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Transmission-Line Modeling of Shielding Effectiveness of Multiple Shielded Cables with Arbitrary Terminations

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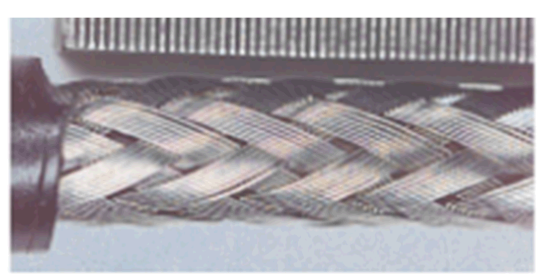
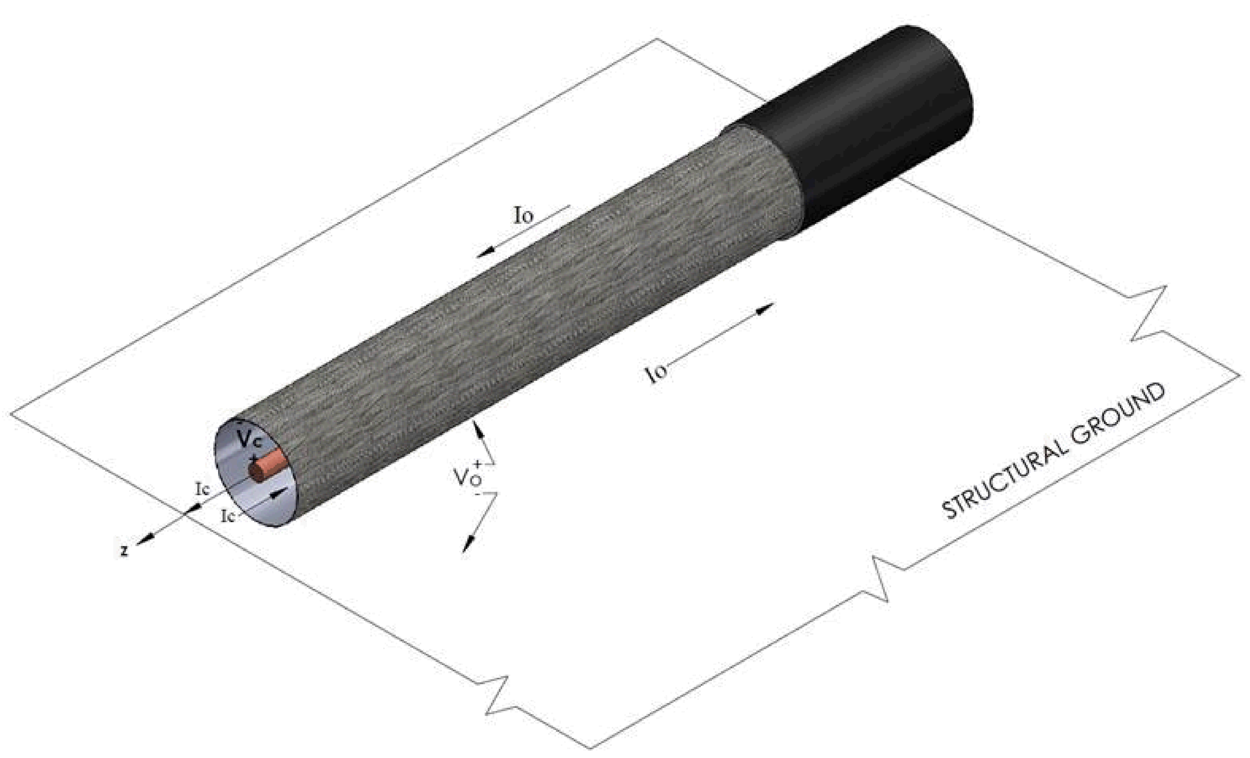
Introduction

- The shielding effectiveness of multiple-shield cables with arbitrary terminations is analyzed via a transmission-line model
- Shields are imperfect conductors and external magnetic and electric fields can penetrate into the interior regions of the cable
- Increasing the number of shields of a cable might improve the shielding performance; however, a cable with multiple shields may perform similar to or in some cases worse than a cable with a single shield

