



ERSLab

F. Nunziata

Introduction

Examples

Lossless media

Lossy media

Fresnel reflection coefficients

Examples

Electromagnetics
and
Remote Sensing Lab
(ERSLab)

Università degli Studi di Napoli Parthenope
Dipartimento di Ingegneria
Centro Direzionale, isola C4 - 80143 - Napoli, Italy
ferdinando.nunziata@uniparthenope.it



Outline

ERSLab

F. Nunziata

Introduction

Examples

Lossless media

Lossy media

1 Introduction

2 Examples

- Lossless media
- Lossy media



Reflection coefficient

ERSLab

F. Nunziata

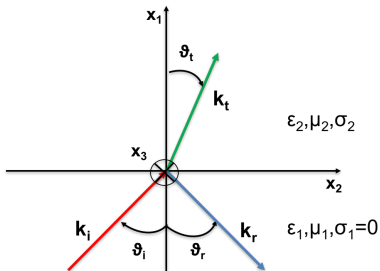
Introduction

Examples

Lossless media

Lossy media

The general formula for the reflection coefficient is given by:



$$R = \frac{Z_2(\hat{x}_1) - Z_1(\hat{x}_1)}{Z_2(\hat{x}_1) + Z_1(\hat{x}_1)} \quad (1)$$



Reflection coefficient

ERSLab

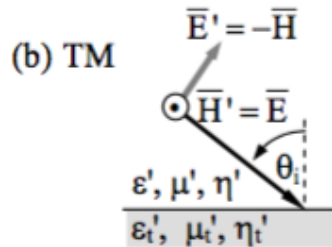
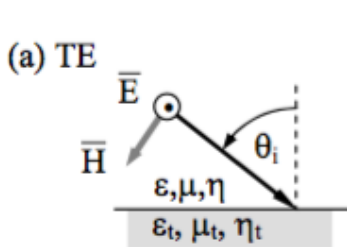
F. Nunziata

Introduction

Examples

Lossless media

Lossy media



$$Z_{TE} = \frac{Z}{\cos \vartheta} \quad Z_{TM} = Z \cos \vartheta \quad (2)$$



Reflection coefficient - TE

ERSLab

F. Nunziata

Introduction

Examples

Lossless media

Lossy media

$$\begin{aligned} R_{TE} &= \frac{\frac{Z_2}{\cos \vartheta_2} - \frac{Z_1}{\cos \vartheta_1}}{\frac{Z_2}{\cos \vartheta_2} + \frac{Z_1}{\cos \vartheta_1}} \\ &= \frac{\frac{Z_2 \cos \vartheta_1 - Z_1 \cos \vartheta_2}{\cos \vartheta_1 \cos \vartheta_1}}{\frac{Z_2 \cos \vartheta_1 + Z_1 \cos \vartheta_2}{\cos \vartheta_1 \cos \vartheta_1}} \end{aligned} \quad (3)$$

Reflection coefficient - TE

$$R_{TE} = \frac{Z_2 \cos \vartheta_1 - Z_1 \cos \vartheta_2}{Z_2 \cos \vartheta_1 + Z_1 \cos \vartheta_2} \quad (4)$$



Reflection coefficient - TM

ERSLab

F. Nunziata

Introduction

Examples

Lossless media

Lossy media

Reflection coefficient - TM

$$R_{TM} = \frac{Z_2 \cos \vartheta_2 - Z_1 \cos \vartheta_1}{Z_2 \cos \vartheta_2 + Z_1 \cos \vartheta_1} \quad (5)$$

- $Z = \sqrt{\frac{\mu}{\epsilon}}$
- When dealing with a non-magnetic medium $\mu = \mu_0$.
Hence:

$$Z = \sqrt{\frac{\mu_0}{\epsilon_0 \epsilon_r}} = \frac{Z_0}{\sqrt{\epsilon_r}} = \frac{Z_0}{n} \quad (6)$$

- where n is the refractive index.



