Coupling Between Lines at High Frequencies

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***Abstract*—A method of calculating the coupling between lines at high frequencies is described. The method involves a small modification in previously presented equations which were limited to frequencies typically below 200 kHz. Experimental data are presented which show the modified equations are accurate well into the megahertz frequency range.**

A METHOD of calculating the coupling between shielded and unshielded lines over a ground plane has been presented previously.[1] For braided cables, the analysis was accurate for frequencies below about 200 kHz. Experimental verification is given here which shows that the formulas given in a previous paper[1] may be extended to at least 65 MHz if the cable's shield resistance R_s is replaced by the cable's transfer resistance R_t in the formulas.

The key factor in determining coupling to or from a shielded line was shown to be the leakage current in the shield-ground plane loop.[1] Measurements have recently been made of this leakage current at high frequencies, and the results compared with the predictions based on transfer resistance rather than shield resistance.

Figure 1 is a schematic diagram of the experimental setup to determine leakage current of a cable over a ground plane. The current probe measures the net current through it, that is, the current in the center conductor minus the return current in the shield. The probe, therefore, effectively measures the leakage current through the ground plane. Figure 2 shows the measured and predicted data. The equation used in the prediction is (see Mohr,[1] eq. (16), with R_s replaced by R_t)

$$i_\ell = i_1 \frac{1}{1 + jw \dfrac{L_s}{R_t}} \tag{1}$$

where L_s is obtained from the earlier work;[1] R_t, for RG-58C/U and RG-223/U, is obtained from Fig. 3. The curves

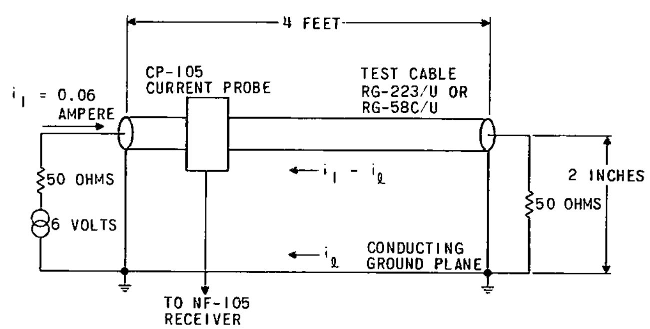

Fig. 1. Experimental determination of leakage current.

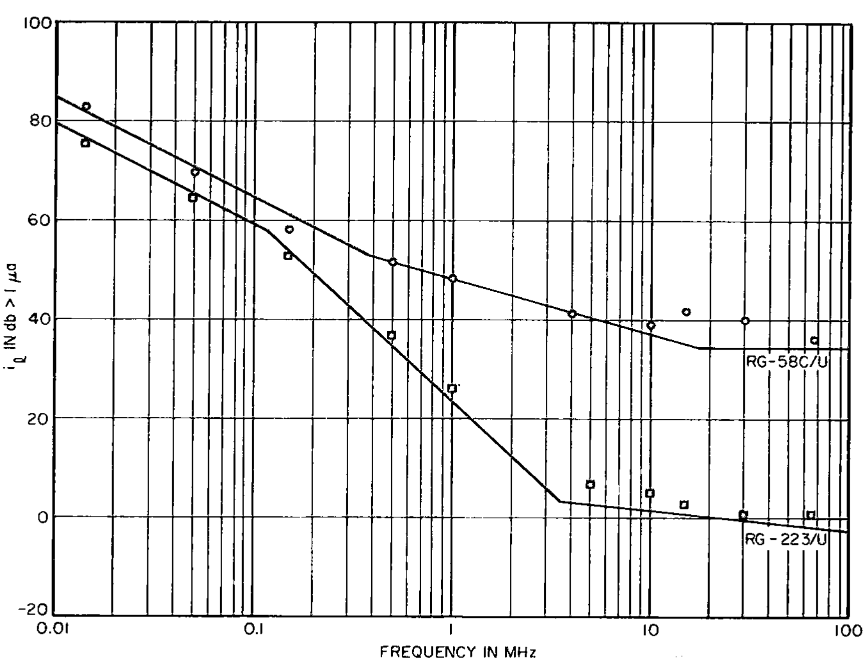

Fig. 2. Leakage current of cable over a ground plan—comparison of theory with experiment.