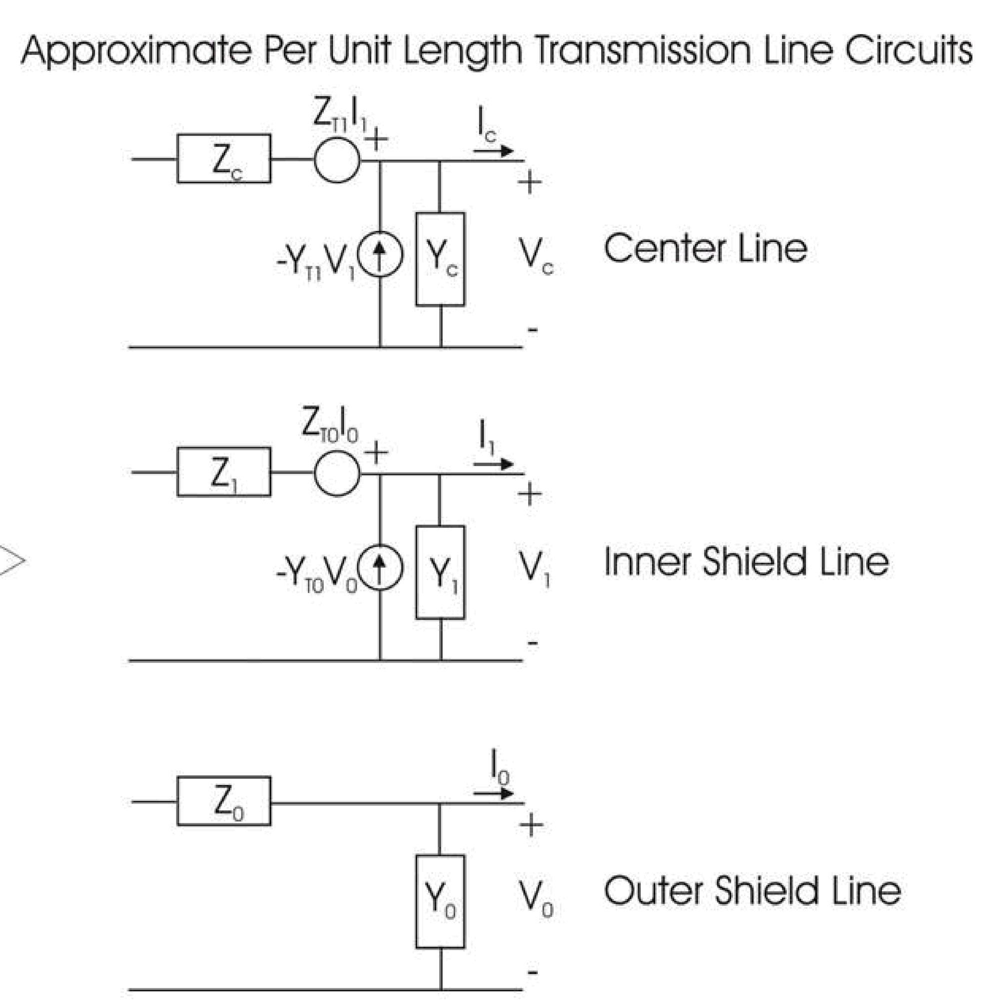
Transmission-Line Model for Multiple-Shield Cables

Belden 8240





(a)



(b)

Assuming N shields, the outer to inner shields are indexed as 0, 1, 2, …, N–1 and then the differential equations for the voltage and current on the 0th shield (outermost shield) are given by

$$\frac{dV_0}{dz}+Z_0 I_0=0 \qquad \frac{dI_0}{dz}+Y_0 V_0=0$$

The current distribution on the outermost shield is known $I_0(z)=I_0 e^{-\gamma_0 z}$

The internal problem is now set by looking at the i^{th} internal shield

$$\frac{dV_i}{dz}+Z_i I_i=Z_{T,(i-1)} I_{(i-1)} \qquad \frac{dI_i}{dz}+Y_i V_i=\tilde{C}_{T,(i-1)}\frac{dI_{(i-1)}}{dz}$$

The sources for the i^{th} transmission line are defined by the transfer parameters of the $(i\text{-}1)^{th}$ shield and these sources drive the coupled voltage and current on the interior shield

We will consider one source at a time [1] and then apply a superposition of results for the final value of the interior current. The complete methodology is reported in [2]

The differential equations for the voltage and current on the inner conductor of the braided cable are

