AN204
Impedance Shifts “Dribble Up/Down”

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Abstract

A “Step TDR” is capable of displaying a cable’s impedance (Z) over its length. When a cable’s impedance is measured, the total impedance appears to slowly gain or drop over the length of the cable. This application note explains the reason for these gains and drops, also known as “Dribble Up” or “Dribble Down” effect.

General

When cables are constructed, the materials used for the conductors and their wire diameter both determine their resistive value per foot (meter). Higher nobility metals (e.g. gold, silver, nickel and copper) and alloys containing them make better conductors and offer less resistance to electric current. Additionally, the wire’s diameter, or total sum of diameters in stranded cable, adds conductive area for current flow. Hence, the better the metal and the more area the lower the resistance and higher the DC current flow in the same length of cable. New factors become involved when AC current is introduced. AC current flow moves the electrons away from the center of the conductor towards each wire’s surface and the constant changing charge brings the inductance of the wires and capacitance from the dielectric value of the insulation between the conductors into the picture. This is the cable’s Impedance (Z_0) characteristic, and it can be determined by the following formula:

$$\boxed{Z_0 = \sqrt{\frac{L}{C}}}$$

Equation 1

Cable Resistance

The cable's resistive characteristic adds to the trace on a step TDR. A step TDR determines the cable's impedance using an AC signal and measuring, in the time domain, the reflected voltage over its length. In particular, the longer that a pulse travels down a cable, the more cable resistance the pulse sees. Looking at Figure 1, the pulse response obeys voltage divider rule;

$$V_O = V_S \frac{Z_L}{Z_L + Z_S}$$

Equation 2

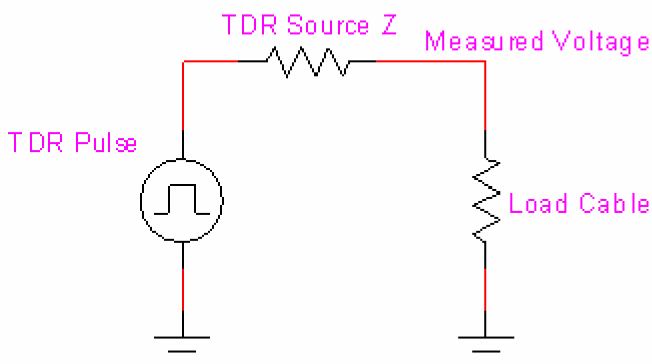

Figure 1

The first instant that the pulse meets the cable, the resistance is nearly zero, and the measured Z_L equals the cable Z_0. As the pulse spends a longer time traveling down the cable, the pulse sees more resistance in addition to the Z_0. This causes the dribble up, i.e. a step TDR trace that slopes upward to the right. Cables with higher resistance exhibit higher dribble up. While the cause is beyond the scope of this paper, we note that pulse TDRs lack the ability to see the cable's resistance.

Many authors attribute dribble up to skin effect on the wires. Some cables, like ultra low resistance power cables, exhibit dribble down. These cables have dielectric loss (conductance between conductors) effects that exceed their low series resistance in the conductors. The further down the cable the pulse travels, the more the conductance adds to the cable Z_0 (adding conductance lowers total Z as explained further on). Sometimes circuits tap across the cable at periodic intervals and cause an effective dielectric loss.

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Figure 2 shows a simplified model of a cable, R_S is the series conductor resistance, R_P is the dielectric resistance, and Z_0 is the cable characteristic Z.

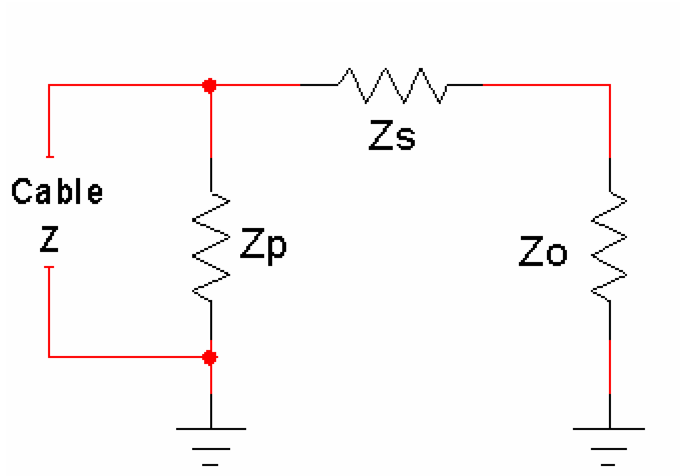

Figure 2.

