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DETERMINATION OF REFLECTION COEFFICIENTS OF THE PARALLEL-POLARIZED AND PERPENDICULARLY POLARIZED WAVES INCIDENT ON THE DIELECTRIC MATERIALS

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Abstract

Parallel-polarized and perpendicularly polarized waves are considered to be incident on the dielectric material. Reflection coefficients for these waves incident on some media (cotton, cotton seed oil, quartz, castor oil, wood (dry), wax, slate, ruby, silicon and salt) are studied by using Maxwell's equations. The variation of reflection coefficients with respect to the angles of incidence is also studied by using MATLAB computation software.

Keywords: Dielectric Materials, Reflection coefficients, Maxwell's equations, MATLAB computational software

Introduction

Maxwell's equations describe electromagnetic radiation as a transverse wave of oscillating electric and magnetic fields. The direction of the electric vibration is called the direction of polarization of the linearly polarized wave. An incident electromagnetic wave that approaches a plane interface between two different media generally will result in a transmitted wave in the second medium and a reflected wave in the first [3].

The fact that electromagnetic waves can be polarized is conclusive evidence that they are transverse waves. Interference and diffraction give evidence of their wave nature, but these effects do not differentiate between longitudinal and transverse waves. Sound waves, for example, are longitudinal and do show interference, but they cannot be polarized, only transverse waves can be polarized [1].

In this work, the variation of the reflection coefficient is studied for the perpendicularly polarized and parallel-polarized waves incident on the media of cotton, cotton seed oil, quartz, castor oil, wood(dry), wax, slate, ruby, silicon and salt [5].

Ackground Theory

Perpendicularly Polarized Wave Incident on Dielectric Material

A linearly polarized plane wave is obliquely incident on a boundary between two media. The electric field is perpendicular to the plane of incidence (the xy-plane) [4]. Perpendicularly polarized wave incident on a boundary between two media. The relation of reflection coefficient is obtained by using Boundary conditions.

$$\rho_{\perp} = \frac{\cos\theta_i - \sqrt{\left(\frac{\varepsilon_2}{\varepsilon_1}\right) - \sin^2\theta_i}}{\cos\theta_i + \sqrt{\left(\frac{\varepsilon_2}{\varepsilon_1}\right) - \sin^2\theta_i}} \qquad (1)$$

where ε_1 = permittivity of the medium 1, ε_2 = permittivity of the medium 2,

θ_i = angle of incidence,

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Parallel-Polarized Wave Incident on Dielectric Media

Parallel-polarized wave is incident on the boundary between two media. Incident electric field E_i, reflected electric field E_r, and transmitted electric field E_t vectors are parallel to the plane of incidence (xy-plane)[2].

For lossless nonmagnetic dielectrics equation (2) becomes by using Boundary conditions.

$$\rho_{//} = \frac{-(\varepsilon_2/\varepsilon_1)\cos\theta_i + \sqrt{(\varepsilon_2/\varepsilon_1) - \sin^2\theta_i}}{(\varepsilon_2/\varepsilon_1)\cos\theta_i + \sqrt{(\varepsilon_2/\varepsilon_1) - \sin^2\theta_i}} \quad (2)$$

where ε_1 = permittivity of the medium 1, ε_2 = permittivity of the medium 2,

θ_i = angle of incidence

Computation of Variation of Reflection Coefficient for the Wave Incident on the Dielectric Materials

Reflection Coefficient for Perpendicularly Polarized Wave

By using equation (1), reflection coefficients ($\rho_\perp$) are calculated for various angles of incidence. Reflection coefficient ($\rho_\perp$) for cotton, cotton seed oil, quartz, castor oil, wood(dry), wax, slate, ruby, silicon and salt are shown in Table 1. Since medium 1 is air (ε_{r1} = 1) and medium 2 is dielectric material, where $\frac{\varepsilon_2}{\varepsilon_1} = \frac{\varepsilon_0\varepsilon_{r2}}{\varepsilon_0\varepsilon_{r1}} = \varepsilon_{r2}$ (ε_{r2} = relative permittivity of medium 2).

