

**ATTENUATION, PROPAGATION CONSTANT, AND IMPEDANCE FOR VARIOUS MEDIUMS**

	<b>Any Medium</b>	<b>Lossless Medium (<math>s = 0</math>)</b>	<b>Low-Loss Medium (<math>e''/e' \ll 1</math>)</b>	<b>Good Conductor (<math>e''/e' \gg 1</math>)</b>	<b>Units</b>
<i>a</i>	$w \left\{ \frac{me'}{2} \left[ \sqrt{1 + \left( \frac{e''}{e'} \right)^2} - 1 \right] \right\}^{1/2}$	0	$\frac{s}{2} \sqrt{\frac{m}{e}}$	$\sqrt{p f m s}$	Np/m
<i>b</i>	$w \left\{ \frac{me'}{2} \left[ \sqrt{1 + \left( \frac{e''}{e'} \right)^2} + 1 \right] \right\}^{1/2}$	$w \sqrt{me}$	$w \sqrt{me}$	$\sqrt{p f m s}$	rad/m
$Z_o$	$\sqrt{\frac{m}{e'}} \left( 1 - j \frac{e''}{e'} \right)^{-1/2}$	$\sqrt{\frac{m}{e}}$	$\sqrt{\frac{m}{e}}$	$(1 + j) \frac{a}{s}$	$\Omega$
$v_p$	$w/b$	$\frac{1}{\sqrt{me}}$	$\frac{1}{\sqrt{me}}$	$\sqrt{\frac{4p f}{ms}}$	m/s
<i>l</i>	$2p/b = v_p / f$	$v_p / f$	$v_p / f$	$v_p / f$	m

Notes:  $e'' = s / w$ ; In free space,  $e = e_o$ ,  $m = m_b$ ; In practice, a material is considered a low-loss medium if  $e''/e' = s / we < 0.01$  and a good conducting medium if  $e''/e' = s / we > 100$ .

## REFLECTION AND TRANSMISSION COEFFICIENTS

Property	Normal Incidence $q_i = q_t = 0$	Perpendicular Polarization	Parallel Polarization
<b>Reflection Coefficient</b>	$r = \frac{Z_2 - Z_1}{Z_2 + Z_1}$	$r_{\perp} = \frac{Z_2 \cos q_i - Z_1 \cos q_t}{Z_2 \cos q_i + Z_1 \cos q_t}$	$r_{\parallel} = \frac{Z_2 \cos q_t - Z_1 \cos q_i}{Z_2 \cos q_t + Z_1 \cos q_i}$
<b>Transmission Coefficient</b>	$t = \frac{2Z_2}{Z_2 + Z_1}$	$t_{\perp} = \frac{2Z_2 \cos q_i}{Z_2 \cos q_i + Z_1 \cos q_t}$	$t_{\parallel} = \frac{2Z_2 \cos q_i}{Z_2 \cos q_t + Z_1 \cos q_i}$
<b>Relation of <math>r</math> to <math>t</math></b>	$t = 1 + r$	$t_{\perp} = 1 + r_{\perp}$	$t_{\parallel} = 1 + r_{\parallel}$
<b>Reflectivity</b>	$R =  r ^2$	$R_{\perp} =  r_{\perp} ^2$	$R_{\parallel} =  r_{\parallel} ^2$
<b>Transmissivity</b>	$T =  t ^2 \left( \frac{Z_1}{Z} \right)$	$T_{\perp} =  r_{\perp} ^2 \frac{Z_1 \cos q_t}{Z_2 \cos q_i}$	$T_{\parallel} =  r_{\parallel} ^2 \frac{Z_1 \cos q_t}{Z_2 \cos q_i}$
<b>Relation of <math>R</math> to <math>T</math></b>	$T = 1 - R$	$T_{\perp} = 1 - R_{\perp}$	$T_{\parallel} = 1 - R_{\parallel}$
<p><u>Notes:</u> (1) <math>\sin q_t = \sqrt{\frac{m_1 e_1}{m_2 e_2}} \sin q_i</math>; (2) <math>Z_1 = \sqrt{\frac{m_1}{e_1}}</math>; (3) <math>Z_2 = \sqrt{\frac{m_2}{e_2}}</math>; (4) for nonmagnetic media, <math>\frac{Z_2}{Z_1} = \frac{n_1}{n_2}</math>.</p>			