

Examination of JSSG 360 ("John Swenson Shield Ground") Effectiveness to Shield Magnetically Induced Common Mode Noise

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Introduction

The John Swenson Shield Ground is a method of using a floating shield around a signal or data cable where an additional wire, running alongside the shield, is connected to the shield ends. The claim is that this connection will improve the shielding effectiveness of the floating shield. It is known that an unconnected shield does not do anything useful, it will actually increase capacitive coupling and will not help to shield magnetic coupling. For effective magnetic shielding, both ends must be connected with a very low impedance path [1] which usually also is the "ground" potential of the system. JSSG claims to greatly increase the shielding effectiveness by using a simple parallel "loop wire" which replaces the normally used low impedance ground.

To quote John Swenson (chief engineer at UptoneAudio, <https://uptoneaudio.com/>), taken from <https://audiophilestyle.com/forums/topic/31554-diy-dc-power-cables/page/9/?tab=comments#comment-659092> (important sections highlighted) :

OK here it is: cable shielding, how to make it work and how almost all cables have it wrong.

The first important question is, what is electrical shielding and how does it really work?

Lets look at the infamous "Faraday cage". For this discussion it is a metal box, with all sides well electrically connected (no gaps). Shielding means that electrical fields outside cannot be sensed inside. Conversely electrical fields inside cannot be sensed outside.

So how does this work? When an electric field from the outside world impinges on the box it causes the electrons in the metal to move, this rearrangement of the electrons creates an electric field inside the metal which exactly counteracts the external field, thus the field is essentially stopped aton the periphery of the box.

The important aspect here is the part "electrons in the metal move". What are moving electrons called? Current. In order for current to flow there has to be a loop. Current will not flow unless there is a loop. In the case of the Faraday cage, the loop is the whole cage. Lets say an electric field impinges on a side of the box, this causes a current flow that goes all the way around the box back to where the field impinges on the box. If the sides are not electrically connected to each other the current cannot flow, thus the electrons cannot move, and the canceling electric field does not get setup, thus no shielding.

It turns out that for AC electric fields it is a little different. Some current can flow due to capacitances between conductors. The electrons can move a little bit one way, then a little bit back. If the frequency is high enough the back and forth movement, which is charging and discharging the capacitance is sufficient for shielding. For a given capacitance the lower the frequency the less effective the shielding. The electrons start moving which charges the capacitance, then stop moving when fully charged, they don't do the full movement necessary to produce the canceling field.

*So what about shielded cables? **I hope is now obvious that for shielding to be effective there needs to be a conductive path from one end of the shield to the other.** If there is not such a path the only shielding that is going to happen is for high frequencies due to capacitances involved with the shield.*

***The best way for the shielding to work properly is a separate wire connected to each end of the shield. This is sufficient for shielding from DC to very high frequencies.** Note the shield does NOT have to be connected an earth ground, the "ground" of the circuit at either end, or any thing else for that matter. A cable with a shield that is not connected to anything else except itself (ie a separate wire from one end to the other of the shield) will be highly effective in shielding what is inside.*

Where does this wire need to go? It can be either inside or outside the shield, but if it is inside it can couple to the signal wires inside, so it is usually best to have it outside the shield. Note it has to be insulated from the shield except for the ends where it connects to the shield. It should intersect as little of the external field as possible so it should NOT be tightly spiraled around the cable. Just running along side the shield is best, although a very loose spiral (say one turn per foot) is almost as good.

So some ramifications of this: The traditional "connect the shield to one end and let the other end float" is not good, it does not allow a loop so shielding does not happen very well. If you add the external wire connected to the shield at both ends, then you CAN connect one or both sides of the shield to the signal ground or some other ground, but you don't NEED to for effective shielding. You will find that in many cases leaving the shield completely disconnected from the rest of the circuit is the best way to go, you get the benefit of properly working shielding without any interaction of the shield with your system. You may wind up with static charges on the shielding so a resistance from the shield to ground may be useful in some cases in order to dissipate static charges.

So how come nobody does this? I don't know. My only guess is that cable shielding has been going on long before the actual mechanism for shielding was worked out, thus by the time it was understood, cable shielding was "standard" and nobody ever even thought about analyzing it based on an understanding of how shielding actually works.

But shouldn't the big companies know about this? It seems they don't. I have read several app notes from Belden that state that shielding is only effective at high frequencies, at audio frequencies and power supply frequencies (60Hz etc) it is totally ineffective.

Audio people are the only ones that seems to at least empirically know about this. Remember phono cartridges and preamps, there is a little green wire that goes from the "ground jack" on the preamp to the tonearm. Everybody assumes that this is to "ground the cartridge" but what it really does is provide a loop from one end of the interconnect shield to the other; it has nothing to do with whether it is "grounded" or not. So if you have (or had) a turntable you were actually taking advantage of this without realizing it.

