An analysis of current flow at the end of shielded twin line at radio frequencies

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Abstract

It is popularly held by hams that a "shielded twin line" synthesised from two parallel coax cables bonded at each end has negligible external fields, and is therefore more suited to installation within a building than ordinary open wire transmission line. This article presents an analysis of the configuration.

1. Analysis

1.1 Coaxial transmission line properties

Let's us refresh important properties of coaxial transmission lines.

Practical transmission lines at radio frequencies have an outer conductor that is much thicker than the skin depth. For that reason, the current that flows on the outside of the outer conductor can be quite different to the current that flows on the inside of the outer conductor.
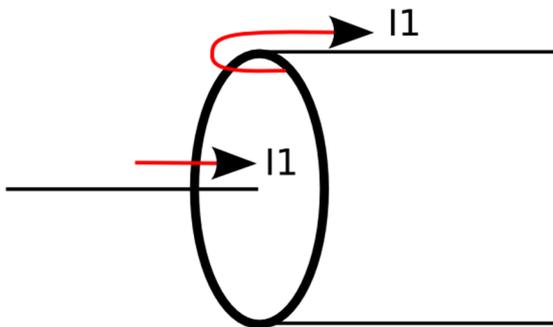

Figure 1

In the normal mode of operation of a coaxial cable (TEM), there are three currents to consider:

- the current flowing on the outside of the inner conductor;
- the current flowing on the inside of the outer conductor, and which is equal in magnitude to the current flowing on the outside of the inner conductor, but opposite in direction; and
- the current flowing on the outside of the outer conductor.

Figure 1 shows the consequence of that at the end of a coax where there is no connection to the shield. Inside the coax, the current I1 that flows on the outer surface of the inner conductor, gives rise to an equal current in the opposite direction flowing on the inner surface of the outer conductor. At the end of the shield, the current flowing on the inner surface of the outer conductor can and does flow around the end of the shield onto the outer surface of the outer conductor, there being no other possible path.

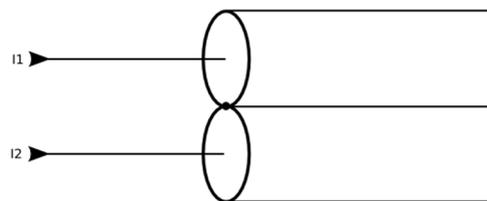The transition from two wire open line to shielded twin line.

Figure 2

Figure 2 shows a transition from a two wire open line to a shielded twin line synthesised from two coaxial lines with their shields connected. I1 and I2 are the currents flowing the open wire line adjacent at the transition. Note that I1 and I2 are complex quantities, and the arrows of themselves are not to imply any particular phase relationship.

The black dot in Figure 2 represents a node at which three current paths join, the inner surface of the upper coax, the inner surface of the lower coax, and the outer surface of the joined coaxes.

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1.2 Differential and Common Mode currents

A pair of conductors in proximity of some other conductors or conducting surface (such as the natural ground) can operate in two modes simultaneously, differential mode and common mode.

Differential mode is where energy is transferred due to fields between the two conductors forming the pair, and common mode is where energy is transferred due to fields between the two conductors forming the pair together and another conductor or conducting surface.

The currents flowing in the two conductors at any point can be decomposed into the differential and common mode currents.

Differential current Id is the component that is equal but opposite in direction, it is half the difference in the two complex line currents I1 and I2.

Common mode current Ic is the component of the line currents common to both conductors, it is half the sum of I1 and I2.

- Id=(I1-I2)/2
- Ic=(I1+I2)/2
- I1=Ic+Id
- I2=Ic-Id

So, for example, if I1=2A and I2=-1A, Id=(2--1)/2=1.5A, Ic=(2-1)/2=0.5A.

1.3 Floating shield

Figure 3 is an explanation of what happens at the dot in Fig 1 where the shields end, and are connected to each other.