Table 1 Reflection coefficients for perpendicularly polarized waves

Angle of incidence	Cotton	Cotton seed oil	Quartz	Castor oil	Wood (dry)	Wax	Slate	Ruby	Silicon	Salt
θ_i	ε_{r2} **1.4**	ε_{r2} **3.1**	ε_{r2} **4.2**	ε_{r2} **4.7**	ε_{r2} **6**	ε_{r2} **6.5**	ε_{r2} **7.5**	ε_{r2} **11.3**	ε_{r2} **12**	ε_{r2} **15**
0	0.08	0.27	0.34	0.36	0.42	0.43	0.46	0.54	0.55	0.58
10	0.09	0.28	0.35	0.37	0.43	0.44	0.47	0.55	0.56	0.59
20	0.09	0.29	0.36	0.38	0.44	0.45	0.48	0.56	0.57	0.61
30	0.11	0.32	0.39	0.41	0.46	0.48	0.51	0.58	0.59	0.63
40	0.12	0.36	0.43	0.45	0.51	0.52	0.55	0.62	0.63	0.66
50	0.16	0.42	0.49	0.51	0.56	0.58	0.60	0.67	0.68	0.71
60	0.23	0.51	0.57	0.59	0.64	0.65	0.67	0.73	0.74	0.76
70	0.35	0.62	0.68	0.70	0.73	0.74	0.76	0.81	0.81	0.83
80	0.70	0.78	0.82	0.83	0.85	0.86	0.87	0.84	0.90	0.91
90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Reflection Coefficient for Parallel- Polarized Wave

By using equation (2), reflection coefficients ($\rho_{//}$) are calculated for various angles of incidence. Reflection coefficient ($\rho_{//}$) for cotton, cotton seed oil, quartz, castor oil, wood(dry), wax, slate, ruby, silicon and salt are shown in Table 2.

Table 2 Reflection coefficient for parallel-polarized waves

Angle of incidence	Cotton	Cotton seed oil	Quartz	Castor oil	Wood (dry)	Wax	Slate	Ruby	Silicon	Salt
θ_i	ε_{r2} 1.4	ε_{r2} 3.1	ε_{r2} 4.2	ε_{r2} 4.7	ε_{r2} 6	ε_{r2} 6.5	ε_{r2} 7.5	ε_{r2} 11.3	ε_{r2} 12	ε_{r2} 15
0	0.08	0.28	0.34	0.37	0.42	0.43	0.46	0.54	0.55	0.59
10	0.08	0.27	0.33	0.36	0.41	0.43	0.45	0.53	0.54	0.58
20	0.07	0.25	0.32	0.34	0.39	0.41	0.44	0.52	0.53	0.57
30	0.06	0.22	0.29	0.31	0.36	0.38	0.41	0.49	0.50	0.54
40	0.03	0.18	0.26	0.26	0.32	0.33	0.36	0.45	0.45	0.50
50	0.00	0.11	0.19	0.19	0.24	0.26	0.29	0.38	0.39	0.43
60	0.07	0.00	0.08	0.08	0.13	0.15	0.18	0.27	0.28	0.33
70	0.20	0.16	0.09	0.09	0.04	0.03	0.00	0.09	0.10	0.15
80	0.45	0.46	0.42	0.40	0.36	0.35	0.32	0.24	0.22	0.18
90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

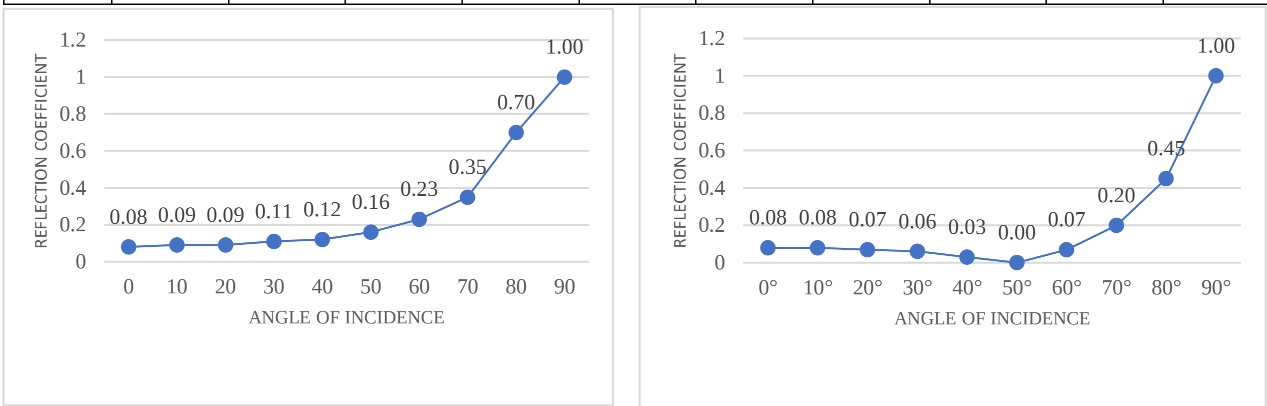

Figure 1 Variation of reflection coefficient with angles of incidence for cotton (Perpendicularly polarized wave and Parallel- polarized wave)

