Chapter 18: Cable Shielding and Crosstalk

18.1 A strong, 60 Hz, magnetic noise source is present near the following transmission lines: untwisted pair inside a steel tube, untwisted pair, untwisted pair inside a copper tube, twisted pair, twisted pair inside a steel tube, *untwisted pair inside a grounded steel tube*, and untwisted pair inside a grounded aluminum tube. Rank these lines in terms of their likely susceptibility to this noise.

18.2 Explain why and when it is difficult to maintain a ground for aluminum structures over a long period of time. Is this also true for copper?

18.3 Explain how a triaxial cable (an inner conductor surrounded by two outer shields) should be connected to a grounded source and floating load for the smallest possible susceptibility to low-frequency noise. Explain the reason behind all of the connections.

18.4 Twisted pair connects a specific source/load combination. Both the source and load are grounded (referenced to ground). How susceptible is this system to strong 60 Hz magnetic fields and 60 kHz magnetic fields? Explain.

18.5 A shielded cable consists of two power conductors and two shielded twisted pair. Should the shielding on the twisted pair be connected together? Should the shielding of the twisted pair be connected to the shield of the overall cable?

18.6 The chassis of a high-frequency transmitter is grounded, yet its chassis is still not at ground potential. Explain. How can this situation be corrected?

18.7 A wiring harness is moved near a cast iron engine block. Will the mutual inductive coupling between the wires in the harness increase, decrease, or remain the same? Explain. Repeat for an aluminum engine block.

18.8S Using a cable catalog, determine the break frequencies of several different types of cables.

18.9S Why and when are twisted shielded pairs used for digital signals and twisted shielded triples used for analog signals in aircraft?

18.10 A grounded camera is several hundred feet from a grounded chassis containing an amplifier, a filter, and a monitor. When a standard coaxial cable is used as the interconnect, the monitor is quite noisy. Propose a method of reducing this noise.

18.11 A three-prong, ac powered, oscilloscope is connected to a noisy circuit. Suddenly, the noise problem disappears. Explain how this could possibly occur.

18.12 An electrically-long floating conductor near a ground plane is exposed to an external, time-varying electromagnetic field. The floating conductor is supported by a very good insulator sitting on the ground. There are no connections between the floating conductor and the ground or other objects. Even though the two ends of the conductor are open circuited, current induced by the external field is still present along the length of the conductor. (However, the current is zero at both ends.) How can this be, and what is the return path(s) for the current?

18.13C Determine the actual break frequency for the transfer function

$$Z_t \approx R_{DC} \frac{(1+j)\frac{\Delta}{\delta}}{\sinh\left[(1+j)\frac{\Delta}{\delta}\right]} \quad \text{where } R_{DC} = \frac{1}{2\pi a \sigma \Delta},\ \delta = \frac{1}{\sqrt{\pi f \mu \sigma}}$$

Compare this result with the transition frequency provided in this chapter.

18.14E An electroexplosive device (EED) is under a high-voltage power line. The maximum electric field is 9 kV/m and the maximum magnetic field is 14 A/m. If the resistance of the EED is 1 Ω, determine the worst case current through it due to the electric field and due to the magnetic field. For one EED, the no-fire current is 50 mA. Can the power line ignite this device? State all assumptions.

18.15C Using the inductance expressions provided in the *Inductance, Magnetic Coupling, and Transformers* chapter, determine an analogous 3-W guideline for a three-conductor system consisting of two circular conductors inside a circular shield. Assume that the radii of the two inner conductors are the same and the two, circular inner conductors are symmetrically placed about the axis of the outer shield.

18.16C Two 20 mil width traces, 10 cm in length, are 30 mils above a large return plane. The center-to-center spacing between the traces is 60 mils. Plot the total crosstalk, in dB, for both the source and load resistances of the victim circuit versus frequency from 1 kHz to 100 MHz. Also, for each of the following cases, determine whether the crosstalk in mainly capacitive or inductive (or about equally both) at the source and load of the victim circuit. The resistances of the generator and victim circuits are

a) $R_s = 1\ \Omega,\ R_L = 10\ \Omega,\ R_{sv} = 1\ \Omega,\ R_{Lv} = 10\ \Omega$
b) $R_s = 1\ \Omega,\ R_L = 100\ \text{k}\Omega,\ R_{sv} = 1\ \Omega,\ R_{Lv} = 10\ \Omega$
c) $R_s = 100\ \text{k}\Omega,\ R_L = 1\ \Omega,\ R_{sv} = 1\ \Omega,\ R_{Lv} = 10\ \Omega$
d) $R_s = 1\ \Omega,\ R_L = 10\ \Omega,\ R_{sv} = 1\ \Omega,\ R_{Lv} = 100\ \text{k}\Omega$
e) $R_s = 1\ \Omega,\ R_L = 100\ \text{k}\Omega,\ R_{sv} = 1\ \Omega,\ R_{Lv} = 100\ \text{k}\Omega$