Reflection coefficients as function of incidence angle only

ERSLab

F. Nunziata

Introduction

Examples

Lossless media

Lossy media

- According to eq.(6), reflection coefficients can be rewritten as:

$$R_{TE} = \frac{n_1 \cos \vartheta_1 - n_2 \cos \vartheta_2}{n_1 \cos \vartheta_1 + n_2 \cos \vartheta_2} \quad (7)$$

$$R_{TM} = \frac{n_1 \cos \vartheta_2 - n_2 \cos \vartheta_1}{n_1 \cos \vartheta_2 + n_2 \cos \vartheta_1} \quad (8)$$

- Using Snell's law $n_1 \sin \vartheta_1 = n_2 \sin \vartheta_2$ and trigonometric formulas, one can write:

$$n_2 \cos \vartheta_2 = n_2 \sqrt{1 - \left(\frac{n_1}{n_2} \sin \vartheta_1 \right)^2} \quad (9)$$

$$n_1 \cos \vartheta_2 = n_1 \sqrt{1 - \left(\frac{n_1}{n_2} \sin \vartheta_1 \right)^2} \quad (10)$$



Reflection coefficients as function of incidence angle only

ERSLab

F. Nunziata

Introduction

Examples

Lossless media

Lossy media

Reflection coefficients

$$R_{TE} = \frac{n_1 \cos \vartheta_1 - n_2 \sqrt{1 - \left(\frac{n_1}{n_2} \sin \vartheta_1\right)^2}}{n_1 \cos \vartheta_1 + n_2 \sqrt{1 - \left(\frac{n_1}{n_2} \sin \vartheta_1\right)^2}} \quad (11)$$

$$R_{TM} = \frac{n_1 \sqrt{1 - \left(\frac{n_1}{n_2} \sin \vartheta_1\right)^2} - n_2 \cos \vartheta_1}{n_1 \sqrt{1 - \left(\frac{n_1}{n_2} \sin \vartheta_1\right)^2} + n_2 \cos \vartheta_1} \quad (12)$$



Outline

ERSLab

F. Nunziata

Introduction

Examples

Lossless media

Lossy media

1 Introduction

2 Examples

- Lossless media

- Lossy media



TE and TM reflection coefficients

ERSLab

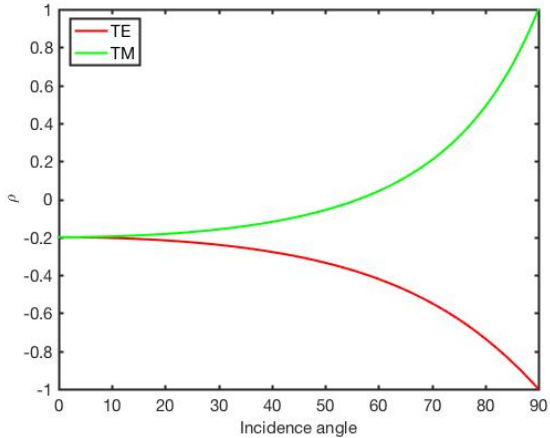
F. Nunziata

Introduction

Examples

Lossless media

Lossy media



$n_1=1, n_2=1.5$



Brewster angle

ERSLab

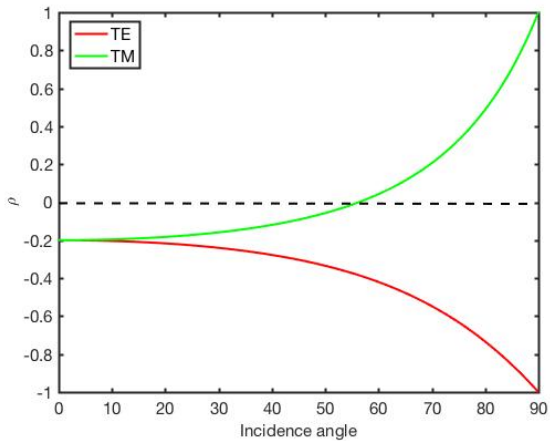
F. Nunziata

Introduction

Examples

Lossless media

Lossy media



$$\vartheta_B = \tan^{-1} \frac{n_2}{n_1}$$

(13)