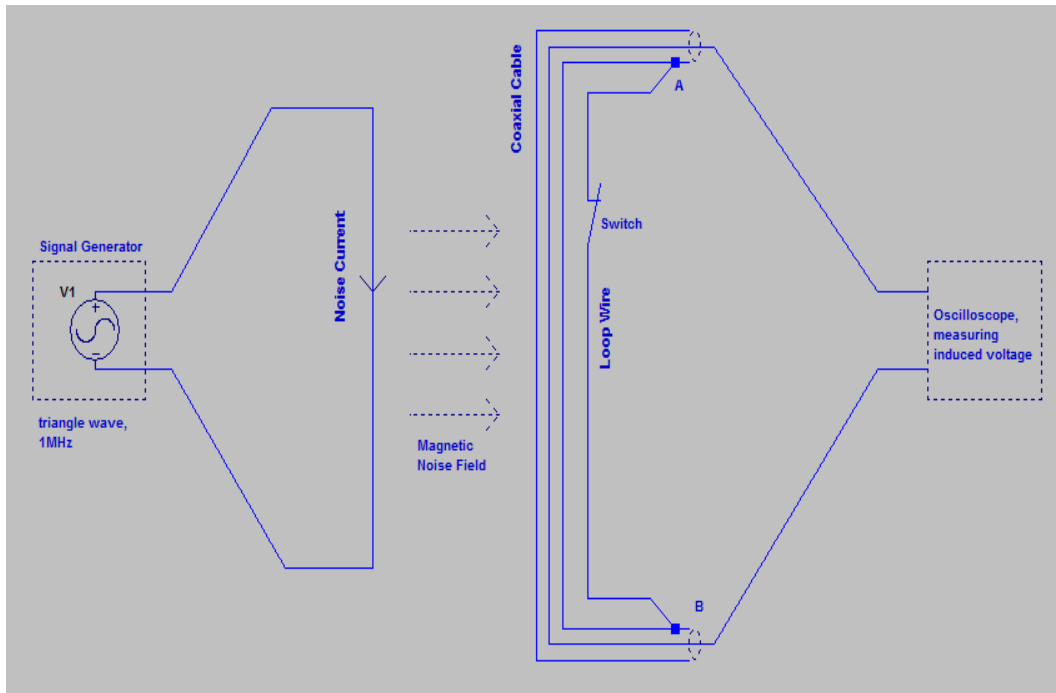
So there you have it, shielding DOES work, but only if you provide a path from one end of the shield to the other. This is effective even if you don't connect the shield to anything else.

John S.

In the context of the well-established knowledge of electronic system design this sounds like... well... dubious at least. A simple thin parallel wire replacing the normally used low-impedance ground connection (with or without any connection to the outside world) with similar or even better results?

Let's see what it is up to in a simple yet conclusive experiment....

Schematic of Test Setup



A signal generator injects a 1MHz**) triangular-shaped current in a wire loop which will emit a magnetic field. The center conductor of a high quality RG58 coaxial cable with low shield resistance and good shield coverage via a braided shield is used as the receiver and the induced voltage is measured with an oscilloscope which is triggered externally by a trigger output of the signal generator. The coaxial cable is placed at some distance (10cm or so) parallel to the injector cable.

