5-22-79
M. Gerel

4.2.2 Radiated Susceptibility

4.2.2.1 Magnetic Induction - RS02 (100V Standard Pulse)

4.2.2.1.1 Case Susceptibility

The magnetic flux at the center of a rectangular loop can be found from reference *, page 133, equation 11, which reduces to:

$$B = \frac{2\mu_o\sqrt{a^2 + b^2}}{\pi\, ab}\, I$$

a, b = sides of the rectangular loop in meters

μ_o = permeability of free space = $4\pi \times 10^{-7}$ Henry/meter

I = Current in loop in Amps

The average width and height of the LRU's are 14 inches and 7 inches respectively, or .36 and .18 meters. Hence,

$$B = \frac{2\,(4\pi \times 10^{-7})\sqrt{(.36)^2 + (.18)^2}}{\pi\,(.36)\,(.18)}\, I = (4.96 \times 10^{-6})\, I \ \frac{\text{webers}}{\text{meter}^2}$$

*Weber: Electromagnetic Theory, Static Fields and Their Mapping, Dover, 1965.

Considering a circuit, inside an LRU, with a wire run of one foot, and a wire-to-wire separation of 1/8 inch, the loop area presented to the flux would be:

$$A = (12)\ (1/8) = 1.5\ \text{in}^2 = 9.7 \times 10^{-4}\ \text{meter}^2$$

Then the voltage induced in this circuit by the flux would be:

$$V = A\frac{dB}{dt} = (9.7 \times 10^{-4})\ (4.96 \times 10^{-6})\ \frac{dI}{dt} = (48.12 \times 10^{-10})\ \frac{dI}{dt}\ \text{Volt}$$

A. <u>400 Hz Induction</u>

For 400 Hz:

$$\frac{dI}{dt} = \omega I_o$$

$$= (800\pi)\ (20)$$

$$= 5.03 \times 10^4\ \text{Amps/second}$$

Therefore, the voltage induced would be:

$$V = (48.12 \times 10^{-10})\ (5.03 \times 10^4)$$

$$= 242 \times 10^{-6}\ \text{volt}$$

$$= 242\ \text{microvolts}$$

without shielding. Electric field coupling is negligible in this case.

B. <u>Spike Induction</u>

For the spike:

$$\frac{dI}{dt} = \frac{\Delta I}{\Delta t} = \frac{56}{1.9 \times 10^{-6}} = 30 \times 10^6\ \text{Amps/second}$$

[56 Amps and 1.9 us were measured]

Therefore, the magnetically induced voltage would be:

$$V = (48.12 \times 10^{-10})\ (30 \times 10^6)$$

$$= 144 \times 10^{-3}\ \text{volt}$$

$$= 144\ \text{millivolts}$$

without shielding. This will be reduced by 20 to 40 dB by box shielding. Electric field coupling will be negligible due to this shielding.

Neither the 400 Hz nor the spike induced voltage level will cause interference to any circuit, through case induction.

4.2.2.1.2 Cable Susceptibility

The magnetic field generated by an infinite wire is:

$$H = \frac{I}{2\pi r}$$

I = Current in wire

r = Distance from wire

For a wire 1.5 meters long,this equation is a good approximation for the field close to the wire.

If the cable against which the wire is placed is 1.5 meters long, and 0.41 inches in diameter, and a typical circuit in the cable consists of a wire and return separated by 0.33 inches (maximum possible separation taking into account insulation thicknesses), then the voltage induced in the circuit is:

$$V = A\frac{dB}{dt} = \mu_o A\frac{dH}{dt} = \frac{\mu_o A}{2\pi r}\frac{dI}{dt}$$

$$= \frac{(4\pi \times 10^{-7})(1.5 \times 0.33)}{2\pi\left(\frac{0.41}{2}\right)}\frac{dI}{dt}$$

$$= (4.83 \times 10^{-7})\frac{dI}{dt}\ \text{Volt}$$

where the field at the center of the cable is taken to be the average field cutting the circuit.

A. 400 Hz Induction

As in the case of paragraph 4.3.2.1.1-A:

$$V = (4.83 \times 10^{-7})(5.03 \times 10^{4})$$

$$= 24.3 \times 10^{-3}\ \text{volt}$$

$$= 24.3\ \text{millivolts}$$

without shielding. Electric field coupling is negligible in this case.

B. Spike Induction

As in the case of paragraph 4.2.2.1.1-B:

$$\frac{dI}{dt} = \frac{\Delta I}{\Delta t} = \frac{44}{2 \times 10^{-6}} = 22 \times 10^{6}$$

44 Amps and 2 us were measured

$$V = (4.83 \times 10^{-7})(22 \times 10^{6})$$
$$= 10.6 \text{ volts}$$

The voltages found above are for the case of induction into a pair of parallel wires. But, the wires inside the cable will be twisted with a minimum of four twists per foot. The maximum uncancelled area presented to the field will be reduced by

$20 \log (2n + 1)$ where n = total # of 360^{o} twists in the coupling length

$20 \log (2 \times 4 \times 5 + 1) = 32$ dB

less than that calculated. Furthermore, the overall shield on the cable will attenuate the high frequency components of the magnetic field spike, thereby slowing its rise time. The rise time will at least double, in which case, the induction is further diminished by 6 dB.

