Shields and Grounding

BACKGROUND: There is always discussion on how to ground a shield. The answer lies in what the worst-case noise situation is. It isn't always the same answer. Do you leave one end open or ground both ends? If you ground only one end, which end?

We can look at how the interference behaves to answer these questions and they follow understood electrical properties within swept frequency regions.

BODY: The first step is to understand what a shield is doing, and how. In the simplest terms, a shield creates two separate "electrical" environments, one on each side of the shield. One side is measured as a RATIO of the field's intensity relative to the other side, in dB.

The shields we are working with are ONLY effective with an EM wave that is predominantly "E" field in nature versus "B" field, or magnetic. Magnetic fields are not shielded or blocked with conductive shields, but need a shield material that blocks magnetic flux lines or a low permeability material…think "material a magnet will stick to." Those kinds of material allow magnetic flux lines an easier path than through air. We can capture and re-route the flux lines in low permeability materials. For this discussion, we will look at mostly electric field shields, stuff that conducts electricity.

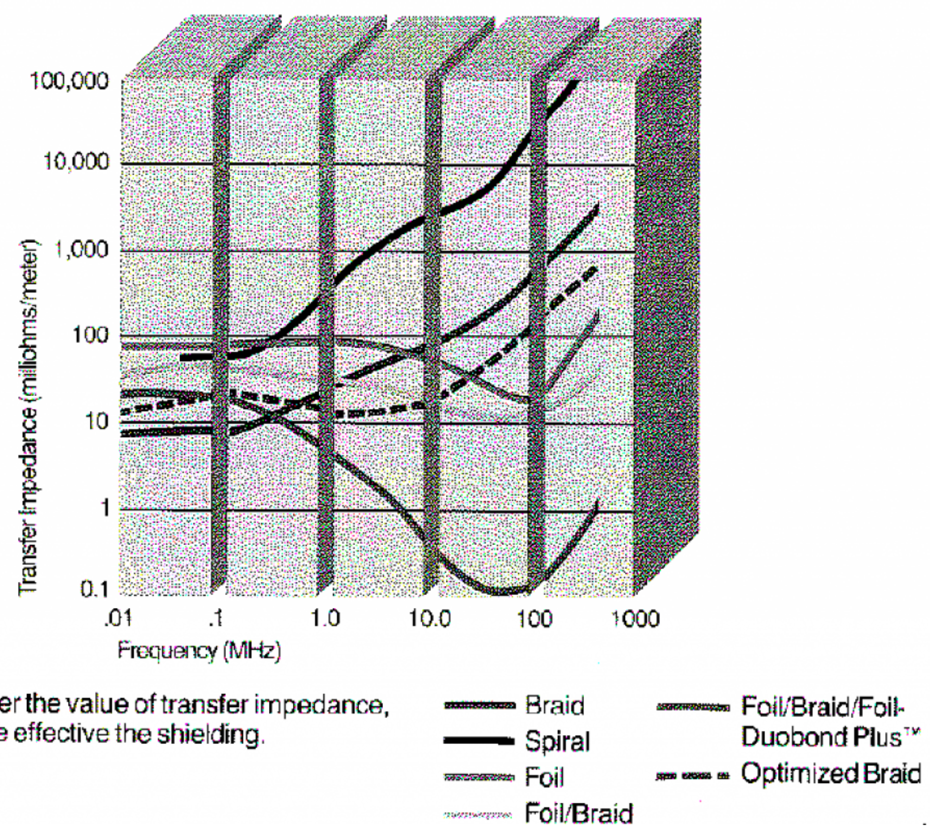
What is an ideal electrical shield? It is a shield that 100% blocks electrical energy at the surface of the shield, and that has infinitely low resistance. Shields don't have infinitely low resistance and they block electrical energy at differing impedance based on the skin depth of the shield at a specific frequency.

We can measure the effectiveness of a shield across frequency with a transfer impedance plot. This is measured in milli-ohm/meter. It describes the resistance we can expect a shield to have, and thus the ratio of the fields energy in the shield based on the CURRENT the resistance causes to flow at that frequency…and it is not linear.

The graph below shows the frequency-dependent nature of a shield. A perfect shield would have NO RESISTANCE and both ends would be identical and thus seem like a SINGLE point of reference to a flow of current. Since we have zero resistance across the shield, we can't have current flow caused by the shields. We CAN have current flow between the two points connected at the ends of the shield. In a "perfect" world the GROUND at both ends is the same potential and thus, an ideal shield has ZERO current flow, and is a measure of the POTENTIAL on one side of the shield relative to the other, in dB.

