PauloMarin consultoria

# Short Papers Series

## Nominal Propagation Velocity

A signal traveling from the input to the output is delayed in time by an amount equal to the length of cable divided by the velocity of propagation (*v*) for the transmission medium. In the case of an ideal transmission line consisting of two conductors in free space, the velocity of propagation is equal to the velocity of light (*c*). For practical cables, the velocity of propagation depends on the properties of the dielectric materials surrounding the conductors. At very high frequencies *v* asymptotes a constant value.

$$v = \frac{c}{\sqrt{m_r e_r}} \qquad (1)$$

Where:

$c$ is the speed of light in free space ($3.10^8$ m/s)

$m_r$ is the relative permeability of dielectric

$e_r$ is the rela tive permittivity of dielectric

The nominal velocity of propagation (NVP) can be simplified as follows

$$v = \frac{c}{\sqrt{e_r}} \qquad (2)$$

Where:

$c$ is the speed of light in free space ($3.10^8$ m/s)

$e_r$ is the relative permittivity of dielectric

This simplified approach for the calculation of $v$ is quite valid in the practice. Physically (and formally) $v$ depends also on the relative magnetic permeability of dielectric ( $m_r$ ) and for dielectric materials $m_r$ approaches 1 ( $m_r$ =1). As there are currents flowing through the conductors, there will be losses also. Waves propagating through those conductors will suffer losses' effect. However this effect is too low that can be neglected for high frequencies.

Thus NVP is usually stated as a percentage of the speed of light in free space and can be calculated as follows

$$NVP = \frac{v}{c} = \frac{\frac{c}{\sqrt{m_r e_r}}}{c} = \frac{c}{\sqrt{m_r e_r}} \cdot \frac{1}{c} = \frac{1}{\sqrt{m_r e_r}} \cdot 100 \ (\%) \qquad (3)$$

Where:

$v$ is the propagation velocity and depends on dielectric characteristics as well as the operating frequency

$c$ is the speed of light in free space ($3.10^8$ m/s)

$m_r$ is the relative permeability of dielectric

$e_r$ is the relative permittivity of dielectric

In practical terms if a given cable has NVP of 62% it means that the propagation of the signals or waves through it is 186,000,000 m/s or $1.86.\ 10^8$ m/s.

**Example:** Consider a transmission medium whose dielectric is made of Polyethylene and the operating frequency is 10 GHz. By considering $c$ (speed of light in free space) equals $3.10^8$ m/s compute the NVP of this transmission medium.

*Solution*

$e_r = 2.25$ (Polyethylene at 10 GHz)

$m_r = 1$ (unless otherwise stated) – dielectric materials

By applying equation (3), follows

$$NVP = \frac{1}{\sqrt{m_r e_r}} \cdot 100 = \frac{1}{\sqrt{1 \cdot e_r}} \cdot 100 = \frac{1}{\sqrt{2.25}} \cdot 100 = \frac{1}{1.5} \cdot 100 = 0.6667\ .100 = 66.67\ \%$$

NVP = 66.67 % $\Rightarrow v \cong 2.10^8$ m/s