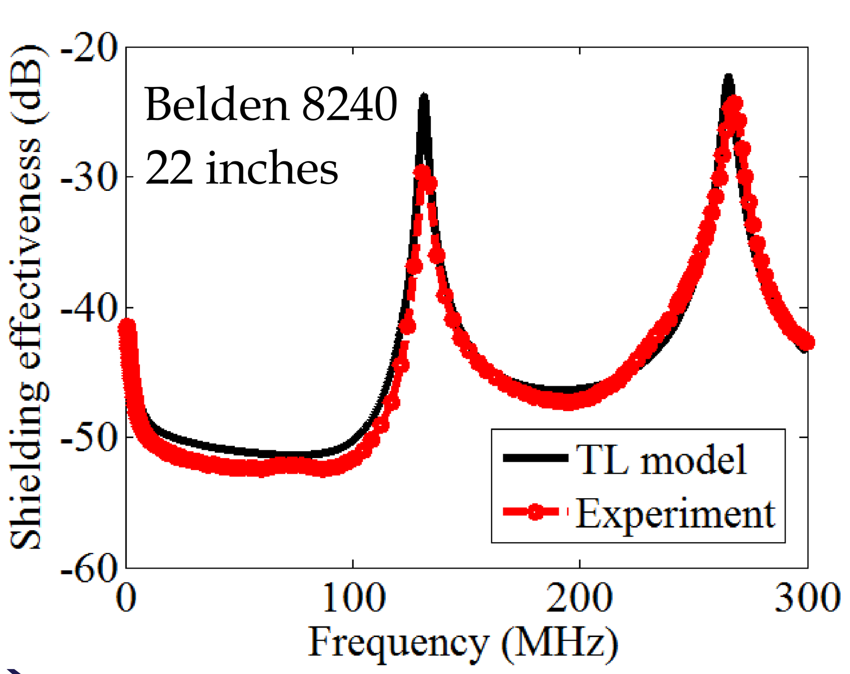
$$\frac{dV_c}{dz}+Z_c I_c=Z_{T,(N-1)} I_{(N-1)} \qquad \frac{dI_c}{dz}+Y_c V_c=\tilde{C}_{T,(N-1)}\frac{dI_{(N-1)}}{dz}$$

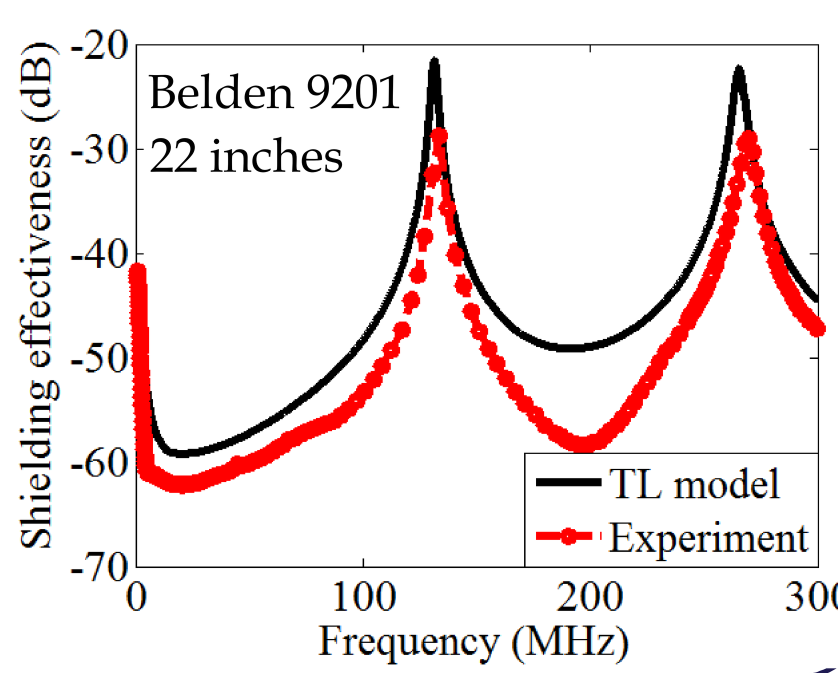
which can then be solved to compute the voltage and current induced on the inner conductor