C. Summary of Cable Induced

Then the induced voltages will be:

400 Hz:

24.3 mV - 32 dB = 0.59 mV

Spike

10.6V - 38 dB = 0.13V

Neither of these induced voltages would cause interference to the circuits.

B. <u>Spike Induction</u>

As in the case of paragraph 4.3.2.1.1-B:

$$\frac{dI}{dt} = \frac{\Delta I}{\Delta t} = \frac{44}{2 \times 10^{-6}} = 22 \times 10^{6}$$

[44 Amps and 2 us were measured]

$$V = (4.83 \times 10^{-7})(22 \times 10^{6})$$

$$= 10.6 \text{ volts}$$

The voltages found above are for the case of induction into a pair of parallel wires. But, the wires inside the cable will be twisted with a minimum of four twists per foot. The maximum uncancelled area presented to the field will be reduced by

$20 \log (2n + 1)$ where n = total # of 360° twists in the coupling length

$20 \log (2 \times 4 \times 5 + 1) = 32$ dB

less than that calculated. Furthermore, the overall shield on the cable will attenuate the high frequency components of the magnetic field spike, thereby slowing its rise time. The rise time will at least double, in which case, the induction is further diminished by 6 dB.

C. <u>Summary of Cable Induced</u>

Then the induced voltages will be:

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<u>Spike</u>

10.6V - 38 dB = 0.13V

Neither of these induced voltages would cause interference to the circuits.

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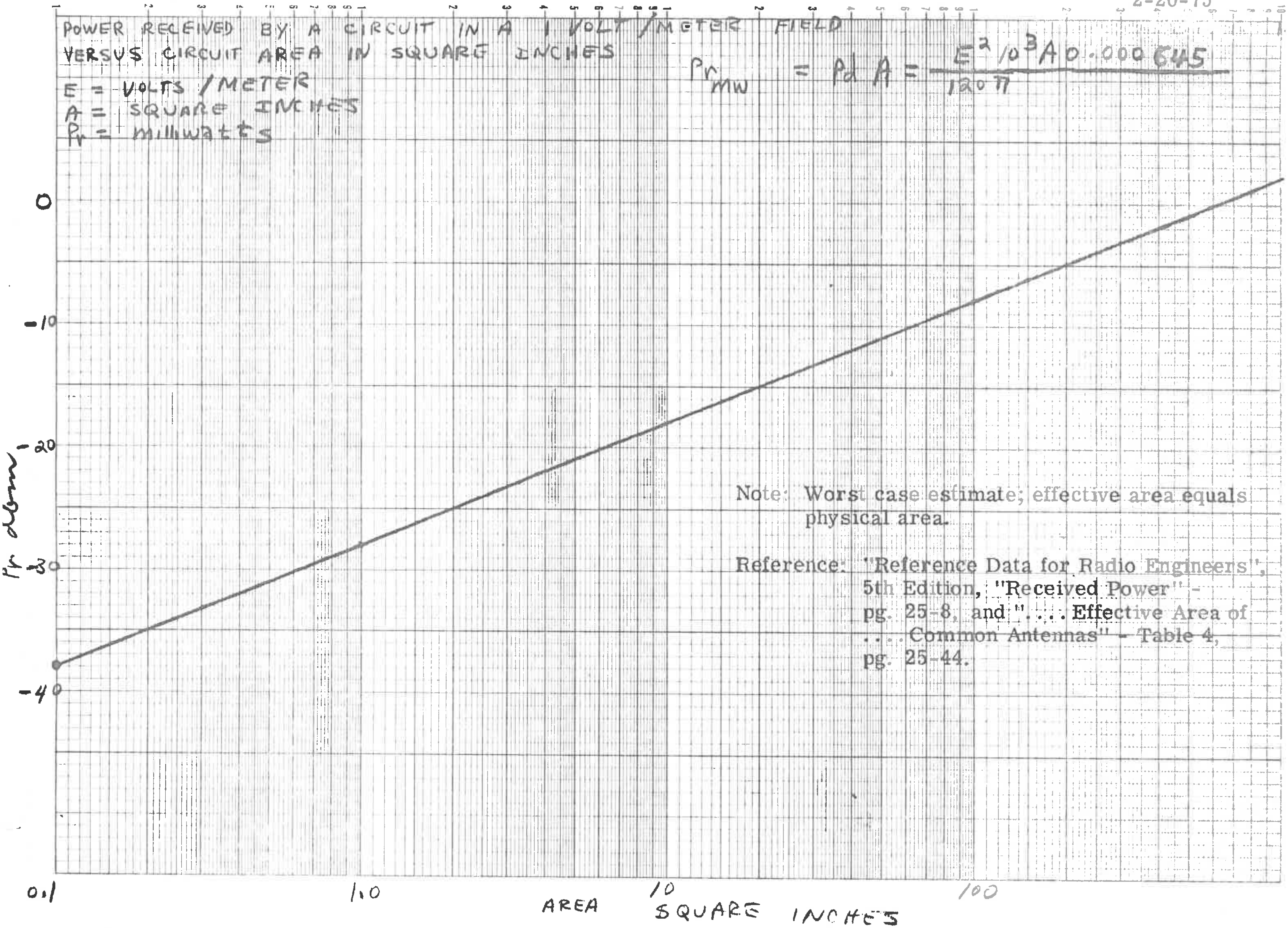