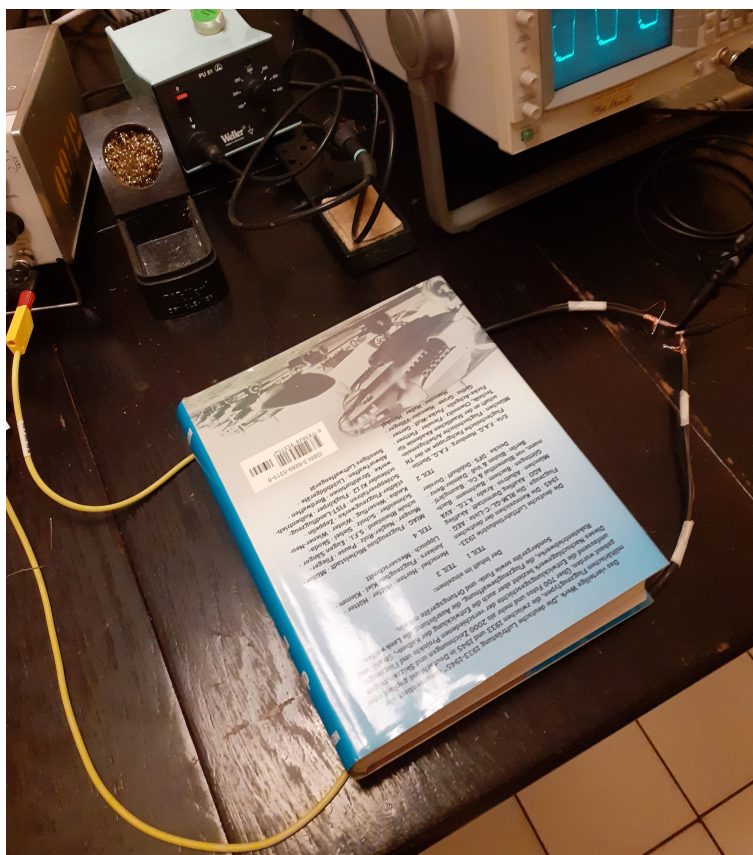
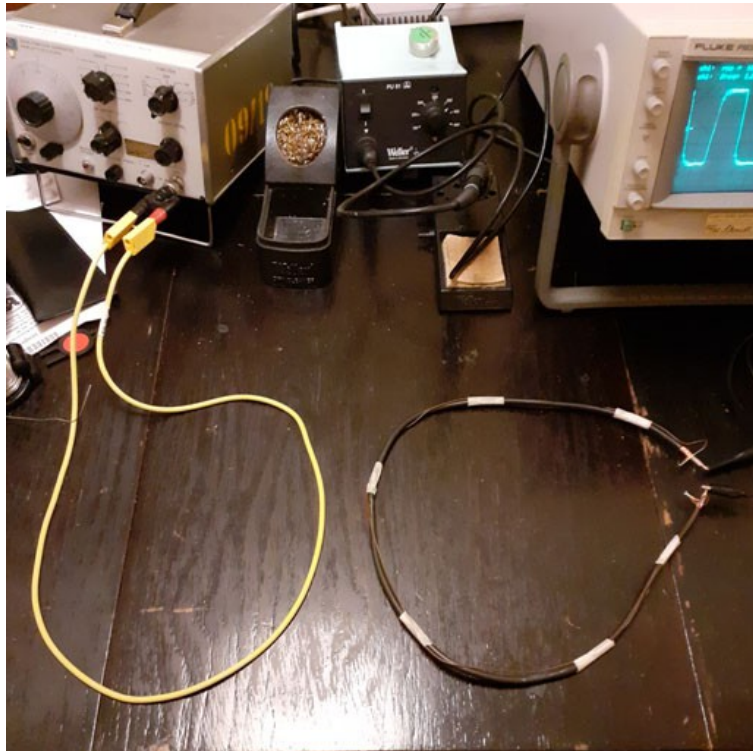
The center conductor represents the signal or data cable to which the JSSG 360 Shielding is applied. Since only the induced common-mode voltage is of interest, this is a valid simplification.

The induced voltage is measured under the following conditions:

- loop wire closed
- loop wire open
- shield ends (A and B) connected with i) a direct short (emulating the normal method of bonding these points to a low impedance common ground plane), ii) a short piece of wire, and iii) a short wire with a clamp-on ferrite, for comparison.

**) Other frequencies as low as 1kHz have been tested as well (according to Swenson's claim that his technique works well at very low frequencies), with exactly the same qualitative results, only the level of the induced voltages reduces proportional to frequency, as physics predict. At 1kHz the voltages were so low (a few microvolts) that an additional x1000 amplifier had to be used to get some display on the scope at all but even with averaging this was still too noisy for a meaningful readout and presentation, therefore a 1MHz test frequency was chosen for simplicity in the presented results.