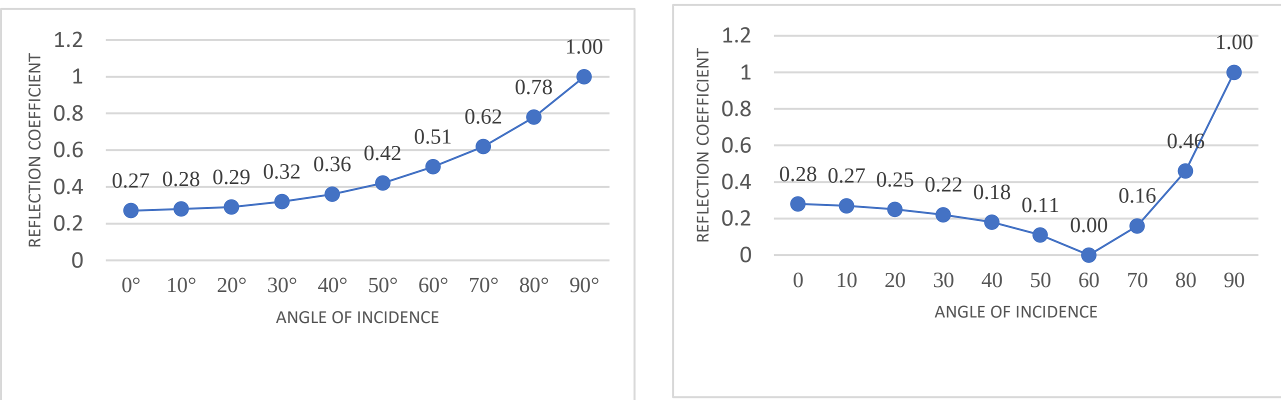

Figure 2 Variation of reflection coefficient with angles of incidence for cotton seed oil (Perpendicularly polarized wave and Parallel- polarized wave)

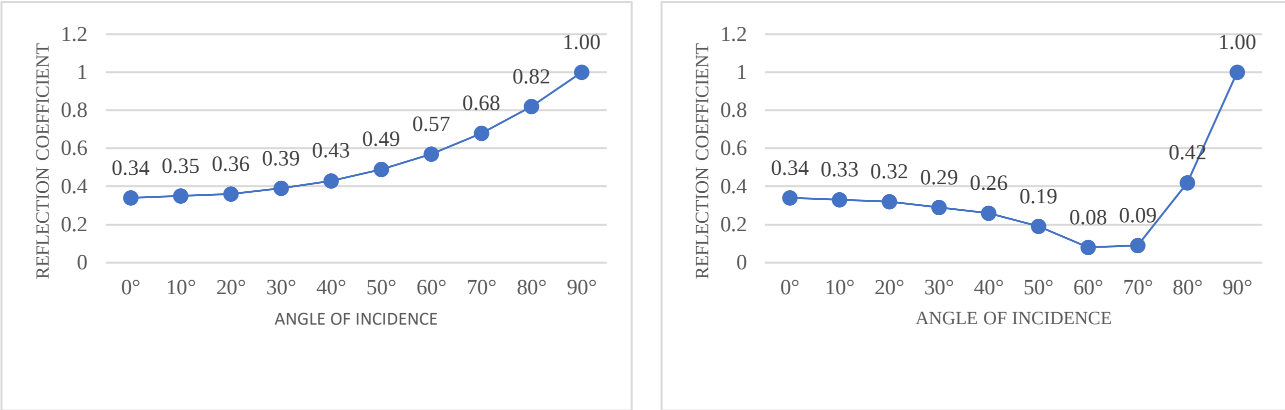

Figure 3 Variation of reflection coefficient with angles of incidence for quartz (Perpendicularly polarized wave and Parallel- polarized wave)