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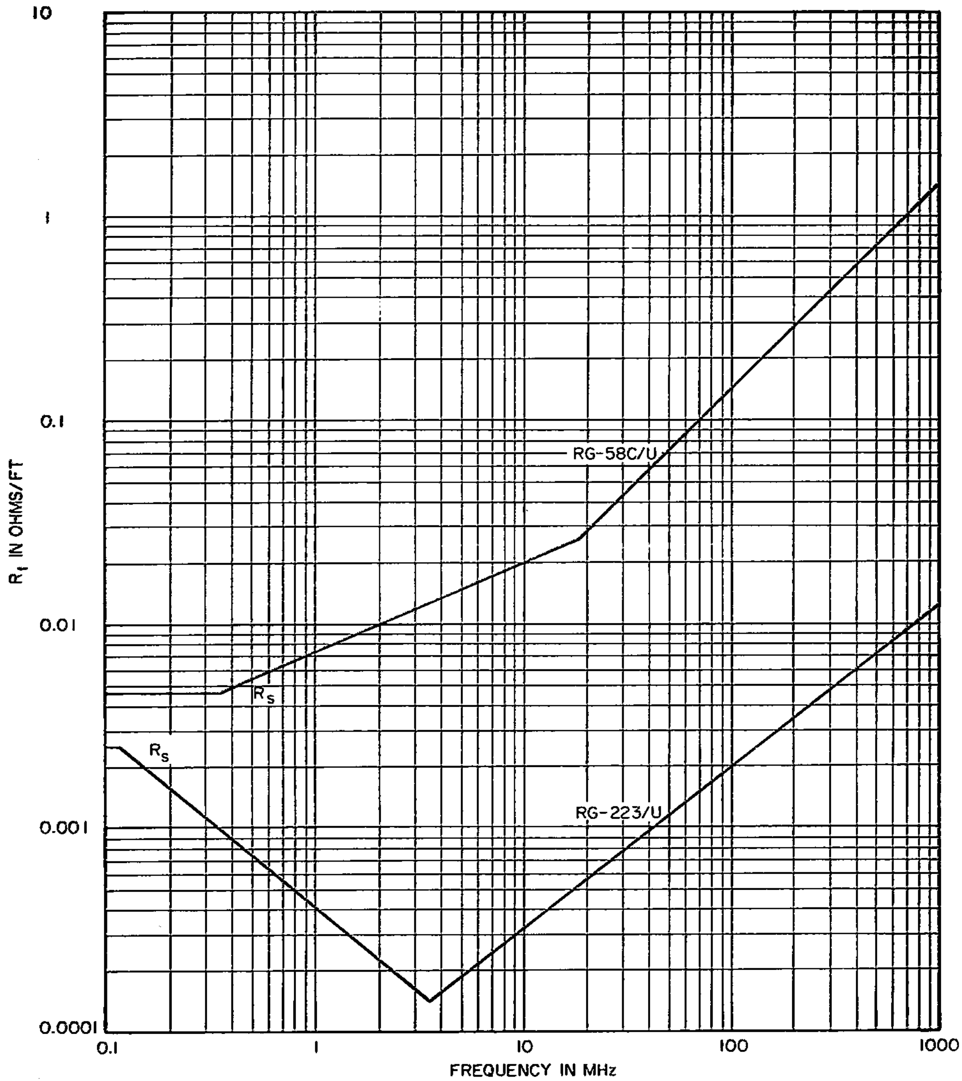

Fig. 3. Transfer impedance vs. frequency.