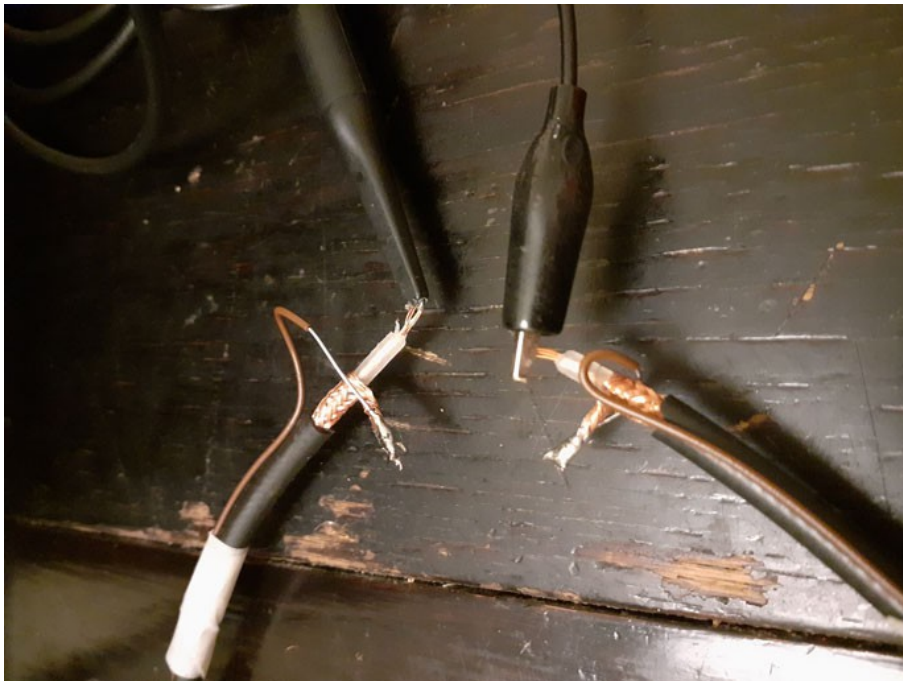
Test Bench



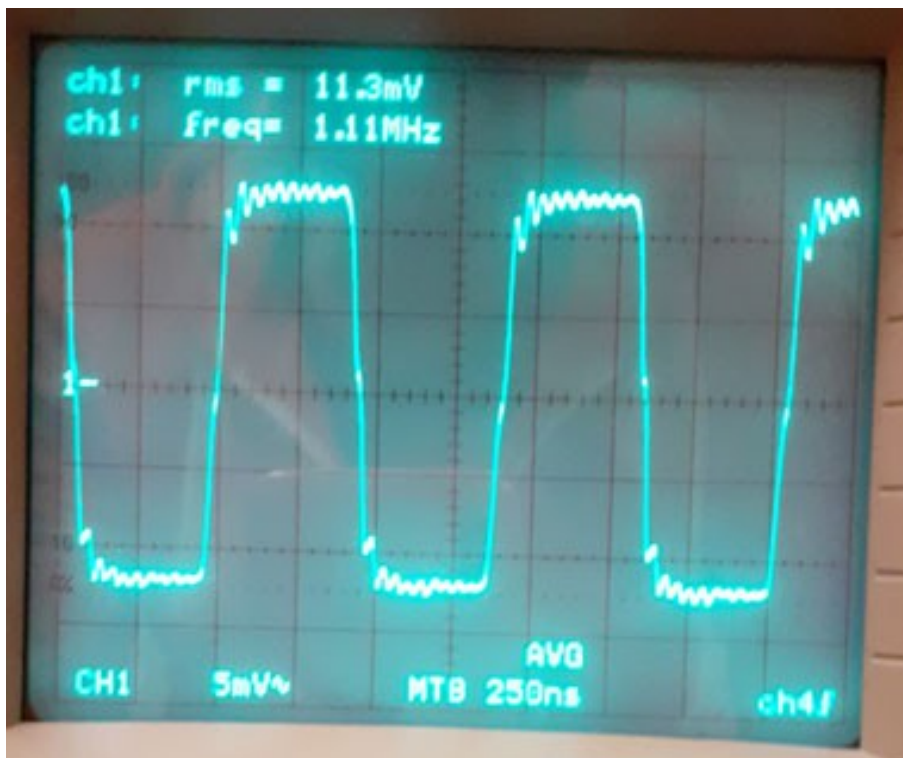
During the test, the cables are fixated with a heavy book because minor changes of cable routing will immediately alter the coupling factor and correspondingly, the induced voltage.

Test #1 : Loop cable connected

Close-up of the loop wire solder connection to the shield and attachment of the scope probe:



Induced voltage with loop wire connected:

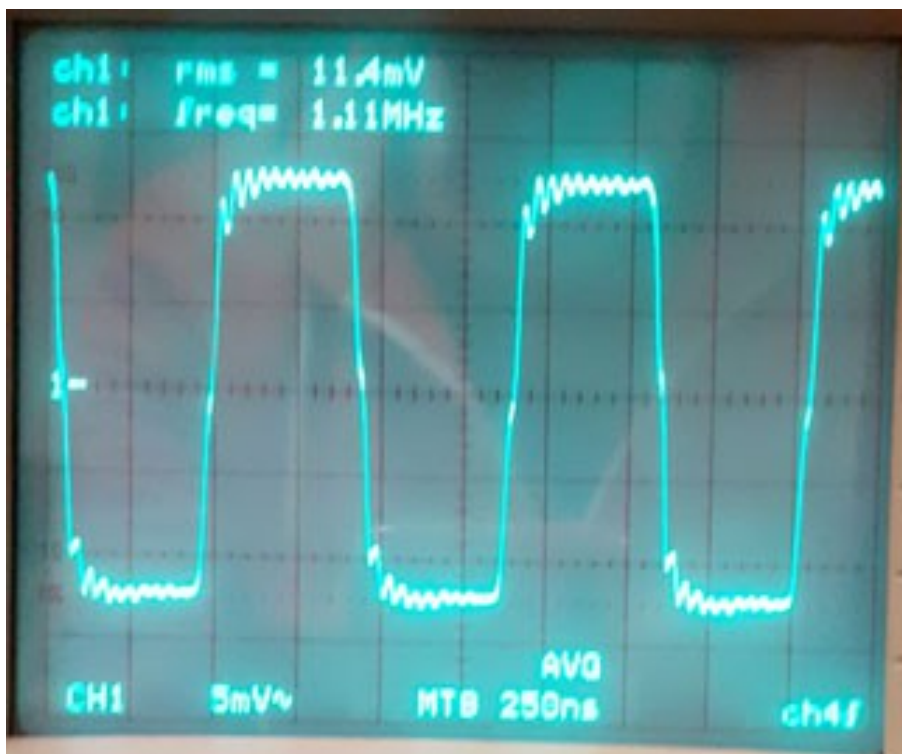


The induced voltage is a square wave (as expected) and the voltage level is 11.3Vrms.

Test #2 : Loop cable not connected

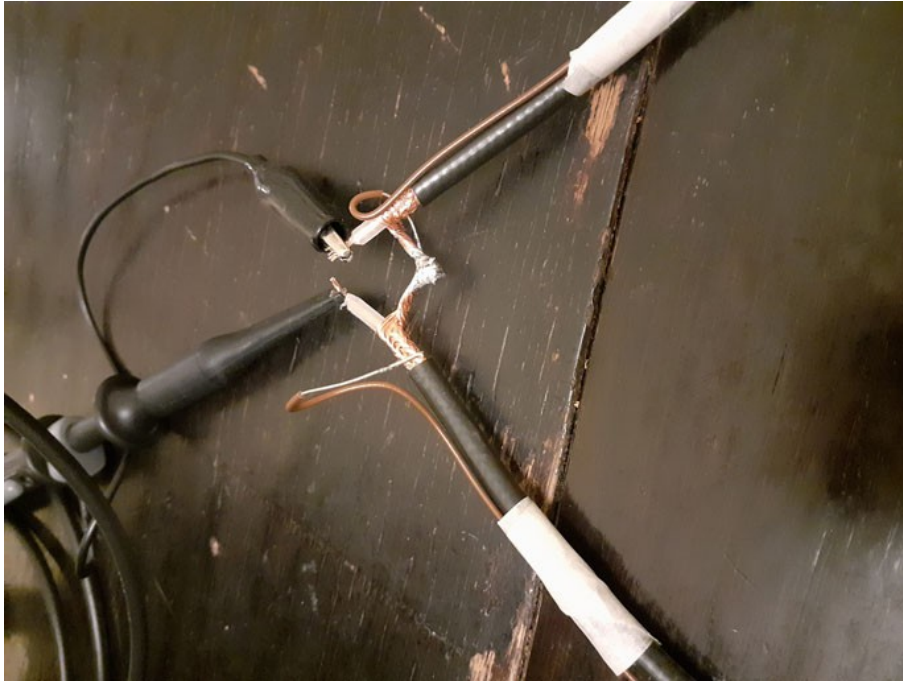


Scope readout:

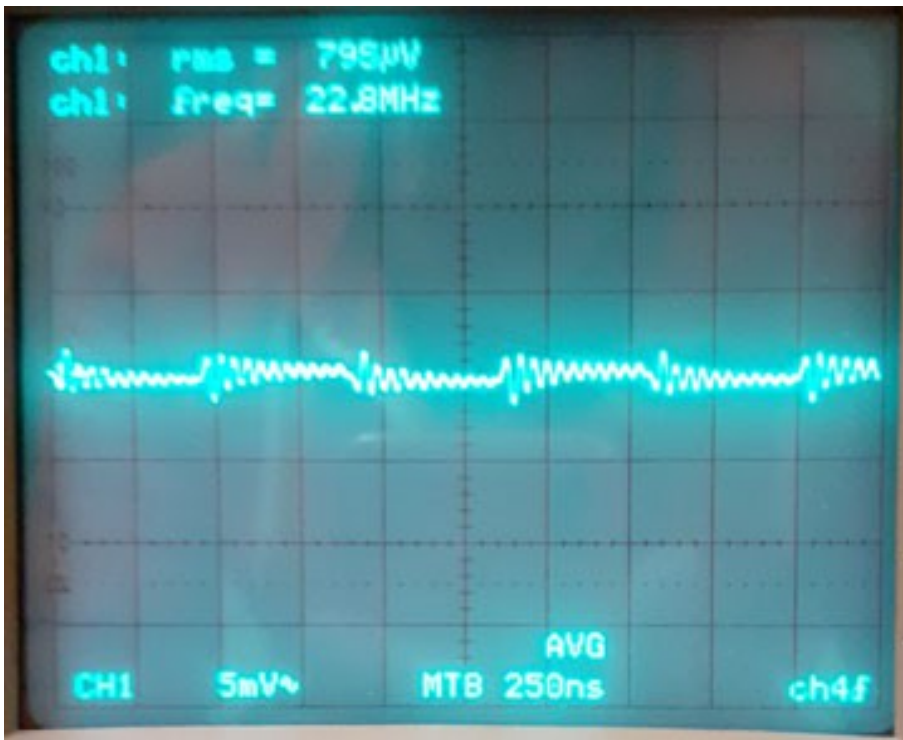


The waveform and induced voltage is exactly the same! (the 0.1mV error represents the measurement precision of the readout).

Test #3 : Short and immediate connection of the shield ends, as per common practice

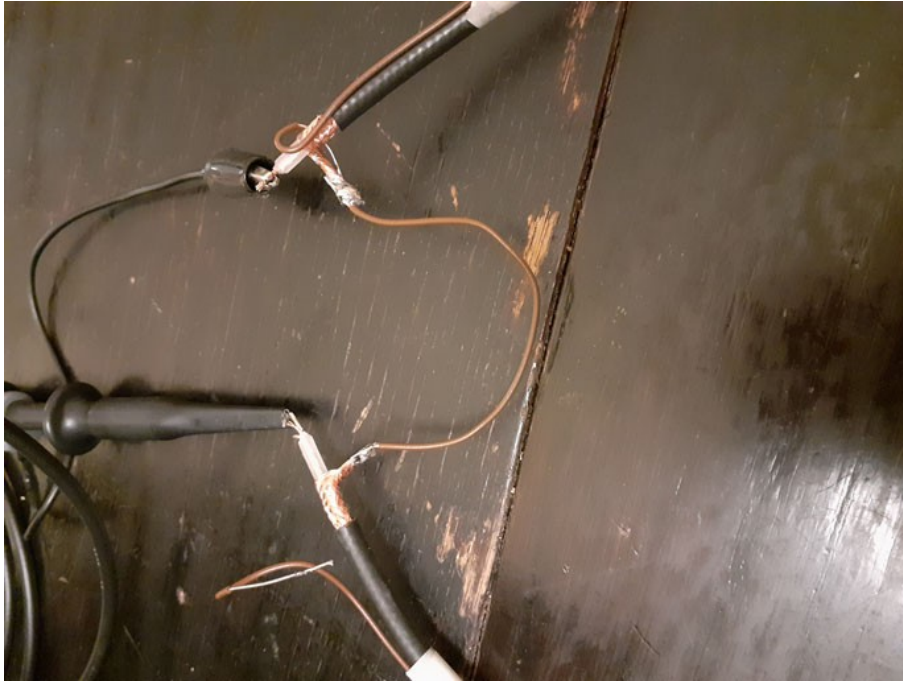


And the corresponding scope plot:

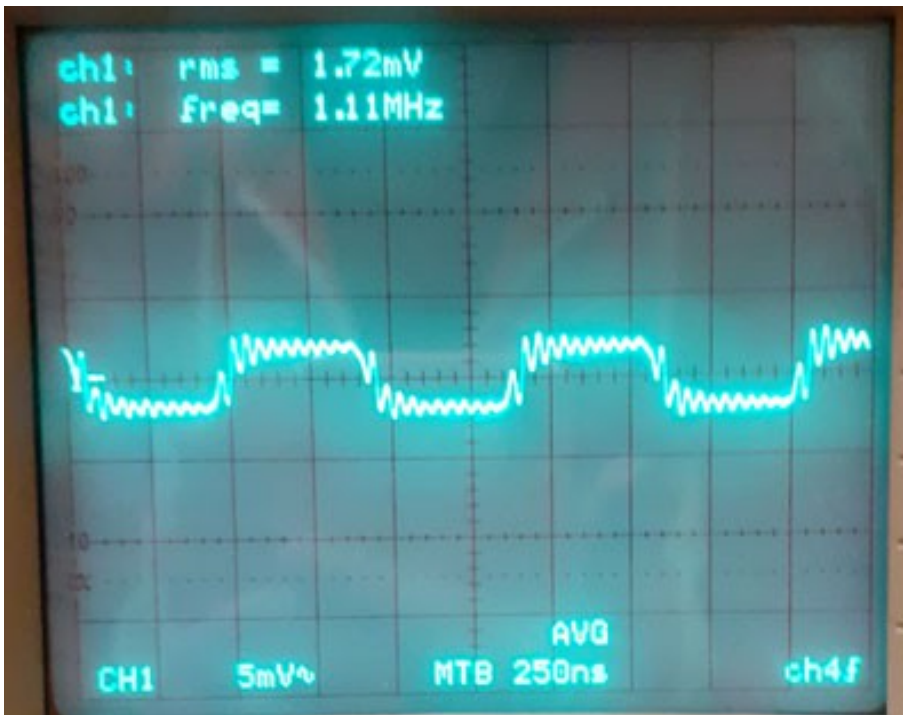


As expected, the direct connection of the shield ends yields a very good suppression of the magnetic noise field. This is the best possible result for this cable and with a good plane replacing the short it will be almost equally good.

Test #4 : Connection of the shield ends with a short piece of wire



Scope readout:

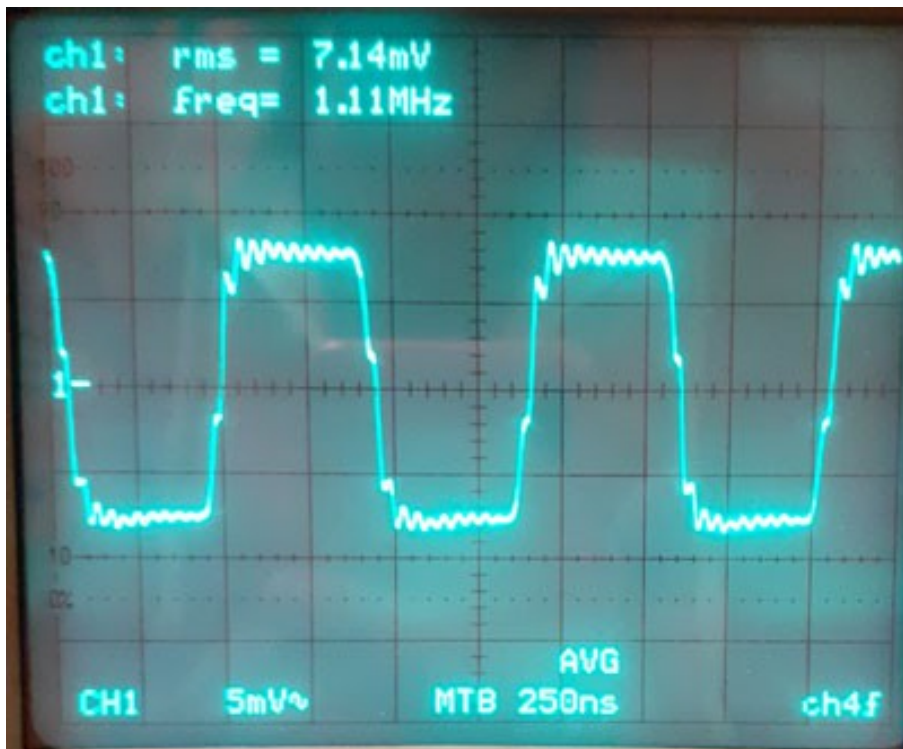


Even this short piece of wire has enough impedance (at 1MHz) to decrease shielding effectiveness quite a bit. Nevertheless, the induced voltage is still reduced by a factor of almost 7, a notable improvement.

Test #5 : Connection of the shield ends with a short piece of wire with a clamp-on ferrite



Scope readout:



That little ferrite spoils the action of the short wire, total attenuation now is only 1.5x. That's why a large solid ground plane with low impedance is paramount, notably when the shield is of high quality.

Conclusion

The JSSG technique does not have any significant effect to increase the magnetic shielding effectiveness of a floating shield.

This is readily explained by theory: Right because the loop wire runs directly along the shield it is subjected to the same noise field, and the inductance is also pretty much the same. Therefore the induced voltage on the shield and the loop wire is the same, too, and the loop wire simply cannot “short out” the shield ends in the same effective way like a solid ground plane (which doesn't need to be connected to anything).

Further, the resistance of the parallel loop wire will always be quite larger than the shield resistance, given that a thin wire is suggested by Swenson to be appropriate. Therefore, even when using this end-to-end connection correctly (not subjected to the same field) its capability to short out the shield ends is very limited.