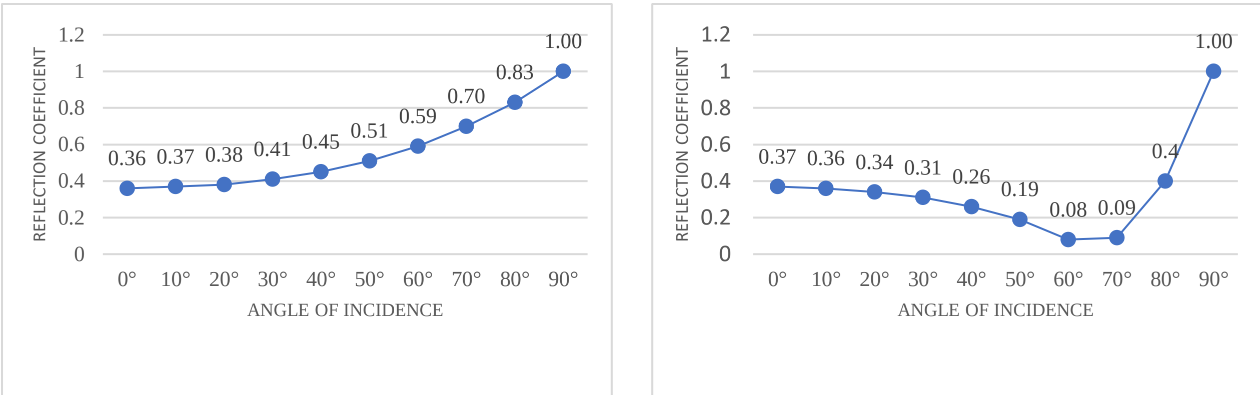

Figure 4 Variation of reflection coefficient with angles of incidence for castor oil (Perpendicularly polarized wave and Parallel- polarized wave)

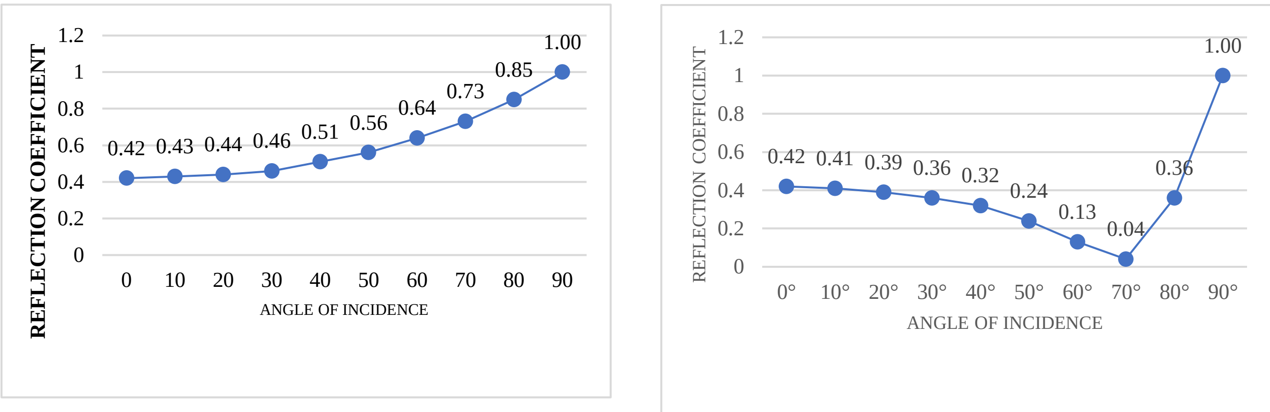

Figure 5 Variation of reflection coefficient with angles of incidence for wood (dry) (Perpendicularly polarized wave and Parallel- polarized wave)