Shielding effectiveness: $$SE(z)=20\log_{10}\frac{I_c(z)}{I_0(z)}$$

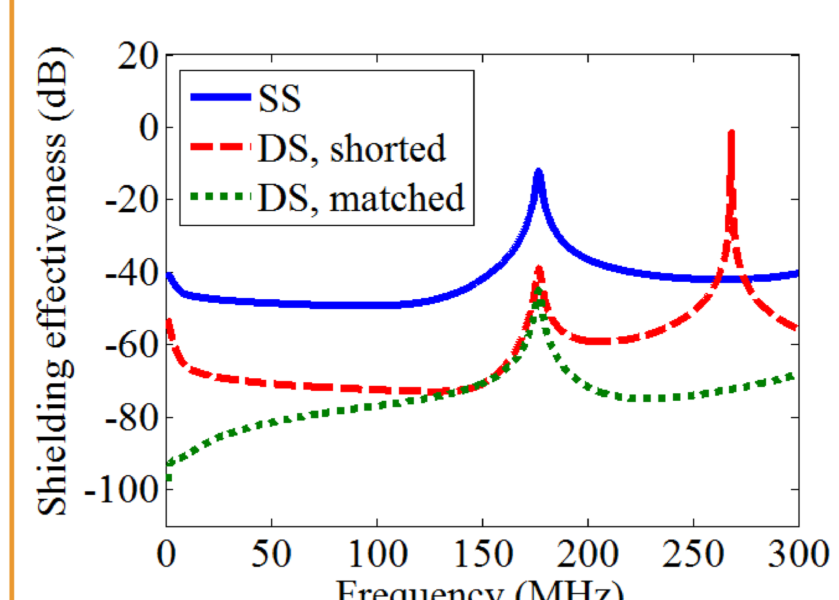
Comparison With Experiments

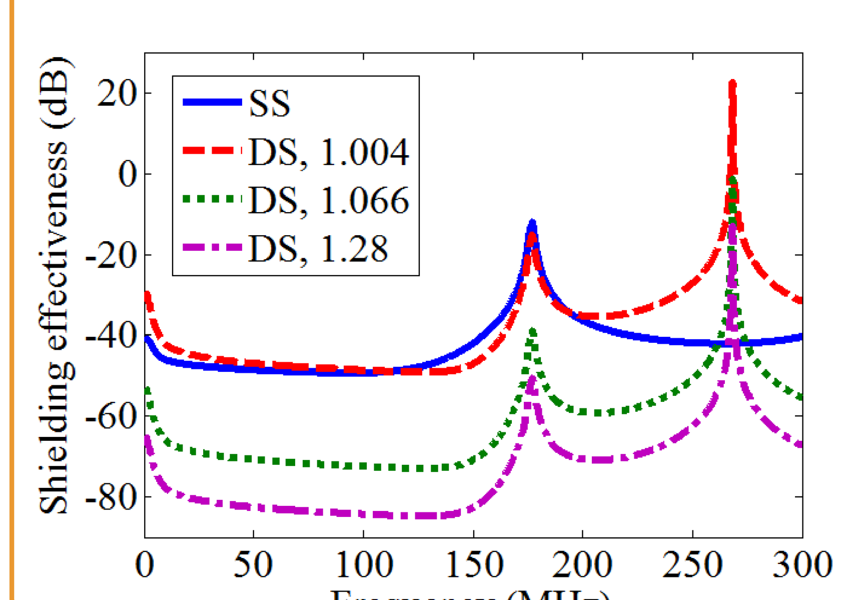
- The current probes at the ends of the cable tester represent 0.5 Ω loads at low frequencies. Near the resonance of the tester, the loads exhibit increasing losses as well as reactive effects
- The presence of reactive loads leads to an overall frequency downshift
- Loss effects associated with propagation down the cable length are included in the transmission line models
- Good agreement between experiments and theory--in both the level of the shielding effectiveness as well as the resonance frequency location





Analysis of Double-Shield Cables





- Inner shield transmission line matched -> shielding effectiveness better than the single-shield cable
- Inner shield transmission line shorted -> an additional resonance around 260 MHz appears, where the cable behaves much worse than the single-shield cable
- Modify the inner b_1 and outer b_0 radii of the braid (i.e. change the inductive and capacitive coupling)
- Shields close: the cable behaves the same or worse than the single-shield case -> Little or no improvement is obtained by adding a second shield

Conclusion

- Formulated a transmission-line model for calculating the shielding effectiveness of multiple-shield cables with arbitrary terminations
- Increasing the number of shields of a cable may not improve the shielding performance
- Cable terminations are one of the main parameters to consider when designing shields

References

[1] E. F. Vance, Coupling to shielded cables: R.E. Krieger, 1987.

[2] S. Campione et al., Progress in Electromagnetics Research C **65**, 93-102 (2016)

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