18.17C Two 20 mil width traces, 10 cm in length, are 30 mils above a large return plane. For a frequency of 100 MHz, plot the total crosstalk, in dB, for both the source and load resistances of the victim circuit versus the center-to-center spacing. Allow the center-to-center spacing to vary from 60 mils to 200 mils. The resistances of the generator and victim circuit are

a) $R_s = 1\ \Omega,\ R_L = 10\ \Omega,\ R_{sv} = 1\ \Omega,\ R_{Lv} = 10\ \Omega$
b) $R_s = 1\ \Omega,\ R_L = 100\ \text{k}\Omega,\ R_{sv} = 1\ \Omega,\ R_{Lv} = 10\ \Omega$
c) $R_s = 100\ \text{k}\Omega,\ R_L = 1\ \Omega,\ R_{sv} = 1\ \Omega,\ R_{Lv} = 10\ \Omega$
d) $R_s = 1\ \Omega,\ R_L = 10\ \Omega,\ R_{sv} = 1\ \Omega,\ R_{Lv} = 100\ \text{k}\Omega$
e) $R_s = 1\ \Omega,\ R_L = 100\ \text{k}\Omega,\ R_{sv} = 1\ \Omega,\ R_{Lv} = 100\ \text{k}\Omega$

18.18C Derive the expression for the mutual inductance between the loops generated by conductors 1-2 and conductors 3-4 for the configuration shown in Figure 1 starting from

$$M = 2\times10^{-7} l_{th} \ln\left(\frac{d_{14}d_{23}}{d_{13}d_{24}}\right) \quad \text{if } l_{th} >> \max\left(d_{12}, d_{23}, d_{13}, d_{24}\right)$$

where the d_{xy}'s represent the distance between conductor x and y. (The loop generated by conductors 1-2 could be representing an embedded set of traces in a multilayer board.) Then, plot this mutual inductance versus the separation distance, s, as s varies from 40 mils to 250 mils. Let d = 15 mils and $2h$ = 60 mils.

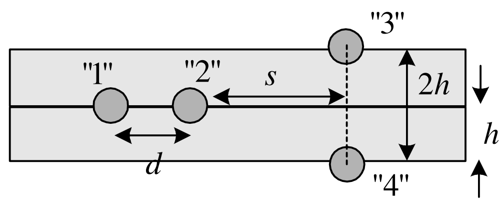

Figure 1

18.19 Sometimes it is stated that the input of an op-amp, which has a very high impedance, is more susceptible to capacitive coupling, than the output of an op-amp, which has a low impedance. Determine whether these statements are reasonable.

18.20 A high-impedance (10 kΩ) microphone is connected to an amplifier via an unshielded twisted-pair line. The 60 Hz power line is interfering with the system. Is the coupling mainly capacitive, inductive, or both? Repeat for a low-impedance 100 Ω microphone.

18.21 Determine a typical rate of current change with respect to time for a TTL gate driving a 25 pF capacitor in parallel with a 45 Ω load. Under what conditions is the resistive component of the current change more important than the capacitive component?

18.22 The current changes suddenly in the source circuit. If the noise level in the victim circuit also suddenly changes, is the coupling likely electric or magnetic? If the noise level in the victim circuit remains constant, is the coupling likely electric or magnetic? Explain.

18.23 Given the approximate expression for the maximum magnetic field in dB from a twisted pair

$$B_{max,dB} = -54.5\frac{r}{p} + 20\log_{10}(a) - 30\log_{10}(p) - 10\log_{10}(r) - 102.1 + 20\log(I)$$

show that decreasing the loop radius, a, or the pitch, p, reduces the magnetic field emissions.

18.24 The primaries of two separate relays are energized by the same source. The hot side of the primary of each relay is brought back to the hot side of the source. These lines are twisted. The ground side of the primary of each relay is brought back to the reference of the source. These lines are also twisted. How susceptible to noisy magnetic fields is this system? How would you improve upon this system?