Temperature Dependence of Coaxial Cable Delay

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As we are in the process of stringing long coaxial cables for the outriggers, the question has come up as to how important it is to bury these cables. One reason to bury the cables is to avoid cable breaks from either animals eating them or vehicles crossing them. The other reason is to reduce the temperature changes in the cables, which will result in changes in the propagation delay of signals. Our experience in CYGNUS was that this can be a significant problem as some cables are warmed by the sun while others remain in shade.

This note is just to repeat the observations we made during CYGNUS on the temperature dependence of signal delay in coaxial cables. Of course, when coaxial cable is warmed, the copper conductors expand resulting in a longer signal delay. The coefficient of thermal expansion of copper is

$$1/L\ (dL/dT) = 1.7 \times 10^{-5}\ K^{-1}.$$

Considering that the propagation velocity in RG-59 is ~2/3 c, the above expansion is an increased delay of +0.08 ps/K m.

The subtler effect is the change in dielectric constant with temperature, which is frequency-dependent. Roughly, for polyethylene at 100 MHZ,

$$1/\varepsilon\ (d\varepsilon/dT) = -8.7 \times 10^{-4}\ K^{-1}.$$

A change in dielectric constant changes the propagation velocity: increasing the temperature decreases ε, which increases the velocity, which decreases the delay. In fact, this effect is in the opposite direction and much larger than the effect from the thermal expansion of copper. The result is that the signal delay of coaxial cable using polyethylene insulator obeys:

$$\Delta t = -\ 0.8\ (L\ \Delta T)\ ps$$

where L is the cable length in meters and ΔT is the temperature change in Kelvin. Thus a 300-m cable will have its signal delay decrease by 1/4 ns for each degree increase in its temperature. This can be a problem if the cables for different outriggers are at different temperatures, or if the cables are of different length and the temperature changes them all by the same amount.

A reference showing measurements of this effect for RG-58 is Kishida, T. *et al*, NIM **A254**, 367 (1987). If you look up this reference, look at page 371. The data is right (we confirmed it in measurements at CYGNUS), although somehow they have quoted the wrong value for the change of the dielectric coefficient.

Note that the inner and outer outrigger cables are of different lengths (by ~300') so their relative T-Peds will be temperature dependent: this is also true of all outriggers vs the pond.

Also note that the measurements are for RG-58 (50Ω) cable, while we use RG-59 (75Ω) cable. However, they both use polyethylene insulator and copper conductors so the conclusions hold for both cable types.