Since we don't have a perfect world, Transfer Impedance describes what to expect at frequencies based on the shield's impedance, and how that shield resistance creates a CURRENT flow and thus a voltage (shield resistance times the shield's impedance = a voltage). When we have different resistances at each end of a shield we have current flow.

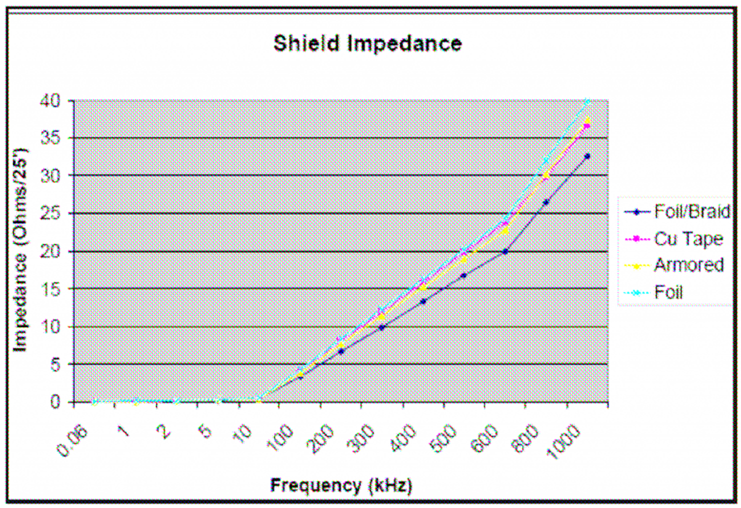
Graph #2 – Transfer Impedance Test Results



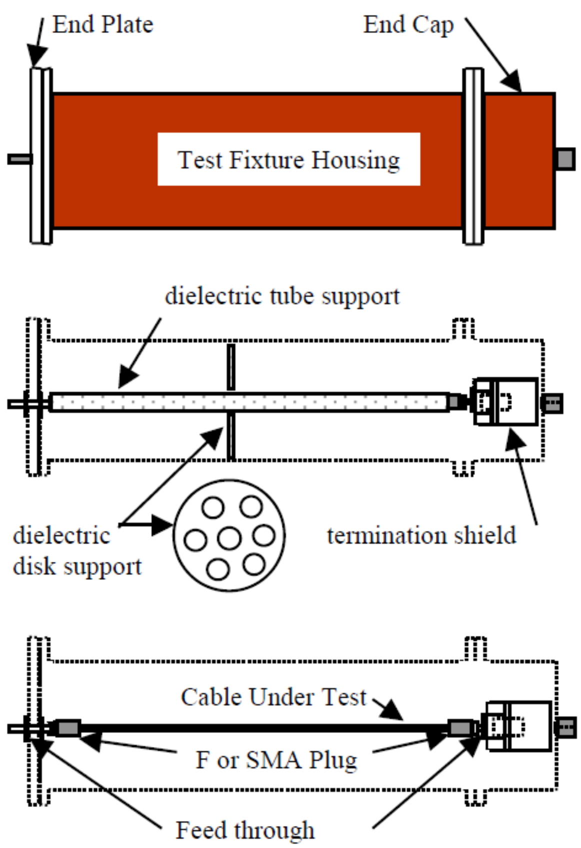
The lower the value of transfer impedance, the more effective the shielding.

Shield Type	**5 MHz**	**10MHz**	**50MHz**	**100MHz**	**500MHz**
Bonded Foil +60% braid	20	15	11	20	50
Tri-Shield+60%Braid	3	2	0.8	2	12
Quad Shield 60% +40% Braid	2	0.8	0.2	0.2	10
Tri-Shield+80% Braid	1	0.6	0.1	0.2	2
Bonded Foil +95% Braid	1	0.5	0.08	0.09	1

The chart below is what JUST the shield impedance looks like for a set length of cable at lower frequencies. We see the same non-linear behavior of shield and frequencies.