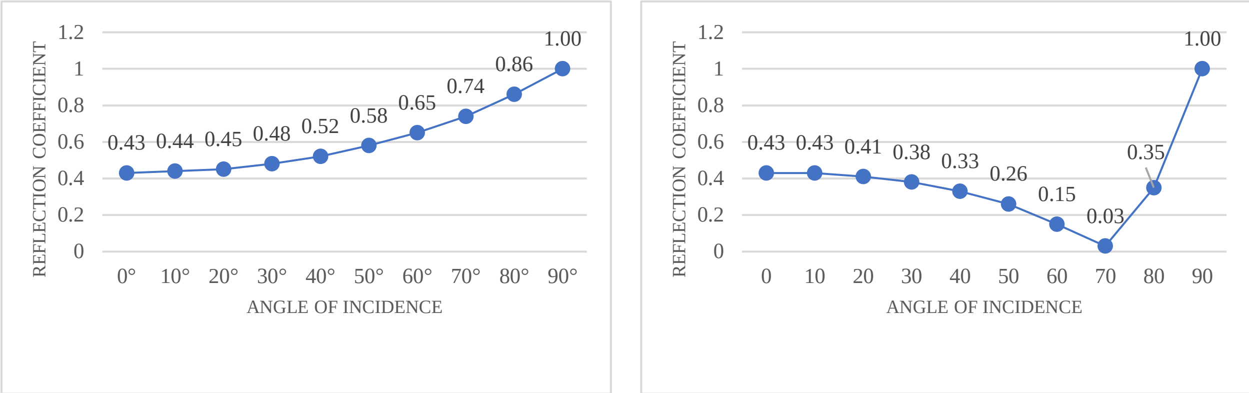

Figure 6 Variation of reflection coefficient with angles of incidence for wax (Perpendicularly polarized wave and Parallel- polarized wave)

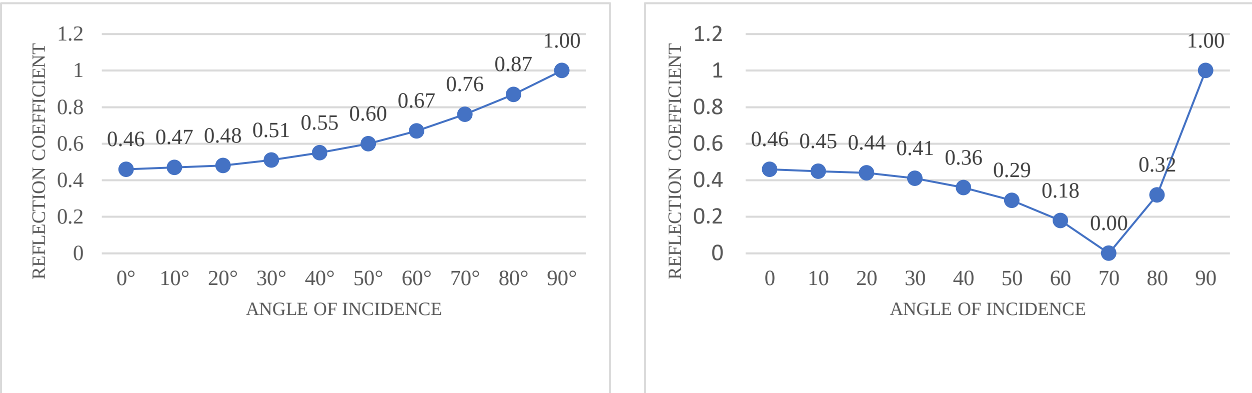

Figure 7 Variation of reflection coefficient with angles of incidence for slate (Perpendicularly polarized wave and Parallel- polarized wave)

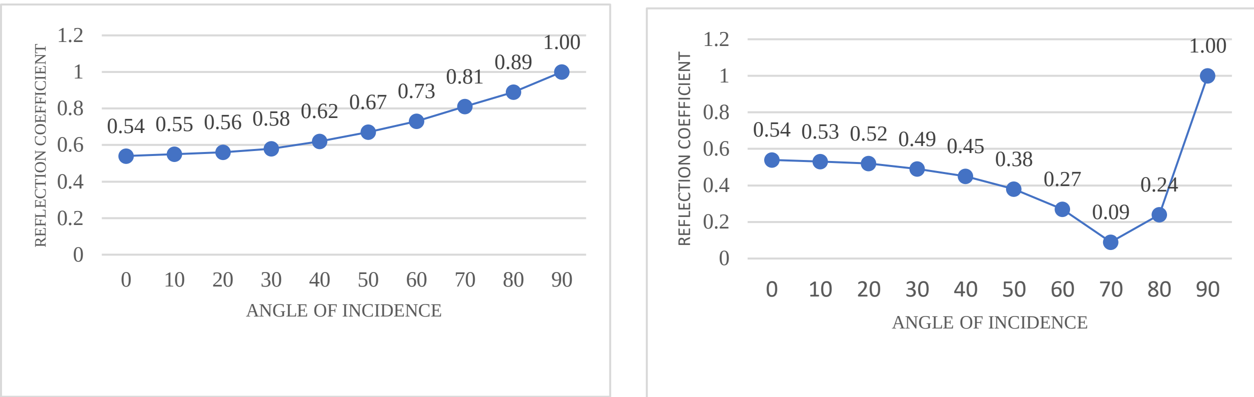

Figure 8 Variation of reflection coefficient with angles of incidence for ruby (Perpendicularly polarized wave and Parallel- polarized wave)