The dashed lines represent the currents flowing on the inner surface of the two outer conductors.

In the upper coaxial line, current I1 flowing left to right on the centre conductor causes an equal current in the opposite direction on the inner surface of the shield, so there is a current I1 right to left.

In the lower coaxial line, current I2 flowing left to right on the centre conductor causes an equal current in the opposite direction on the inner surface of the shield, so there is a current I2 right to left.

The solid black horizontal line represents the outer surface of the joined outer conductors.

By Kirchoff's current law, the current flowing on the black conductor or outer surface of the joined outer conductors is I1+I2.

So, the current flowing on the outside surface of the shields is the total common mode current, the sum of the current mode current in each of the conductors of the two wire line, I1+I2 which equals 2*Ic, and the fields near the shields will be due to 2*Ic, essentially the same case as for the two wire line.
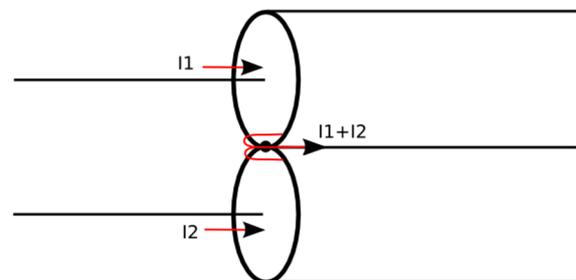
Figure 3

Figure 4

Figure 4 shows the current flows on the coax structure. The currents I1 and I2 flowing on the inner surfaces of the outer conductor flow to the outer surface of the outer conductors.

Remembering that quantities I1 and I2 are complex quantities, if I2=-I1, there is zero common mode current, and the current flowing on the outer surface of the shields is I1+I2=I1--I2=0. In a practical antenna system, it is unlikely that I2 is exactly equal to -I1, and so there will be common mode current, and it the same magnitude on both sides of and adjacent to the shield ends.
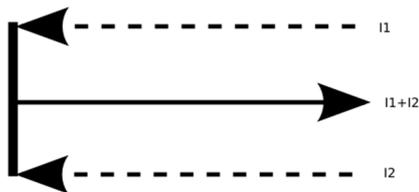
At distances of more than about three times the separation between the wires, the fields due to each of the differential currents are in opposition and almost cancel each other, whereas the fields due to the common mode currents are almost the same and reinforce each other. On a two wire line carrying significant common mode current, at a distance of more than about three times the separation, the fields will be principally due to the total common mode current, 2*Ic.

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The floating shielded twin line does not of itself significantly reduce the total common mode current flowing into the shack. Not only does the shielded twin line do nothing significant to reduce the effects of common mode current, but it would often be lossier than the equivalent open wire line and so degrade antenna system efficiency.
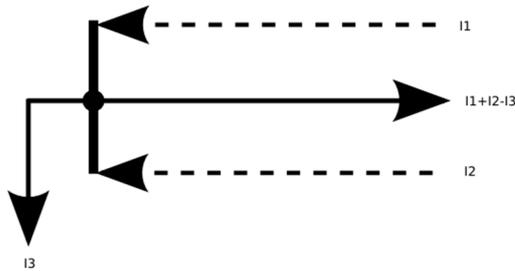
1.4 Grounded Shield

Figure 5

Figure 5 shows the current paths if an additional connection is made the ends of the shields, eg a connection to ground. I1 and I2 now divide between two current paths, the new I3 and the old path along the outside of the shields. In the antenna feed line scenario, if the portion of the total common mode current I1+I2 flowing to I3 can be made large, the residual common mode current on the shields of the shielded twin line may be made small.

Effectively grounding the shields at the transition and increasing the common mode impedance of the shielded twin line can divert a significant port of the total common mode to ground and reduce the common mode current flowing into the shack. The grounded shielded twin line may reduce the effects of common mode current, but it would often be lossier than the equivalent open wire line and so degrade antenna system efficiency.

