Radiation from Common Mode Currents – Beyond 1GHz

(Three Methods Compared)

By

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ABSTRACT: The measure of common mode current on a cable can be closely correlated to the radiated emissions from that cable. However, in popular texts this is only demonstrated to 200MHz. This Tech Short describes three different methods for calculating radiated emissions and compares them the measured radiated data.

DISCUSSION: Envision this… We were enthralled in taming a wild product. Days have passed without progress, when out of the blue a wise, old engineer whips out a current probe and starts measuring cables. He exclaims, "With enough common mode current, even a cable will radiate!" Ever since, the current probe has been one of the first tools I grab when evaluating a design.

After discovering this wonderful tool, I soon realized that at higher frequencies the standard equation used to link common mode current began to severely over-predict. This Tech Short describes the experiment and conclusions I drew from evaluating three different approaches to correlating common mode current to far-field radiation.

METHOD #1: Standard Approach

From my well worn copy of Noise Reduction Techniques in Electronic Systems, H.W.Ott, the following equation is presented:

$$E := \frac{4\,\pi\,x10^{-7} \cdot f \cdot I \cdot L\,\sin(\theta)}{r}$$

E = volts/meter, **r** = measurement distance (m) , **L** = cable length (m), **I** = current in A, and **f** in Hertz, $\theta = \pi/2$.

This approach has the power of simplicity. It can easily be calculated on a piece of scratch paper. This equation has been demonstrated effective up to 200MHz in Introduction to Electromagnetic Compatibility, C. Paul, pg. 424.

METHOD #2: Balanis – Thin Wire Dipole

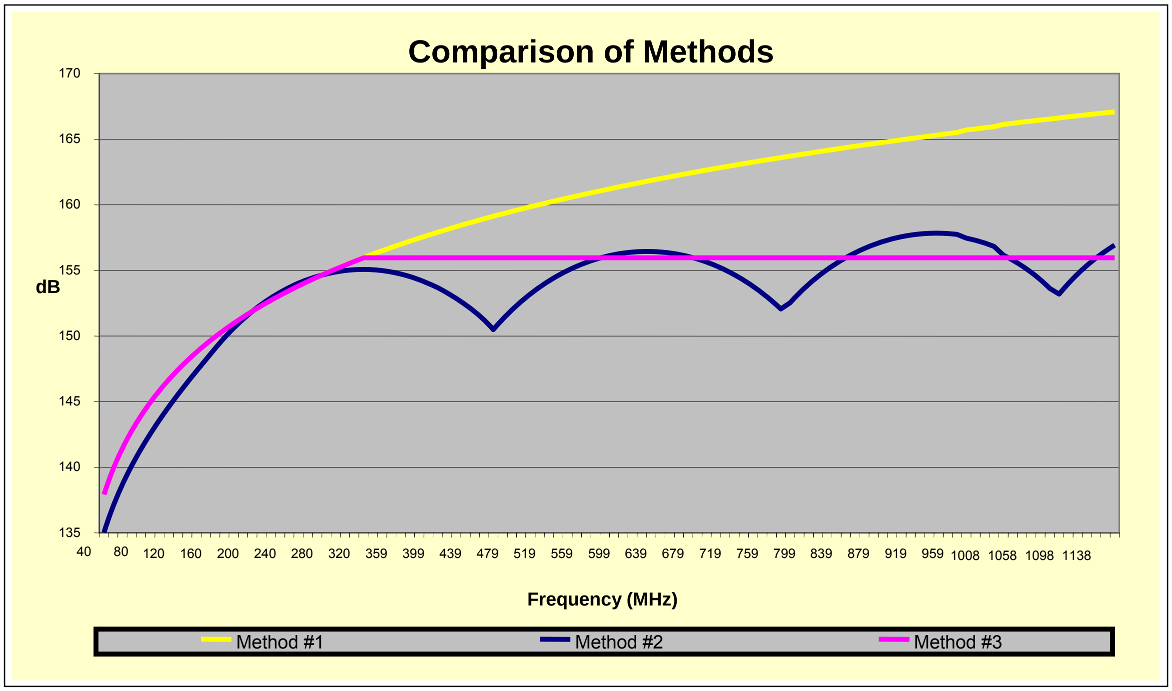
The standard equation from method #1 is derived from an equation presented in a wonderful book on antenna theory by Constantine Balanis, Antenna Theory-Analysis and Design.

$$E_{\theta} := j\eta \cdot \frac{Ioe^{-jkr}}{2\,\pi\,\,r} \cdot \frac{\left(\cos\left(\frac{kl}{2} \cdot \cos(\theta)\right) - \cos\left(\frac{kl}{2}\right)\right)}{\sin(\theta)}$$