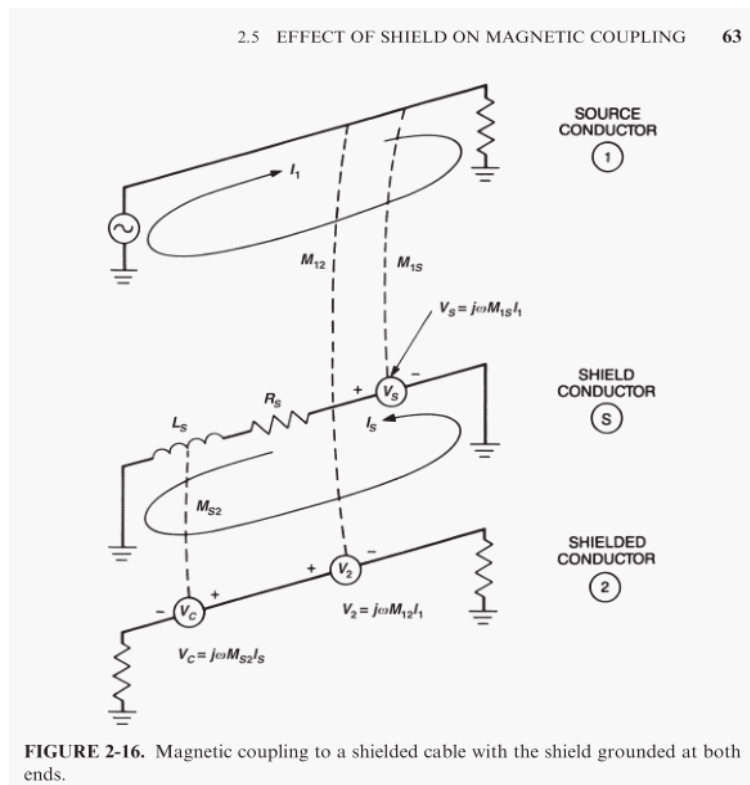
References:

[1] Henry W. Ott, *Electromagnetic Compatibility Engineering*, John Wiley and Sons, 2009, Section 2.5, “EFFECT OF SHIELD ON MAGNETIC COUPLING”

Forgive me this closing personal remark:

Ott's work is a most important and valuable practical textbook Mr. Swenson seems to never have heard of... or if he actually read it he didn't seem to grasp much. While he got the “always connect both ends of a shield” thing right as well as that connection doesn't need to be connected to anything else (while most often it is), he missed that the connection must be low impedance and more importantly, it must not pick up the exact same field! Otherwise there will be no magnetic shielding effect at all.

Fig 2-16 in Ott's book tells it all:



Addendum

Shortly after I published the above I got some flak from members of the forum where I chose to post this initially. The main complaint was why I did measure at "such a high frequency of 1MHz" -- they seem to have missed that I wrote I had tested down to 1kHz but choose to post the 1MHz results for good reasons -- when Swenson explicitly claims his methods works well at very low frequencies where traditional methods fail (repetition from the quote given earlier):

"The best way for the shielding to work properly is a separate wire connected to each end of the shield. This is sufficient for shielding from DC to very high frequencies. [...] So how come nobody does this? I don't know. My only guess is that cable shielding has been going on long before the actual mechanism for shielding was worked out, thus by the time it was understood, cable shielding was "standard" and nobody ever even thought about analyzing it based on an understanding of how shielding actually works.

But shouldn't the big companies know about this? It seems they don't. I have read several app notes from Belden that state that shielding is only effective at high frequencies, at audio frequencies and power supply frequencies (60Hz etc) it is totally ineffective."

Ok, here we go, experiment repeated at audio frequencies of 20Hz...20kHz. Setup is the same as before but with the signal generator and scope replaced by a RME Adi-2 Pro FS audio interface and the REW analysis software. The phones output was used as it can supply a lot of current, levels were increased up to the point where the protection kicks in, and backed off several dB from there.

Rather than measuring a fixed frequency I ran a sweep and effectively measured the transfer function of the magnetic pickup. Eight sweeps, at 96kHz sample rate, have been averaged and slightly smoothed (1/12 oct) to give clean plots where any small difference in shielding effectiveness at those frequencies should easily be visible. Complete plot pane shifted manually to 0dB@1kHz.



Some pickup of mains frequencies is visible... the receiving loop of course also picks up any magnet field in the air. But again, not the slightest difference whether the "shorting loop wire" is connected or not (and notably no shielding effect whatsoever), whereas shorting the shield ends gives the expected settling of the error voltage above a few kHz, in perfect accordance to the literature. The droop visible in all curves above 10kHz may come from sender loop inductance but is irrelevant here.