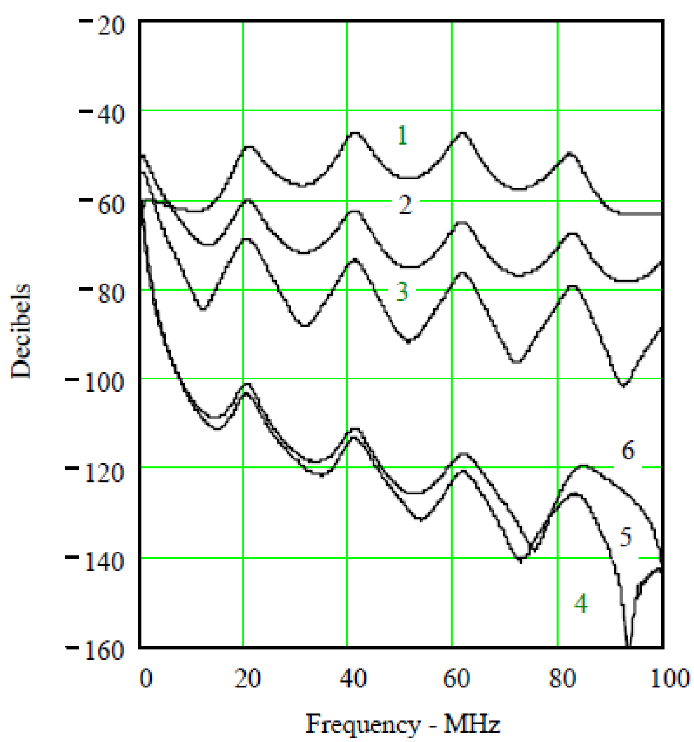
A SEED (Shield Effectiveness Evaluation Device per IEC 61196-1) test shows the dB relationship to a Lower Shield Impedance. Series number 5 with a 95% coverage 45-degree braid and Duofoil tape is clearly superior.



	Layer Thickness (mm)			
Foil Type	Al Foil	Polyester	Al Foil	Width (mm)
a	.00889	.02286	.00889	19.05
b	.0254	.02286		25.4

Table 3.
Test Sample Construction

#	Foil (inner)	Braid / Angle	Foil	Braid/Angle (outer)
1		95% b. c. /23°		
2	a	40% Al /38°		
3	a	60% Al 27°		
4	a	80% Al /27°	b	
5	a	95% Al /42°	b	
6	a	60% Al /27°	a	40% Al /20°
7		95% t. c. /23°		
8		95% Ag-Cu /28°		95% Ag-Cu /40°
9	.0122mm polyester/ .0178 mm Cu	92.5% t. c. Tin Dipped 64°		



Okay, we can see a shield is not perfect, and not linear. So how does this say what to do with each end of a shield? We have to weigh the CHOICE of HOW the shield WORKS to decide our fate.

–If you have ideal grounds and meet IEEE bus bar grounding (see the 568C.2 or later grounding specifications) limits it means BOTH ends can be grounded and the shield current will inductively couple less interference than the shield ATTENUATES through its material composition.

–If we have severe ground differential, we can induce a strong current in the shield that CAN, if the shield's resistance is higher, induce noise into the core that is WORSE than if we disconnect one end. We convert our shield to an antenna, not a shield!

– An antenna does NOT create two separate environments between them with the ratio of one measured to the other. One end of the antenna is infinite impedance (the open end) with the other end at ground. The antenna "wire" is as close to zero impedance as possible in order to NOT attenuate the antenna's signal going to ground. The signal won't go to the open end, but seeks the lowest potential in the circuit.

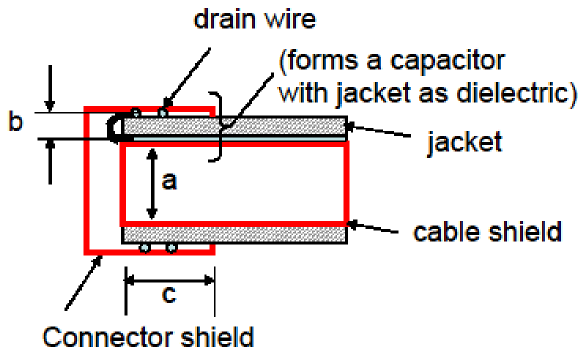
We trade the noise caused by a poor ground resistance potential between shield ends for the induced noise in an antenna's wire parallel to the signal wires that induces a voltage based on the antenna resistance. In an antenna type ground, it is best to ground the SEND end, as the SIGNAL on the internal wires is as LARGE as possible relative to the antenna signal, improving the signal to noise between the two.

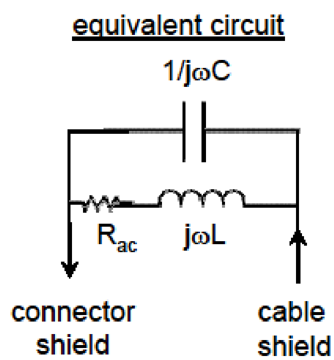
An often-ignored aspect of shields is HOW to ground one at lower frequency versus RF. There is a big difference and again, it is based on the shield characteristics at each frequency.