1.5 Line loss

The matched line loss in a synthesised shielded twin line is the same as in the constituent coax. For example, if a pair of 20m long RG58 cables is used to synthesise a 100Ω line to feed a multiband dipole which happens to be a full wave at 40m (feed point Z approximately 4000+j0Ω), the loss in the line can be found from TLLC for 20m of RG58 terminated in half the load impedance, 2000+j0Ω.

Table 1: Loss of 20m length with load of 4000+j0Ω at 7MHz

Line type	Loss (dB)
Twin RG58	6.3
Twin RG6	2.8

Wireman 551 ladder line	0.43
Home made open wire, 2mm copper spaced 150mm	0.11

Table 1 compares three line types of length 20m with a load of 4000+j0Ω at 7MHz. It can be seen that the twin coax has much higher loss than the other open wire lines. This use of coax as a balanced line is often promoted as having some magical shielding qualities, but what it has is very high loss on extreme loads.

2. Others on the subject

2.1 QST June 2008

(Doctor 2008) was asked a question about shielded twin line: "... I have the ladder line terminated to double coaxes that run about 12' (4m) inside the house to an antenna tuner. Should this pair of coaxes be grounded at one end or both ends?"
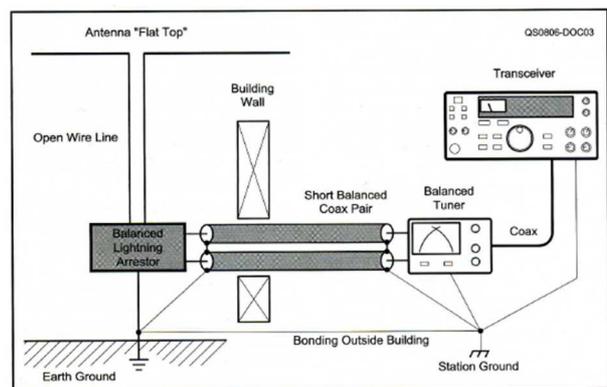

Figure 6

Figure 6 is from the QST article and shows "The Doctor's" interpretation of the question. Though the diagram shows both ends of the shielded twin as grounded, the advice in the text is "Whilst it is critical for proper operation for the shields of the two coaxes to be tied together at each end, whether they are tied to "ground" is not important to operation, but can make a big improvement in lightning protection".

This explanation ignores the effect of common mode current, it is an incomplete treatment and therefore misleading.

2.2 ARRL Antenna Handbook

Figure 7 is Fig 24 from the ARRL Antenna Handbook (Straw 2003, p24.21).

The ARRL Antenna Handbook has a small section on shielded twin lines, stating:

"Shielded balanced lines have several advantages over open-wire lines. Since there is no noise pickup on long

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runs, they can be buried and they can be routed through metal buildings or inside metal piping. ... The shields are connected together (see Fig 24A), and the two inner conductors constitute the balanced line. At the input, the coaxial shields should be connected to chassis ground; at the output (the antenna side), they are joined but left floating."
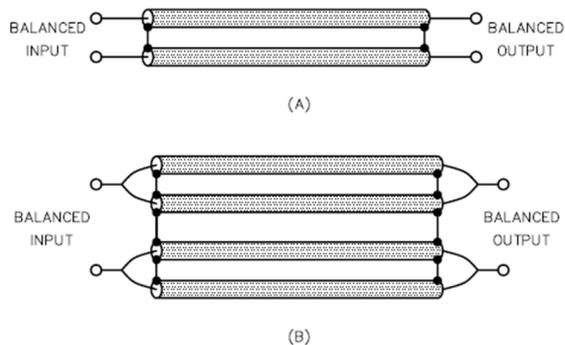

Fig 24—Shielded balanced transmission lines utilizing standard small-size coaxial cable, such as RG-58 or RG-59. These balanced lines may be routed inside metal conduit or near large metal objects without adverse effects.