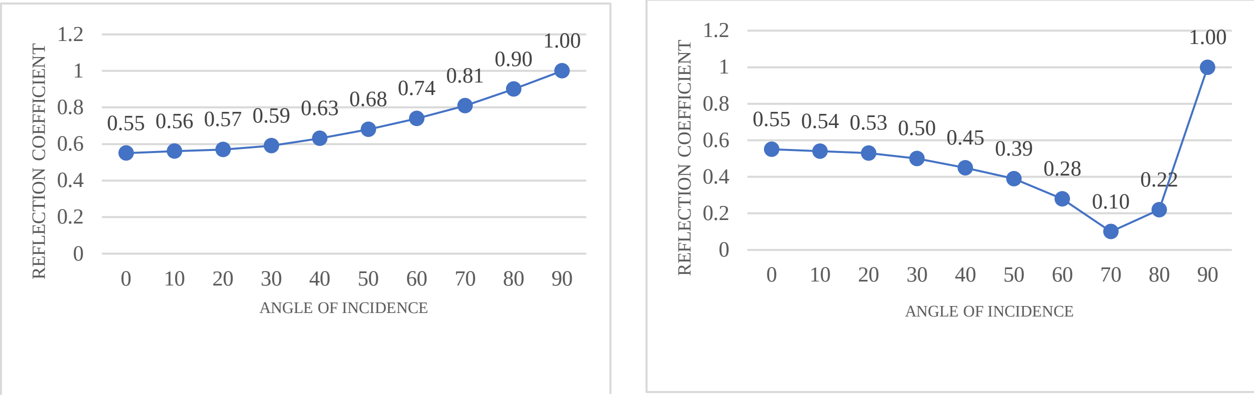

Figure 9 Variation of reflection coefficient with angles of incidence for silicon (Perpendicularly polarized wave and Parallel- polarized wave

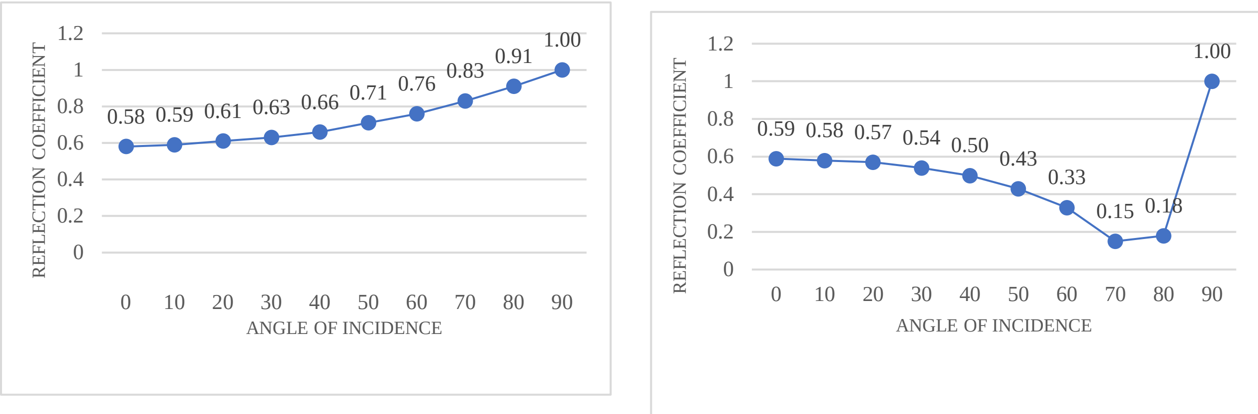

Figure 10 Variation of reflection coefficient with angles of incidence for salt (Perpendicularly polarized wave and Parallel- polarized wave)

The variation of reflection coefficient with angles of incidence for cotton, cotton seed oil, quartz, castor oil, wood (dry), wax, slate, ruby, silicon and salt for perpendicularly polarized wave and parallel- polarized wave were shown in Figure 1, 2,3,4,5,6,7,8,9 and 10.

