TABLE 11-1 COMPARISONS OF VELOCITY, IMPEDANCE, AND THE PROPAGATION CONSTANT FOR FREE SPACE, LOSSLESS MATERIAL, AND CONDUCTING OR LOSSY MATERIAL

	Velocity	Intrinsic impedance	Propagation constant
Free space	$c = \dfrac{1}{\sqrt{\mu_0\epsilon_0}} = \dfrac{\omega}{\beta}$ $\approx 3 \times 10^8$ (m s^{-1})	$\eta = \sqrt{\dfrac{\mu_0}{\epsilon_0}} \approx 120\pi\ (\Omega)$ $\approx 377\Omega$	$\gamma = j\beta$ $= j\omega\sqrt{\mu_0\epsilon_0}$ (m^{-1})
Lossless dielectric	$U = \dfrac{1}{\sqrt{\mu\epsilon}} = \dfrac{c}{\sqrt{\mu_r\epsilon_r}}$ $= \dfrac{\omega}{\beta}$ (m s^{-1})	$\eta = \sqrt{\dfrac{\mu}{\epsilon}} = \sqrt{\dfrac{\mu_0\mu_r}{\epsilon_0\epsilon_r}}$ $\approx 120\pi\sqrt{\dfrac{\mu_r}{\epsilon_r}}\ (\Omega)$	$\gamma = j\beta$ $= j\omega\sqrt{\mu_0\epsilon_0\mu_r\epsilon_r}$ (m^{-1})
Lossy dielectric, $\epsilon = \epsilon' - j\dfrac{\sigma}{\omega}$	$U = \dfrac{\omega}{\beta}$ (m s^{-1})	$\eta = \dfrac{\sqrt{\mu/\epsilon'}}{\sqrt{1 - j\dfrac{\sigma}{\omega\epsilon'}}}\ (\Omega)$	$\gamma = \alpha + j\beta$ $= j\omega\sqrt{\mu\epsilon'}\left(\sqrt{1 - j\dfrac{\sigma}{\omega\epsilon'}}\right)$ (m^{-1})
Slightly lossy dielectric, $\dfrac{\sigma}{\omega\epsilon'} \ll 1$	$U = \dfrac{\omega}{\beta}$ (m s^{-1})	$\eta \approx \sqrt{\dfrac{\mu}{\epsilon'}}\left(1 + j\dfrac{\sigma}{2\omega\epsilon'}\right)\ (\Omega)$	$\gamma = \alpha + j\beta$ $\approx j\omega\sqrt{\mu\epsilon'}\left(1 - j\dfrac{\sigma}{2\omega\epsilon'}\right)$ (m^{-1})
Good conductor $\dfrac{\sigma}{\omega\epsilon'} \gg 1$	$U = \dfrac{\omega}{\beta}$ (m s^{-1})	$\eta \approx \sqrt{\dfrac{\omega\mu}{\sigma}}\angle 45°\ (\Omega)$	$\gamma = \alpha + j\beta$ $\approx \sqrt{\pi f\mu\sigma}\,(1 + j)$ (m^{-1})