The charts below are derived from TWO slightly differing MODELS of RF shield inductive reactance resistance. I have this paper for those interested. But, the data is the same message in that as frequencies increase, the shield reactance goes UP. This necessitates a FULL 360 ground at the shield termination point in RF circuits. This is why good RF connectors are fully capturing the shield all the way around the cable. On your RF digital cables, use 360 degree grounds for the best true shielding.

RF RESISTANCE WITH RESPECT TO FREQUENCY – METHOD 1

FOLDED FOIL F/UTP WITH FOIL CONTACT



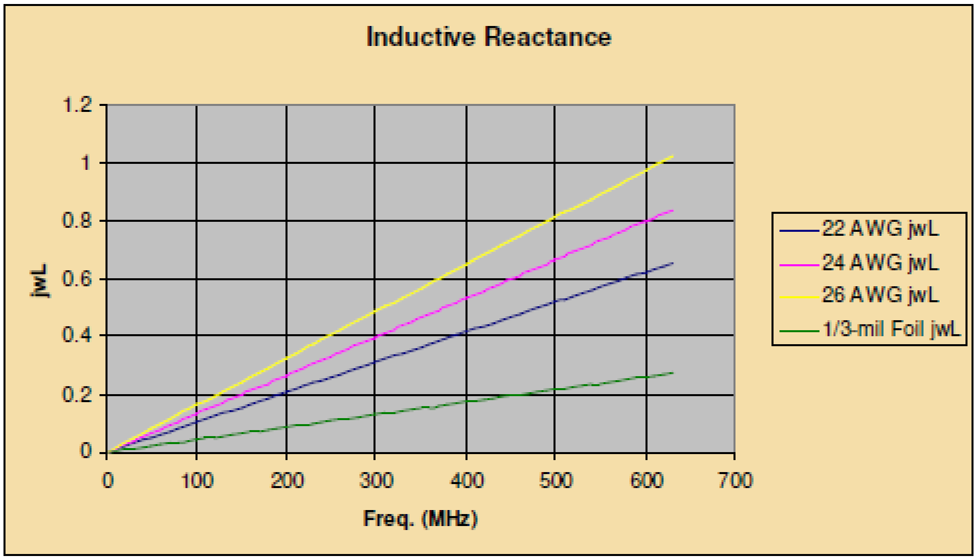


at high frequencies

$R_{ac} << j\omega L$

P. Kish
Belden
28Jan11

RF RESISTANCE WITH RESPECT TO FREQUENCY – METHOD 2



SUMMARY – Most systems will have proper GROUND differentials between them and thus have near ZERO shield current. The shield relative to the signal wires will ATTENUATE outside interference. When you have poor grounds, it may be beneficial to unhook the "receiver" end of the shield and hope that the induced antenna current voltage is less severe than the induced voltage caused by differential shield ground potentials. This should be a SECOND choice, not the first. A properly working shield, by design, has a KNOWN shield dB rating that can be trusted in a proper electrical circuit.

An antenna ground's induced voltage onto the cable is not fully described and is dependent on the GROUND proximity point and shield's distance from the signal wires. In severe situations, it may be the best choice to mitigate noise to the lowest possible reference value as it is pretty hard to REMOVE a shield already on a cable. Some, such as coaxial cables, can't be mitigated and need to be properly designed to EXCEED the ground differential by several orders of magnitude so as not to aggravate any ground differential.

ICONOCLAST will use double ground interconnect shields and proper DCR RCA grounds. Power cables should also use grounds at BOTH ends if you have a proper GROUND plane resistance such that ZERO current flows and thus you have ZERO induced voltage from differential current. An antenna type ground CREATES a differential in each end of the "antenna" by design (one end is ideally infinity the other is ideally zero) and is thus a second choice if you have known ground issues.

One last note, those heavy 10 AWG power or more cables, may provide benefit as they induce less ground differential resistance than smaller power cords as the ground wires are larger. The circuit may not need the power delivery of a larger cable, but the lower ground resistance values may be of benefit on longer runs in marginal power grid situations. This will improve a shield's current to nearer zero across frequencies. The dB isolation numbers values are for a proper shielded system with IEEE and TIA compliant shield differentials.

The Transfer Impedance numbers are between two-reference point probes on a shield, and DO NOT need the ground potential differences for characterizations.