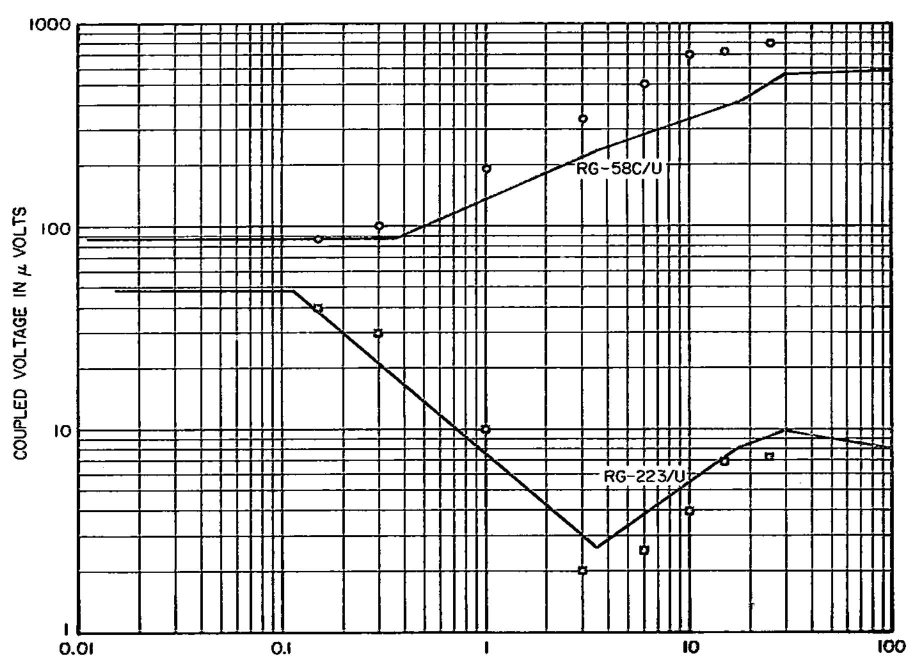

Fig. 4. Coupled interference, open-wire line to shielded-wire line—comparison of theory with experiment.

in Fig. 3 are derived from data given elsewhere.[1],[2] It is seen that, at low frequencies, R_t is equal to R_s.

The experimental data out to 65 MHz in Fig. 2 are seen to be generally within 6 dB of the predicted values. The coupling formulations in a previous paper[1] (based on magnetic coupling due to current in the shield-ground plane loop) should, therefore, be accurate out to at least 65 MHz. This was verified out to 25 MHz, with available experimental data, for the case of coupling from an open-wire line to shielded lines as described in the following.

Figure 4 shows a comparison of predicted and measured coupling from an open-wire line to shielded lines. The data were taken on the configuration depicted in Fig. 5. The equation used in the prediction was (from eq. (28), Mohr[1])

$$e_d = 2\pi f M i_1 \frac{R_d}{R_c + R_d} \alpha_{S2} \alpha_{C2} \tag{2}$$

where α_{S2} is a function of fL_{S2}/R_{t2}, and α_{C2} is a function of $fL_{C2}/(R_c + R_d)$.

The current i_1 in the interfering line was not measured directly; it was determined from the known open-circuit voltage of the generator and the impedance of the interfering circuit (including source and load resistances) and inductive reactance of the no. 20 AWG wire.

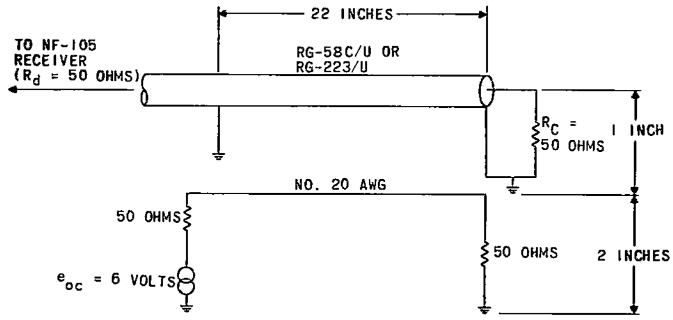

Fig. 5. Experimental determination of coupled signal—open-wire line to shielded-wire line.

It is concluded that the prediction techniques given before[1] may be extended well into the megacycle frequency range if the transfer impedance of the cables is used in place of the shield resistance in the formulations. It is expected that this correction will be accurate at still higher frequencies provided the line lengths involved are much shorter than one-half wavelength.

References

[1] R. J. Mohr, "Coupling between open and shielded wire lines over a ground plane," *IEEE Trans. Electromagnetic Compatibility*, vol. EMC-9, pp. 34–45, September 1967.

[2] "Electromagnetic shielding principles," Rensselaer Polytechnic Institute, Troy, N. Y., under A. F. Contract AF 30 (602)-401 March 1, 1956.

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