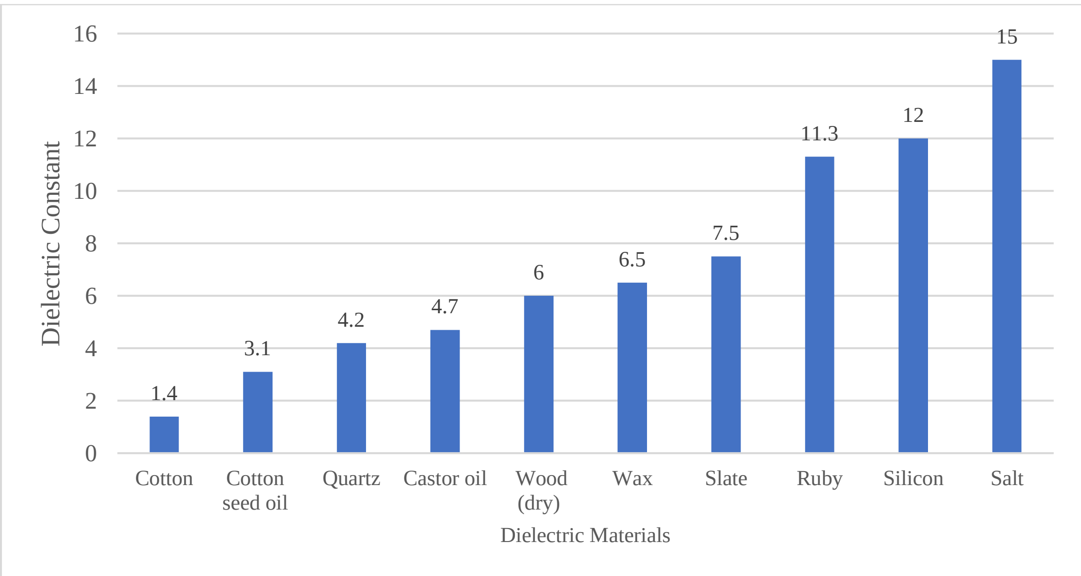

Figure 11 Variation of dielectric Constant vs dielectric Materials

MATLAB Program for the Computation of Reflection Coefficient

For Cotton,

```
% Program for the calculation of reflection coefficient
% for the perpendicularly polarized wave.
thitai-[0:10:90];
% angle of incidence from 0 to 90.
epsir2=1.4;
% relative permittivity of medium 2.
a=cosd(thitai)-sqrt(epsir2-sind(thitai).^2);
b=cosd(thitai)+sqrt(epsir2-sind(thitai).^2);
rho=a./b;
d=abs(rho);
% absolute value of reflection coefficient.
plot(thitai,d, 'k', 'linewidth', 2.2)
xlabel('Angle of incidence(degree)')
ylabel('Reflection coefficient'') reflection coefficient
%Program for the calculation of % for the parallel-polarized wave.
thitai [0:10:90];
% angle of incidence from 0 to 90.
epsir2=1.4;
% relative permittivity of medium 2.
a=(-epsir2)*cosd(thitai)+sqrt(epsir2-sind(thitai).^2);
b=epsir2*cosd(thitai)+sqrt(epsir2-sind(thitai).^2);
rho=a./b; d=abs(rho);
% absolute value of reflection coefficient.
plot(thitai,d, 'k', 'linewidth',2.2)
xlabel('Angle of incidence (degree)')
ylabel(''Reflection coefficient'')
```

Discussion and Conclusion

In this work, the variation of reflection coefficient with respect to the angle of incidence has been studied for perpendicularly polarized wave and parallel-polarized wave. The direction of propagation of the wave is only from air to those media (cotton, cotton seed oil, quartz, castor oil, wood (dry), wax, slate, ruby, silicon and salt).

In the case of perpendicularly polarized wave, as the relative permittivity becomes higher, the graphs (reflection coefficient versus angles of incidence) shift move towards higher reflection coefficient. Reflection coefficient is between 0.0839 and 1 for the medium of cotton and 0.5896 and 1 for the medium of salt. No angle of incidence, at which reflection coefficient is zero, was found. Reflection coefficient is 1 at the angle of incidence of 90° for all media.

In the case of parallel- polarized wave, as the relative permittivity becomes higher, reflection coefficient becomes greater for the same angle of incidence. Reflection coefficient is between 0.0839 and 1 for the medium of cotton and 0.5896 and 1 for the medium of salt. Reflection coefficient is 1 at the angle of incidence of 90° for all media.

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