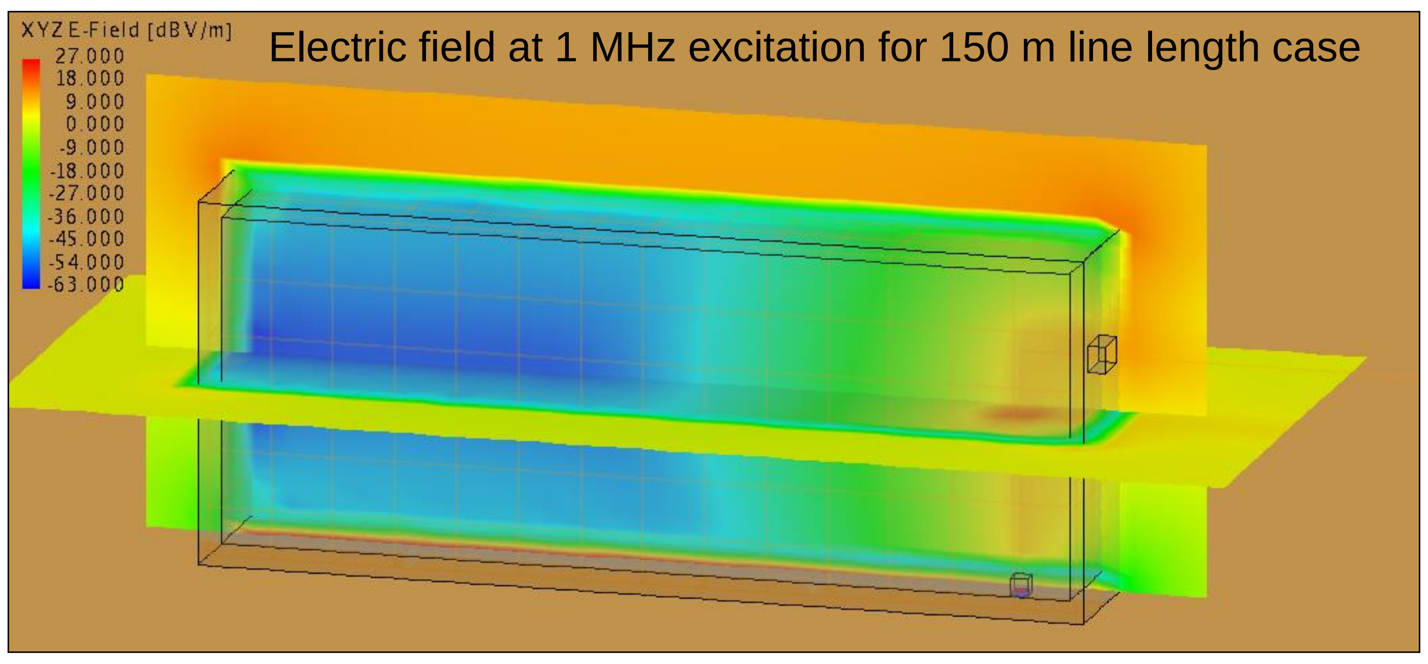



Maximum induced current magnitudes comparing line height for each simulation frequency

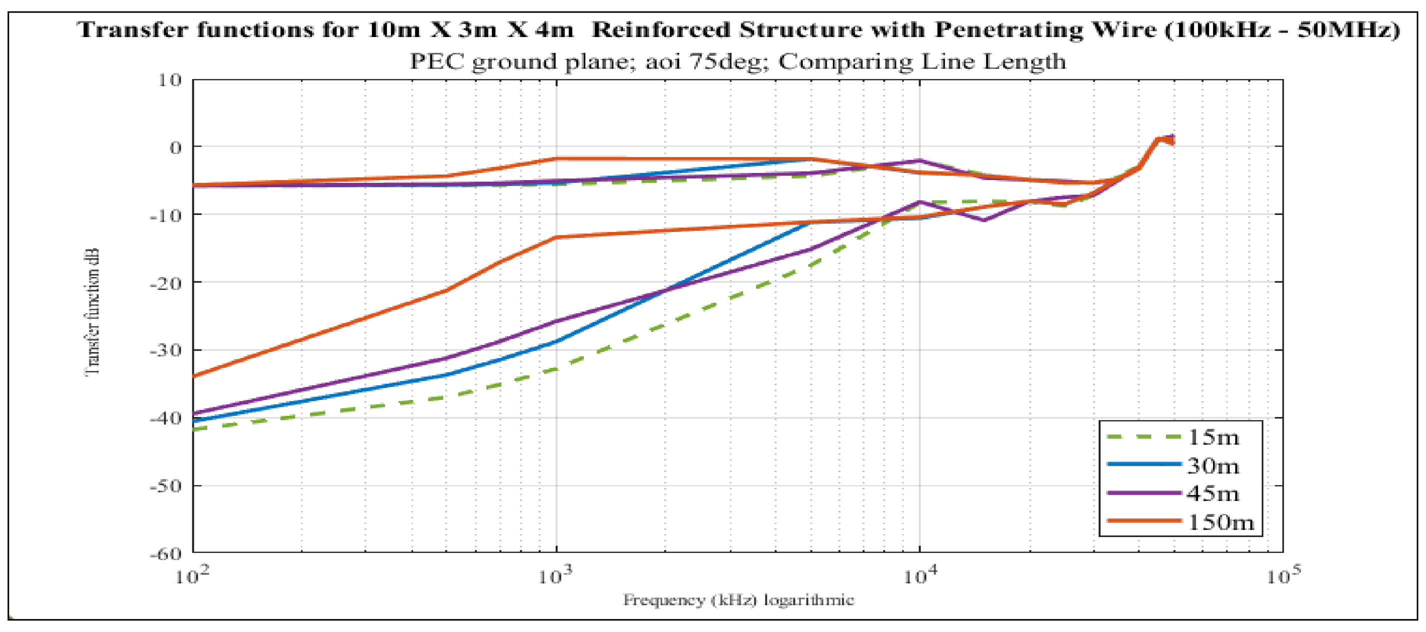
Maximum induced normalized currents calculated for each case comparing line height, radius, termination, and length.

Maximum current induced at fundamental resonant frequency

Large currents for all high frequency components




Electric field at 1 MHz excitation for 150 m line length case




## Concluding Remarks

This work studied the electromagnetic shielding effectiveness of a reinforced concrete structure considering various parameters associated with penetrating cables. Additionally, EM cable coupling was analyzed as a function of the same parameters. Increasing the cable height and radius results in stronger coupling and thus stronger radiated effects into the structure's interior. The effects of various line parameters are less distinguishable at frequencies above 30 MHz due to the structure's high pass filter behavior. Lines of increased length experience notably larger normalized induced currents. However, maximum termination voltages do not appear to be significantly affected by line length.

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