ULTRA HIGH FREQUENCY RADIATED SUSCEPTIBILITY
RS-03

Where, l, the length of the conductor in the susceptible circuit is > 1/8 λ use a long wire resonant antenna as a model. The figure on the next page gives the radiation resistance and the gain with respect to a half-wave dipole of such an antenna. For lengths between 1/8 λ and 1/2 λ use the characteristics given for 1/2 λ.

The following relationships apply:

$$P_r = 31.2 \frac{G_1}{f^2} E^2$$

and

$$e_i = 11.2 \frac{\sqrt{G_1 R_r}}{(f)} E$$

where

G_1 = gain of antenna with respect to a half-wave dipole

f = frequency in MHz

P_r = received power in watts (delivered by a matched antenna to a matched load)

E = field intensity in volts per meter

R_r = radiation resistance in ohms (consider this to be the source impedance)

e_i = induced voltage (open circuit voltage)

The equations were derived from the relations given on pages 25-7 and 25-8 of "Reference Data for Radio Engineers," Fifth Edition, Howard W. Sams & Company, Incorporated, 1968.

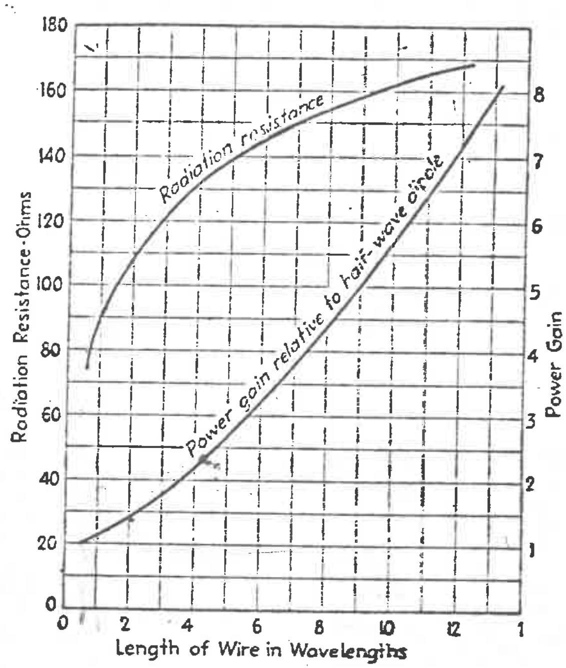

FIG. 21.—Radiation resistance and power gain of an isolated resonant antenna.

Source: F. E. Terman, "Radio Engineers' Handbook," New York, McGraw-Hill Book Company, Inc., 1943, Page 790.

MEMO TO:	E. W. Karpen	FILE:	PDSD-EMC-1548
FROM:	R. J. Mohr	DATE:	22 May 1973
SUBJECT:	Radiated Susceptibility Prediction		
ATTACHMENT:	Radiated Susceptibility of Braided Cable and Connectors.		
REFERENCE:	Times Wire and Cable Company, Cat. No. TL-2, Figure 15.		

Some recent EMC requirements have been stated in terms of the maximum permissible power pickup in a specified radiated field. This is a fairly difficult requirement to model. However, data collected to date can serve as a yardstick to gauge future such requirements. The data is believed to be representative primarily of the cable and connectors and not the units under test, which were well shielded.

The attachment outlines approximately the worst case data as a function of frequency. The ordinate, is the dB difference between the incident field (dBuV/m) and the pickup measured in a 50 ohm receiver (dBuV).

Several comments on the test conditions can aid judgement in applying the data.

1. The data was taken on project 5509-76.

2. Units tested were:

   - A 6-port channel separation filter having four (4) OSM, and two (2) type N connectors.
   - A 4-port filter box - all type N connectors.

3. The units under test were irradiated with known levels of incident fields, inside a shielded room. Power at each connector was measured with all other connectors terminated.

4. The connector output was carried to the 50 ohm receiver, located outside the shielded room, via a 70 inch long RG 9/U cable which had an extra 7/8" braid over the cable jacket.

In applying the attached curves, it should be assumed (till better information is available) that the curve labeled "Type N" represents the cable leakage, while the curve labeled "OSM" represents OSM connector leakage. Where a RG 9/U cable (without an extra braid) is used, the leakage should be increased. The decrease in shielding should be estimated to be at least 10 dB (Reference 1).

As more data becomes available, the curves should be updated.

R. J. Mohr

RJM/lmd

cc: W. C. Brown

Radiated Susceptibility of Braided Cable and Connectors