Figure 7

The explanation completely ignores the effect of common mode current, and the proposed floating shield connection does not prevent common mode current flowing on the outside of the shielded twin line. If there is common mode current, as there would often be, the claimed advantages over open wire line do not exist. The treatment is incomplete and bears little relation to practical applications, and is therefore misleading.

(Straw 2007) contains the same content.

2.3 W4HDX multi band dipole

W4HDX (Spencer 1984) described a multi band dipole with twin coax feed.

Figure 8 is Fig 3 from (Spencer 1984).

An NEC model of a W4HDX dipole for 3.5MHz and up at 10m height gives a feed point impedance of $29-j350\Omega$. Fed with the recommended 26m of twin RG58C/U, line loss of 6.8dB can be expected. Under these conditions, 21% of the power from the ATU is delivered to the dipole feed point. This stunningly bad feedline performance is not mentioned in the article, but probably contributes to the claimed low noise 'magic' of this antenna.

W4HDX does also offer RG8 as an option, and in this case the line loss would be 4.3dB or line efficiency of 37%.

The configuration does not prevent common mode current, it just routes common mode current to ground at the tx end of the feedline. Common mode current induced on the feedline and flowing at the dipole end of the

feedline flows onto the radiator element, so there is not the noise shielding that is claimed.
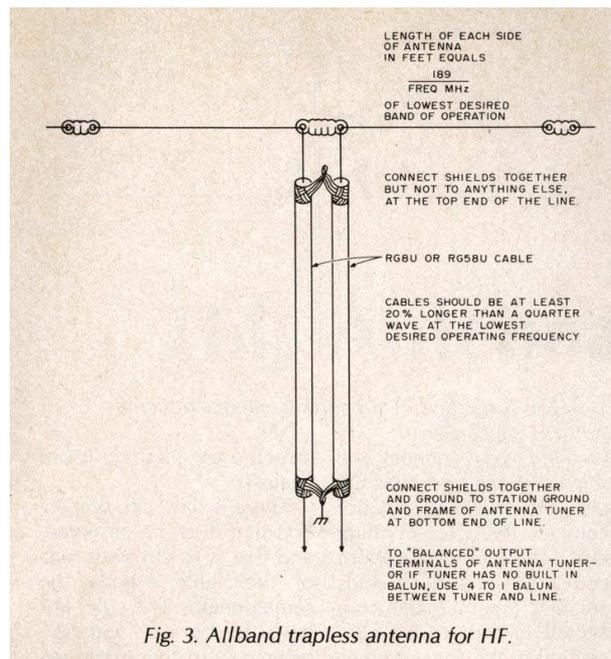

Fig. 3. Allband trapless antenna for HF.

Figure 8

3. Conclusions

- The floating shielded twin line does not of itself significantly reduce the total common mode current flowing into the shack. Not only does the shielded twin line do nothing significant to reduce the effects of common mode current, but it would often be lossier than the equivalent open wire line and so degrade antenna system efficiency.

- Effectively grounding the shields at the transition and increasing the common mode impedance of the shielded twin line can divert a significant port of the total common mode to ground and reduce the common mode current flowing into the shack. The grounded shielded twin line may reduce the effects of common mode current, but it would often be lossier than the equivalent open wire line and so degrade antenna system efficiency.

4. References

- Spencer, J. Feb 1984. This antenna is too good to be true. 73 magazine.
- Straw, Dean, ed. 2003. The ARRL Antenna Book. 20th ed. Newington: ARRL.
- ———. 2007. The ARRL Antenna Book. 21st ed. Newington: ARRL. 24.23
- The Doctor. June 2008. The doctor is in In QST. Newington: ARRL.

5. Changes

Version	Date	Description
1.01	25/04/2009	Initial.
1.02	04/03/2011	W4HDX added.
1.03	15/02/2016	Converted to Word