EMP Shielding Effects of Multiple Layers of Steel Reinforcing Bars

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Abstract— In this presentation we discuss the shielding effectiveness of multiple layers of steel reinforcing bars (rebar) in very thick concrete structures.. While the effect is simple for a single layer, the presence of multiple layers becomes complicated in the time domain. We show results for the shielding in both the frequency and time domain, using the IEC 61000-2-9 E1 waveform for the incident field specification.
Keywords-EMP Shielding, EMP Coupling

I. INTRODUCTION

The analysis of the effects of rebar has been performed treating it as a perfectly conducting wire grid. We modify the treatment by including the relative permittivity, and examining the effect of multiple layers. The permittivity has two effects, firstly the lowering of the skin depth in the reinforcing bars themselves, and, secondly, having an effect on the magnetic field associated with the wave.

II. TIME DOMAIN EFFECTS

The sheet inductance per square of a set of perfectly conducting parallel wires is

$$L = \frac{\mu_0 w}{\pi} \ln\left(\frac{w}{\pi a}\right) \qquad (1)$$

where L is the inductance, $2w$ is the wire spacing, a is the wire radius and the other terms have their conventional meanings. To this we must add the interior rebar inductance, determined by the magnetic field within a skin depth and we must also add the effect of rebar resistance which is modified by the small skin depth in the rebar due to the high permittivity. These are frequency dependent, but can be chosen at a suitable center frequency of interest for fields penetrating the reinforced concrete. These are all be included in a finite difference model of the concrete, and upon calculation of the fields penetrating a thick concrete wall with multiple sets of rebar, we obtain the surprising result shown in Fig.1, where only fields on the order of 200 MHz penetrate when an IEC 61000-2-9 E1 waveform is applied normally incident to the surface. Since very little of the frequency content is above 100 MHz, the residual is very small and the late portion of the time waveform appears to be more related to the escape of energy trapped between the layers than the original EMP waveform most of whose VHF energy is generated at the beginning of the time waveform.

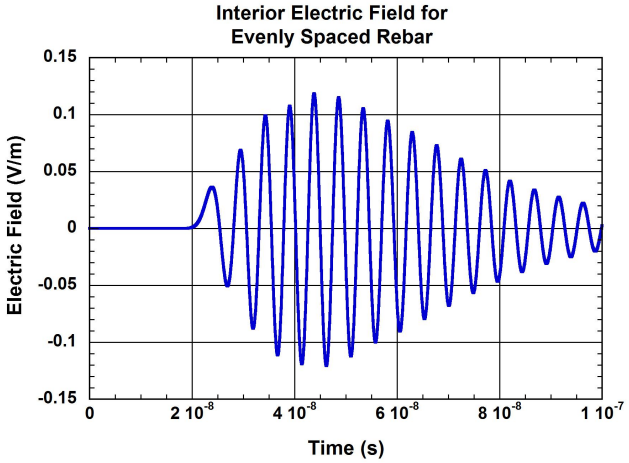

Figure 1. Interior electric field with widely spaced layers of rebar.

III. FREQUENCY EFFECTS

Performing the penetration calculation in the frequency domain for a slightly different spacing gives the result shown in Fig 2. The f^3 (60 db/decade) behavior shows that the effect of the three sets of rebar is multiplicative, which we find only true for wide spacing between layers.

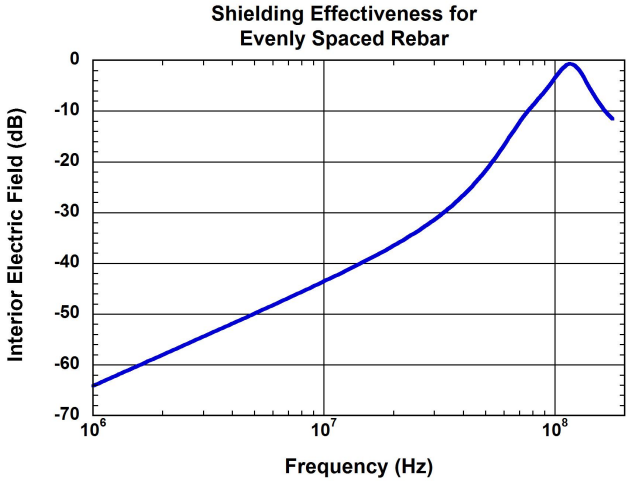

Figure 2. Shielding effectiveness for widely spaced layers of rebar.

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