E1 HEMP Exposure of Ungrounded Shielded Cables

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Abstract—It is a good idea to use shielded cables (or conduit) for wiring that could get exposed to E1 HEMP, such as power substation yard cables, with the shields grounded at both ends (preferable using 360° bonds to the metal enclosures [1]. However sometimes grounding occurs only at one end. Such open-ended shielded cables are discussed here, and a very simple model is presented. Experimental results will also be shown in the full presentation.

Keywords- shielded cables; shield grounding; E1 HEMP

I. BACKGROUND

Sometimes E1 HEMP is a concern but high frequency effects are not fully appreciated. For example, sometimes open-ended shields are used for substation yard cables, as represented in Fig. 1. One reason for this is to avoid ground potentials driving high currents along the length of the shield. However, we will show this is bad for E1 HEMP. This issue was demonstrated to us when we tested an assembled shielded serial cable and found essentially no shielding. Opening one connector, we saw it was not grounded – with a ground added the shielding improved greatly. In this paper we only consider a fast pulse (E1).

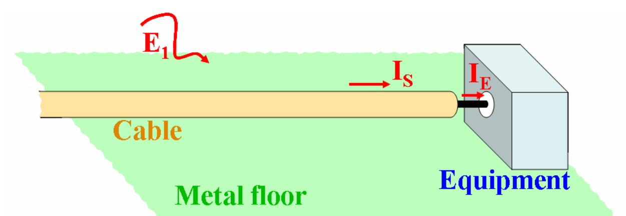

Figure 1. Example of E1 HEMP coupling to an ungrounded shielded cable.

II. MODEL DEVELOPMENT

Our concern is the current on the core wires entering the equipment (I_E in the figure). To start to model this, consider Fig. 2, where the drive is backwards – we drive a current on the unshielded part of the cable and look at the currents that get onto the shield and onto the core wire. Here we have three transmission lines, indicated by the three numbered currents - #2 is a coaxial line, the other two are lines-above-a-ground-plane.

An approximation to this is shown in Fig. 3, where all the transmission lines are made to be coaxial. Here we assume the shield is infinitely thin. In this case the E and B fields associated with the I_3 signal propagate unmodified into the two separate lines on the right. Thus the lines can be drawn as the two-wire transmission lines in Fig. 4, and the lines are governed by:

$$\begin{aligned} I_3 &= I_2 = I_1 \\ Z_3 &= Z_2 + Z_1 \\ V_3 &= V_2 + V_1 \end{aligned} \quad (1)$$

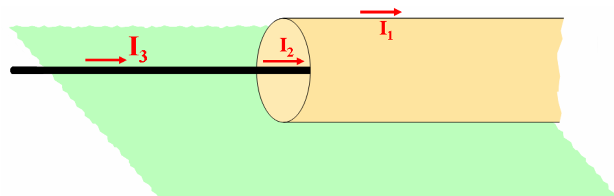

Figure 2. Current (I_3) being driven into an ungrounded shielded cable – resulting in currents I_1 and I_2.

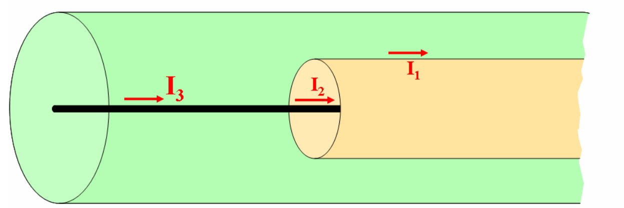

Figure 3. Simpler model of the setup in Fig. 2.

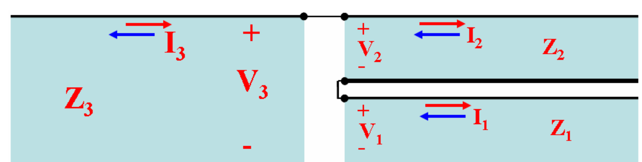

Figure 4. Two-wire transmission line equivalent of the coaxial transmission line setup of Fig. 3. (Ignore the blue arrows until they are discussed.)

III. OPEN-END MODEL

We can then model the case in Fig. 1 by driving I_1 instead, getting the currents shown by blue arrows in Fig. 4. Letting "x" show the separation of Z_3 into Z_1 and Z_2:

$$\begin{aligned} Z_1 &= x\, Z_3 \\ Z_2 &= (1-x)\, Z_3 \end{aligned} \quad (2)$$

we can solve the transmission line problem to get:

$$\begin{aligned} V_3 &= V_1 \\ I_3 &= x\, I_1 \end{aligned} \quad (3)$$

That is, the full voltage on the driven shield is transferred to the core wire, and the fraction "x" of the current transfers. Thus, if tens of dB shielding are desired, then an open-ended shielded cable will not provide it. Test results will also be presented.

REFERENCES

[1] MIL-STD-188-125-1, "Department of Defense Interface Standard, High-Altitude Electromagnetic Pulse (HEMP) Protection for Ground-Based C4I Facilities Performing Critical, Time-Urgent Missions, Part 1, Fixed Facilities", 7 April 2005.