X3T9.2/90-19
Jim Filia - 3M

IMPEDANCE NOMOGRAPH

The Impedance Nomograph follows classical transmission line electrical formulas. Every cable when tested in the proper configuration with accurate test methods will be a straight line on the Nomograph. If you know any 2 values the other 2 must fall on a straight line. This includes open line, flat cable, twisted pair, shielded or unshielded, balanced (differential) or unbalanced (single ended), twist and flat, etc.

All the electrical formulas are based on the effective velocity (speed) of the electrical signal traveling down a cable. This speed is determined by the effective dielectric constant of the insulator and characteristics of the wire. Here are some of the formulas and derivatives.

$$\text{IMPEDANCE}_{\text{(OHMS)}} = \sqrt{\frac{L}{C}}$$

$$\text{IMPEDANCE}_{\text{(OHMS)}} = \frac{999 \cdot \text{PD (NS/FT)}}{\text{CAPACITANCE (PF/FT)}}$$

$$\text{INDUCTANCE}_{\text{(uh)}} = \text{IMPEDANCE}^2_{\text{(OHMS)}} \cdot \text{CAPACITANCE}_{\text{(UF/FT)}}$$

$$(E_R)\ \text{EFFECTIVE DIELECTRIC CONSTANT} = \left(0.983 \cdot \text{PD}_{\text{(NS/FT)}}\right)^2$$

$$\text{VELOCITY} = \frac{1}{\sqrt{\frac{L}{C}}} = \frac{C}{\sqrt{E_{R\,\text{(EFFECTIVE)}}}}$$

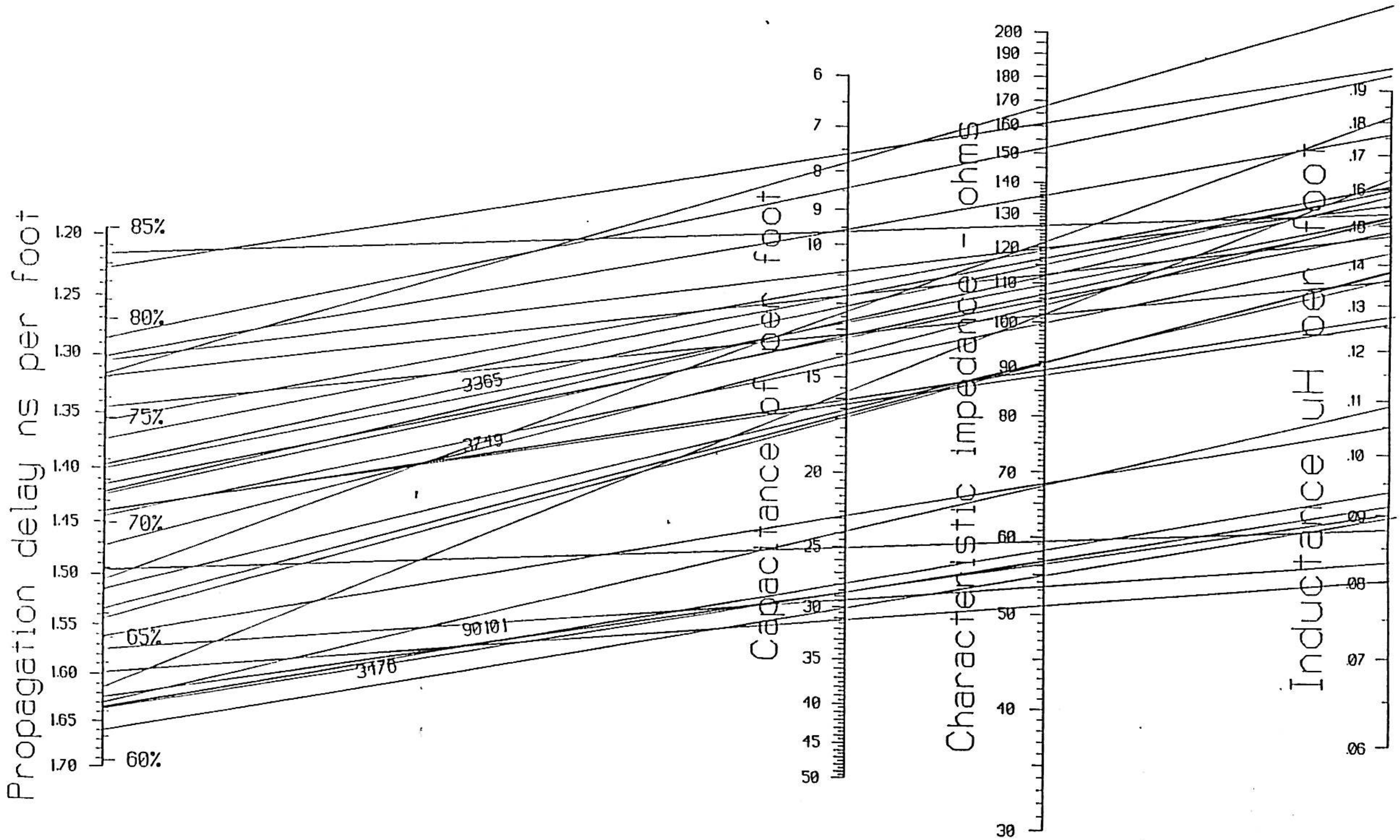
A check of most manufacturers catalogs show a deviation from a straight line on the Nomograph when catalog values charted. The problem is how cable values are measured. For instance propagation delay has typically been measured with a TDR (time domain reflectometer). This is a very poor instrument for accurately measuring PD. Scaling factors, operator interpretation, rise time degradation, and frequency scattering combine to produce an error of at least plus or minus 1 ns (nano second) over a 10 foot sample length. The corresponding impedance deviation error would be over 10 ohms. There are far better methods for measuring PD with an accuracy and repeatability of at least 25 pico seconds (.025 nano seconds) over 10 feet. This equates to about .2 ohm impedance deviation.

Capacitance can be accurately measured by using a 10 foot sample length and a 4 or 5 terminal digital LCR instrument such as the HP 4275A, at a test frequency of 1 Mhz. Using this 1 Mhz test frequency is very important for accurately determining characteristics of a cable used as a transmission line.

The second Nomograph shows all of 3M's cables plotted using improved cable test methods. The types of cables are flat, twisted pair, PFC, shielded and unshielded, twist and flat, flat in round, jacketed and unjacketed, 26, 28, 30, 32 gauge, solid or stranded and tested balanced or unbalanced. Note that every cable is a straight line, although the slope changes depending on the cable construction.

Jim Fiala
3M EPD lab

Transmission-line impedance nomograph



Jim Fiala EPD Lab

Transmission-line impedance nomograph