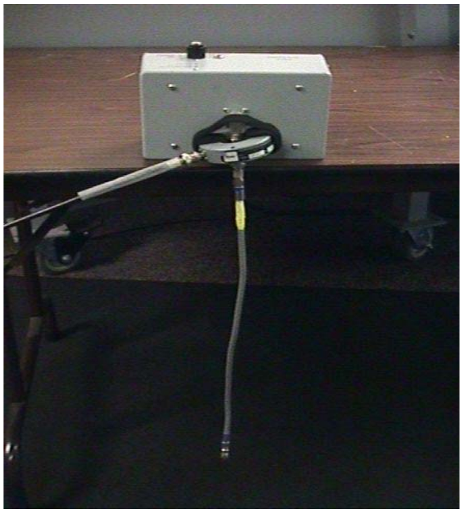
This equation in a bit unwieldy to use, but has the benefit of avoiding approximations. In order to implement this, I needed to hand enter several factors based on the length of cable. These factors include, the effect of the ground-plane, and the angle where the maximum emission would be found.

METHOD#3: The Plateau

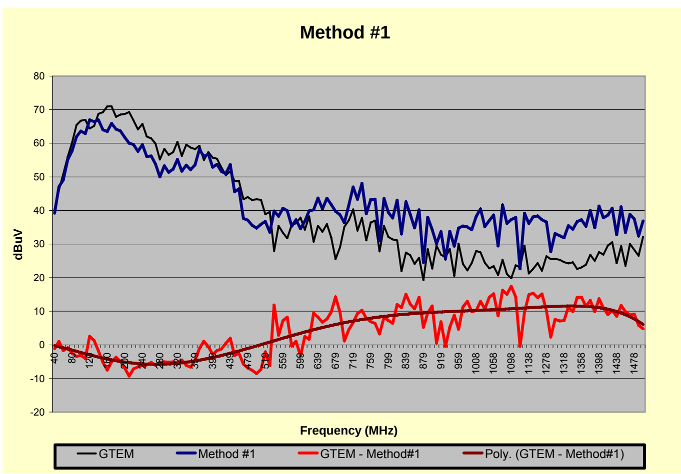
The standard equation is used in this approach up to the frequency when the cable is $\lambda/2$ long. Then the correction factor is maintained at the $\lambda/2$ value throughout the frequency range of concern.



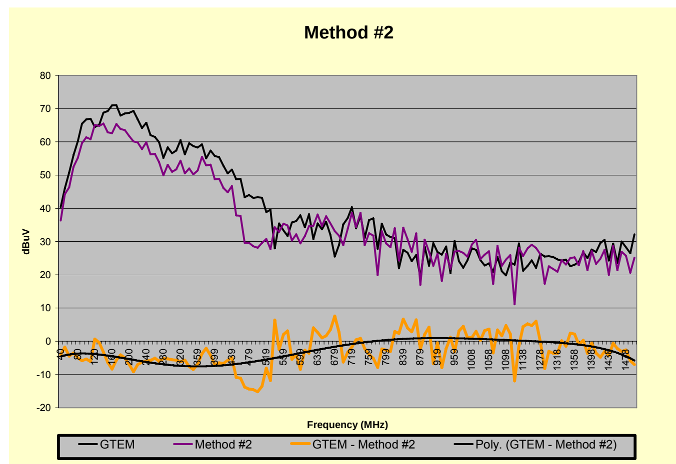
TEST METHOD:
A 47cm length of coax cable, with a split shield, was attached to a Royce field site source, and measured with a current probe. The split in the shield makes the coax into a very nice antenna. In pre-compliance testing, the current probe is swept up and down the cable to find the maximum current, but since such a large number of frequencies were measured that approach was not practical for this experiment. In this case, 5 different positions along the cable were chosen to measure the current. The radiated emissions data was taken in an EMCO 5704 GTEM! Test chamber.



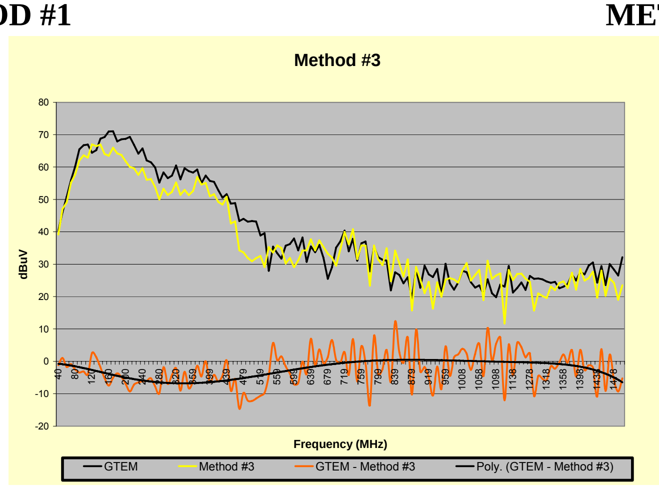
RESULTS:



METHOD #1



METHOD #2



METHOD #3

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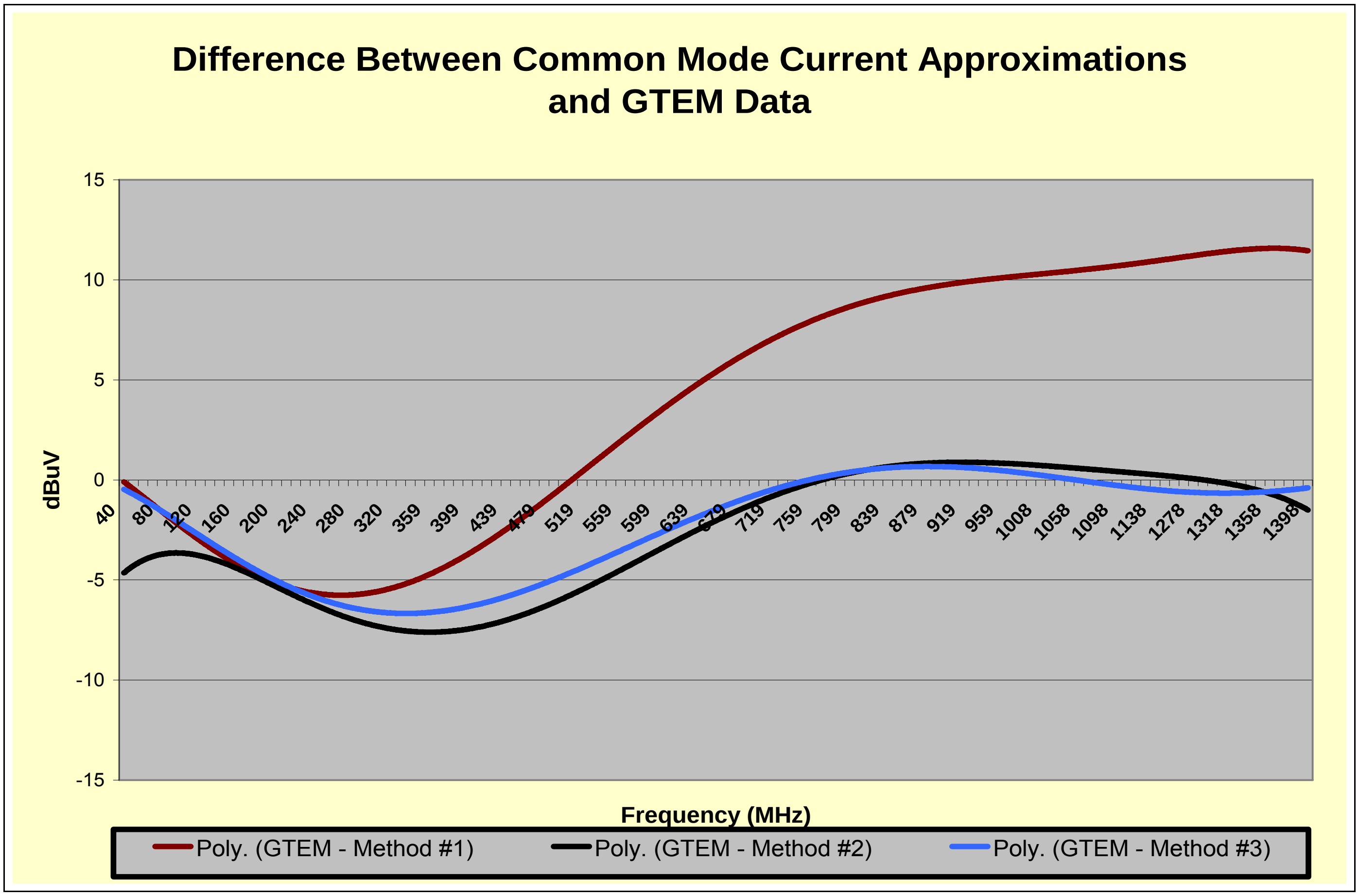

Approaches #1 and #3 are by far easier to implement than approach #2. All three approaches show an under approximation around 200MHz, but I believe this is a GTEM artifact. The coax cable was larger than the recommended GTEM measurement volume.

CONCLUSION:
Predictions from common mode current measurements can reasonably reflect radiated emissions. Method #1 is accurate to a half-wave length of the cable being measured, after which the prediction start to significantly over-predict. Method #2 is accurate for several wavelengths, but very cumbersome. Any accuracy that may be gained is swamped by the difficulty of use, and the variation of setup. (We don't measure perfect dipoles very often.) Method #3 proved to be the best approach. It is as simple as the first method, with comparable accuracy to Method #2.

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