TECHNICAL ARTICLE

GROUNDING PROBLEMS

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Low-level circuits are often interconnected using shielded cables, mainly for protection against externally induced noise. Aside from the effectiveness of the shield designs themselves, even more important is the integrity of the connection to ground. A poor ground may be worse than none at all.

THE SIGNAL RETURN PATH

Used as a signal return path, typical in coaxial cables, the shield serves a secondary purpose of screening the center conductor from external fields. This dual role can exist in non-coaxial cables as well.

The resistance of a braided shield is typically much lower than that of other conductors. This may be desirable in the return circuit, but it is especially important in presenting a low impedance against external induction. For this reason, terminations must be carefully made or the shield will be useless as a noise barrier. In fact, since the shield is a straight "wire" and its area much larger than the conductor(s) inside, a massive imbalance of induced current can occur, causing noise. An unshielded twisted pair would likely be more immune to noise.

SIMPLE SHIELDING

As a pure barrier to EMI, a grounded shield acts as a conductive channel for the conductor(s) within. "Anchored" at ground potential, which prevents it from floating wherever the magnetic or electrical environment may lead it, the shield serves not so much as a means of walling off noise as to simply divide an offending electric field and send part of it into the ground.

It is important to know that no shield can protect against magnetic fields as effectively as mere physical space between the noise source and the affected conductors. As little as 0.5 inches can reduce magnetic coupling by more than 30 dB, improving to about 70 dB with a 4-inch separation. This is probably the best remedy for noise originating in high-current wiring.

GROUND LOOPS

Ground loops cause a lot more noise than warranted, considering how easy it is to eliminate them with thoughtful installation. Ground loop noise is easy to picture: every conductor, including the airframe itself, has some resistance, and any current passing through it produces a voltage drop between its source and its load. See Figure 1.

The ground loop problem develops where more than one circuit share the same return conductor, often a shield intended to be the ground, so the voltage drop from one current path simply shows up in another, adding "someone else's noise" to an otherwise clean signal.

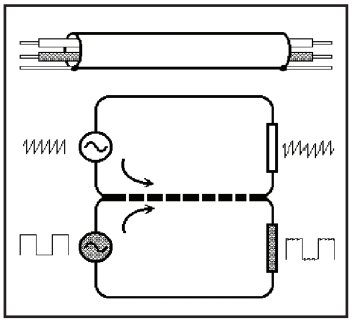

Figure 1. Ground Loops. The influence of one signal on another as a result of using a common conductor (shown as dashed line). Similar signal corruption can result from any current induced in any circuit – even stray fields, which can be especially troublesome and audible in 400 Hz aircraft power systems.

Further, where several systems are "daisy-chained" to ground, any one of them can act as a weak link and reflect its current fluctuations as noise through them all. Common grounds are best run in a star configuration.

FRAME GROUND

The return path should never be a frame ground. While it may be metal and able to conduct, is not intended to be an active conductor. The ideal return for any circuit should be exclusive to that circuit, though it is not uncommon to share return paths where the current of every signal is very low.

Nevertheless, good practice suggests no more than five signal conductors per ground. Using a frame for a signal return or current-carrying "lo" is poor economy and an open invitation to problems. Best to reserve the frame for its structural role; however, connecting it to battery ground at one point will achieve the effect of a universal electrostatic shield for the entire aircraft.

An improved all-around approach to using a ground is to use it only as a ground, confining signals and power lines to dedicated conductors. A balanced, shielded twisted-pair audio line would be an example.

GROUNDING PROBLEMS

WILL THE REAL GROUND PLEASE IDENTIFY ITSELF?
Is there more than one "real" ground? Yes.

1. For a signal path the "real" ground is the system ground, the true destination for the return signal. No other reference point is as good. Good practice for connecting a protection-only shield calls for terminating it at system ground. This keeps it from floating with "alien" signal sources and becoming a source of noise to the very circuit it is intended to protect. It might be likened to an extension of the system housing itself.

2. What ground do you use between systems? Fact is, they may necessarily share the ground, as in the case of a signal between them via coaxial cable. If this is so, meticulous ground termination procedures are required at each end. Otherwise, a poor connection may cause serious noise almost anywhere, and continuity of the return path may be important. Ideally, signal returns should be isolated from ground and any shields terminated at one end only. See Figure 2. In some cases, the insulated outer shield of triax and quadrax offer the shielding and the isolation desired. This permits the establishment of inner shielding as signal ground and return path, if necessary.

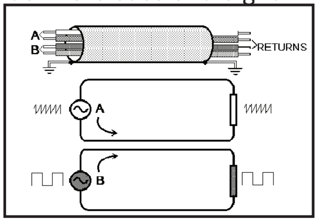

Figure 2. Separate return paths prevent the direct influence of one signal on another. This does not rule out coupling between conductors but eliminates the "free ride" of extraneous signals by way of a ground loop.

3. The "universal" ground, the airframe, is the shell housing all other systems. But it is only the shell and is best in its strictly passive role to all other systems, such as the avionics box which deserves its own recognition. This is true also of every other system on board. Each one, from engine starters to cabin entertainment systems to TCAS, will perform more effectively and with less interference using its own ground path.

The value of the "universal" shield is questionable in aircraft with composite-material construction, which leads to other concerns about the effects of HIRF-High Intensity Radiated Fields.

TWISTED PAIRS

Not the name of a rock group.

Shielding is at its best in blocking electrostatic noise fields, and is helpful in shunting some electromagnetic interference, but not near as effective in eliminating EMI as twisting pairs of signal conductors. This has been a popular noise-killer from the early days of telephones.

Every conductor residing in a changing magnetic field acts like the secondary of a transformer – producing some current replicating the waveform of the "primary," or source of the field. (Changes in the field may be due to AC or any varying current in the field source conductor(s) or even physical motion of a DC conductor, such as vibration.) In fact, transformers are designed to take advantage of this fact.

Allowing that every circuit is a circuit (a two-way path for the movement of electrons, or the signal), current will flow in both wires: the pair. External fields happily induce some current in these conductors, caring not at all whether this will pollute the signal in the circuit.

Untwisted pairs invariably position one conductor closer to the field source, and while they may receive nearly the same induction (thus having a "balanced" noise in both), it is never actually quite the same. As a result, there will always be at least some undesirable differential current induced.

By twisting the signal pair, the conductors alternate in nearness to the noise field over each twist cycle, effectively canceling the effect of the polluting field. In effect, while the noise is present in both wires, the twist helps assure it will be equal in each wire, and the result is near-perfect balancing.