Coaxial Cable Dielectrics – Velocity of Propagation and Attenuation

There are a few considerations taken by RF engineers when selecting the ideal coaxial cable for an application, such as, the frequency or frequencies, the power, the insertion loss and even the jacket type for environmental conditions.

But what about the "velocity" of coaxial cable? What is this and why does it matter?

"Velocity" or "Velocity of Propagation" (Vp) refers to the speed at which a signal propagates through the coaxial cable. The velocity is a function of the dielectric (the insulation material) rather than the conductive portion of the construction (a copper core for example). Velocity is independent of frequency. Velocity is fastest through free space; any other medium is going to be slower.

So why does Vp have any significance and what causes dielectrics to vary?

The Vp will affect any design in which the "time domain" becomes significant and will also impact on the propagation loss (attenuation).

In RF terms, timing is very much about phase. RF devices depend widely on phasing signals constructively (or even destructively) such as when feeding separate antenna ports in an array. Controlling phase delay in coaxial cable requires an assessment of the Vp of the cable to understand the speed of the RF wave in that medium.

Rf signals travel at the speed of light in free space but when entrapped in a coaxial cable the characteristics of the dielectric have significant impact. Cable dielectrics are chosen based on dielectric strength, physical characteristics (such as flexibility) and cost. Unsurprisingly, "faster" dielectrics are generally less dense (E.G., foam) and become "slower" with more dense dielectrics (E.G., polyethylene).

For a given cable diameter, a "faster" cable will generally have a slightly lower loss although there are also other characteristics at play here such as the ratio between the inner and outer conductors. Some changes may not even be visible to the naked eye. Some typical dielectric materials and associated Vp:

Dielectric Material	Cable examples	RFI Part numbers	% Of velocity of the speed of light*
Solid Polyethylene	RG58 C/U, RG174/U, RG213, RG214, RG223/U	8174, 8058, 8223, 8213	66-70%
Cellular Polyethylene (Foam)	RG58, FSJ1, FSJ2, FSJ4	9014, 9001, 9006	76 - 84%
Foam Polyethylene	CNT400, RG58	9001, 9006, CNT-400	87-91%
Solid Teflon (PTFE)	RG142, RG400, RG393, RG178, RG178 B/U. RG179, RG59	8178, 8142, 9142, 8400, 8179, 8059	66-69%
Low Density Polyethylene	LDF1, LDF2, LDF4, AVA5	LDF1-50, LDF2-50, LDF4-50, AVA5-50	86-91%

- Speed of light = 3×10^8 meters per second in free space

So, for example, if a 2-meter wavelength signal was to be injected in an RG214 cable, the length of RG214 required to represent the wavelength would be 1.3M of cable (66% of 2 Meters).

In some critical applications such as radar or GPS timing where phase measurements are critical, cables may even be cut to phase and validated before use.

Fortunately, for most common RF applications below 10GHz, this type of accuracy is rarely required and, cable choices are likely to be made with practicality in mind.

In summary:

- Vp impacts speed and attenuation of an RF signal passing through a cable.
- The denser the dielectric, the slower the Vp.

Where does this matter?

- Has a direct impact on attenuation.
- VP is critical to phased applications such as;
  - Antenna phasing
  - Multi-coupling interconnections
  - Duplexer and filter interconnections
  - Tuned stubs

Do you have any challenging cable or connector applications that we might be able to assist you with?
Get in contact with our Customer Experience Team on 1300 000 734 or enquiry@rfi.com.au