TM reflection coefficient for varying n_2

ERSLab

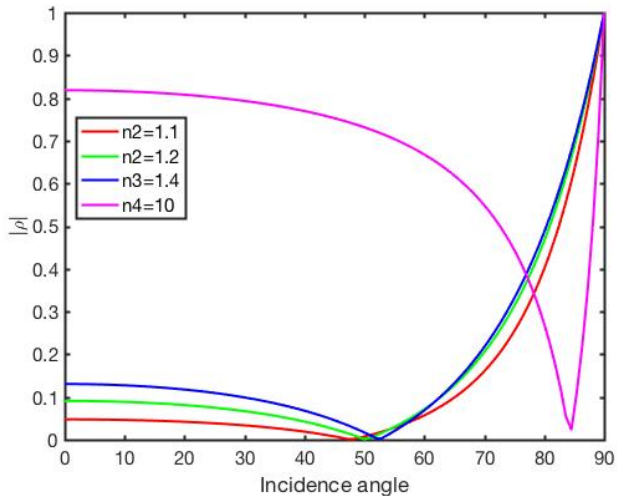
F. Nunziata

Introduction

Examples

Lossless media

Lossy media





Outline

ERSLab

F. Nunziata

Introduction

Examples

Lossless media

Lossy media

1 Introduction

2 Examples

■ Lossless media

■ Lossy media



TE and TM reflection coefficients

ERSLab

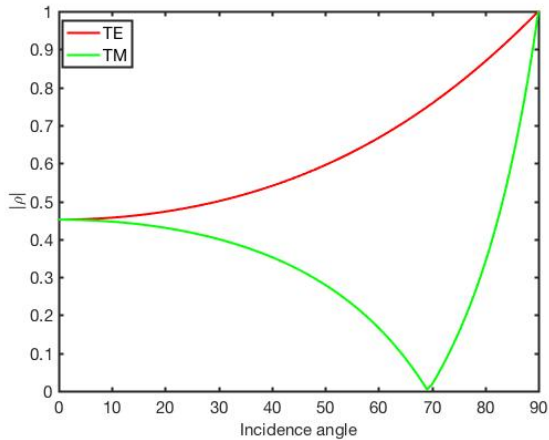
F. Nunziata

Introduction

Examples

Lossless media

Lossy media



$$n = \sqrt{\epsilon_c} = \sqrt{\left(\epsilon - j\frac{\sigma}{\omega\epsilon}\right)}$$

(14)

$\omega = 100\text{MHz}$, $\epsilon = 7$, $\sigma = 0.001$



TE and TM reflection coefficients

ERSLab

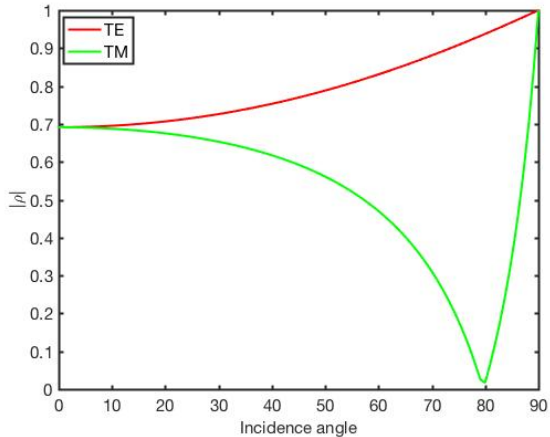
F. Nunziata

Introduction

Examples

Lossless media

Lossy media



$$\omega = 100\text{MHz}, \epsilon = 30, \sigma = 0.02$$