Equation 3 shows total Z of the cable in Figure 2 (calculated using ohms law)

$$Z_{TOTAL} = \frac{Z_P\,(Z_O + Z_S)}{Z_P + Z_O + Z_S}$$

Equation 3.

Normally, a cable has greater series resistance and negligible dielectric losses, so Z_P approaches infinity and Z_{TOTAL} is approximately Z_s+Z_0. As the Z_s term increases, the TDR trace dribbles up. In the low resistance power cable, which normally are found in very long lengths, Z_S stays near zero, while Z_P can get to a few Kohms or less (Z_P causes higher losses at TDR frequencies while still exhibiting lower losses at 60 cycles). The Z_{TOTAL} for this type of power line approaches Z_P in parallel with Z_0 as Z_s approaches zero, causing the step TDR trace to dribble down.

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Example Plots

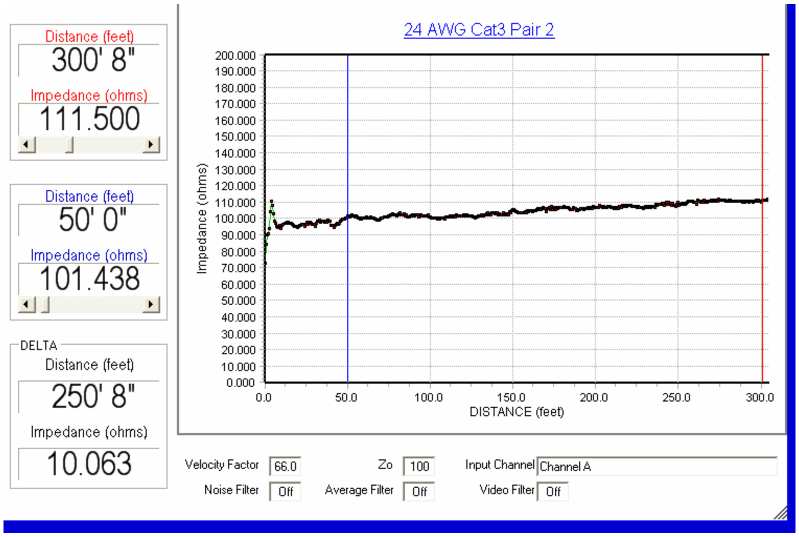

Figure 3

Figure 3 is an example of a TIA Category 3 data cable's dribble up. A nominal gain of about 10 Ω over 250 feet (76m) as marked by the blue and red cursors.

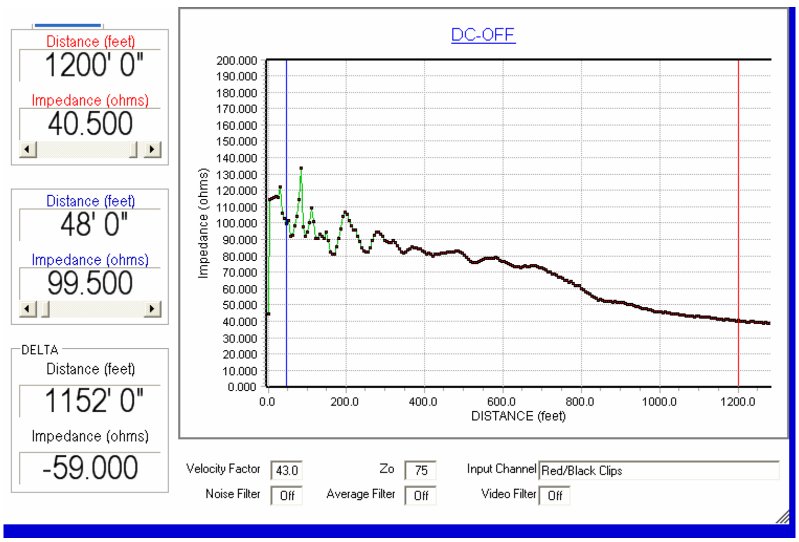

Figure 4

Figure 4 shows a large gauge cable. Ignoring the spikes caused by connected electronic packages, this twisted pair cable appears to loose about 60 Ω over 1152 feet (351m) as marked by the blue and red cursors.

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Conclusion

The nominal gain or drop in measured impedance is attributable to the relative amounts of dielectric and conductor losses over the length of a cable. Cable types with the most dribble up will be small conductor twisted pair types which have equal resistive loss in both conductors. The least amount of dribble up will be seen in coaxial cables which have far less resistive loss in the shield than the center conductor. Dribble down occurs in large gauge conductor wires like power cables where dielectric losses far exceed resistive losses.

Appendix

AN210	Cable Resistance in Coax
AN220	Cable Resistance in TWP

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