FACULTY OF ENGINEERING, SCIENCE AND TECHNOLOGY

Design of a Microwave Ellipsometry System.

B.Eng.(Hons.) Communication and Electronic Engineering Final Year Project

Name of Student: **Ignacio Salan Padillo**

Name of Supervisor: **Dr.David Smith**

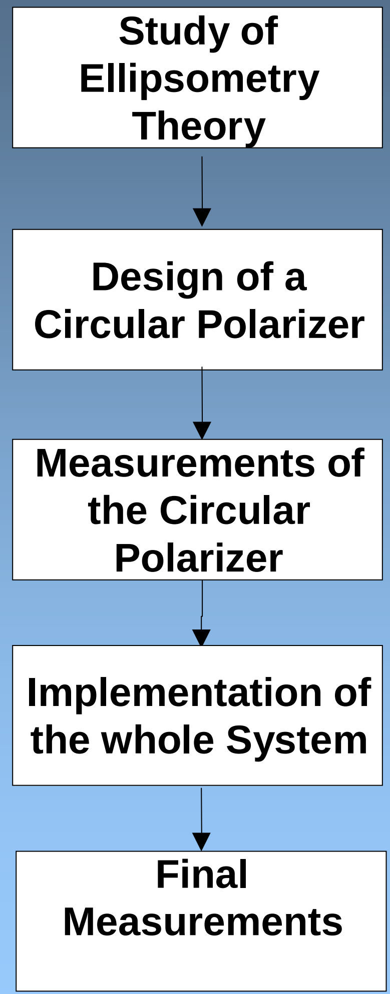
Year of submission: **2003**

Introduction and Aims of the Project

This project concerned with the investigation of material properties using a microwave ellipsometry system. Ellipsometry is a powerful and sensitive technique for investigation properties of dielectric material. The technique is based on the principle that the state of polarization of an electromagnetic wave changes on reflection from a surface.

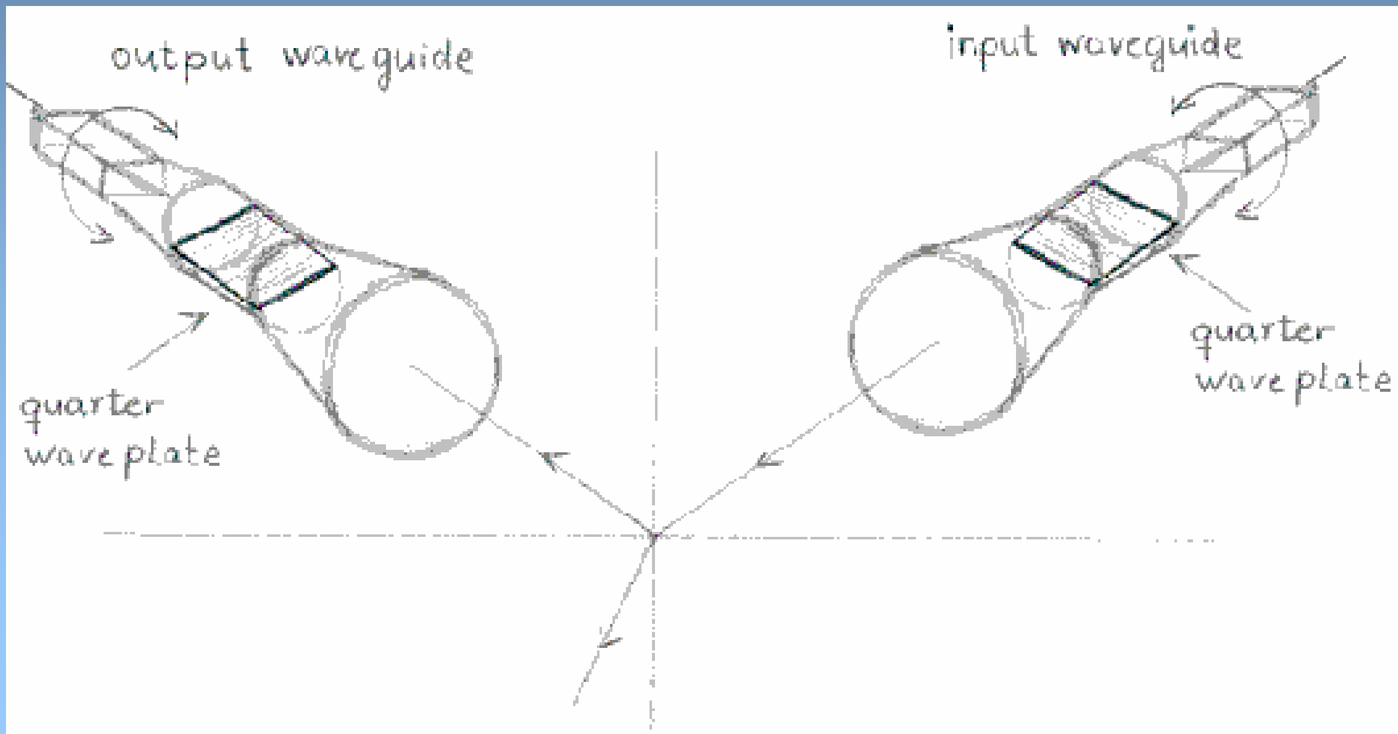
This project is divided into two parts; the first one is the development and design of a waveguide polarizer to change the polarization form linear to circular polarization. And the second part to include this device in the microwave ellipsometry system, this second part includes experimental and theoretical results in order to achieve accuracy and quality using microwave technology instead of optical and traditional techniques.

Design Procedure

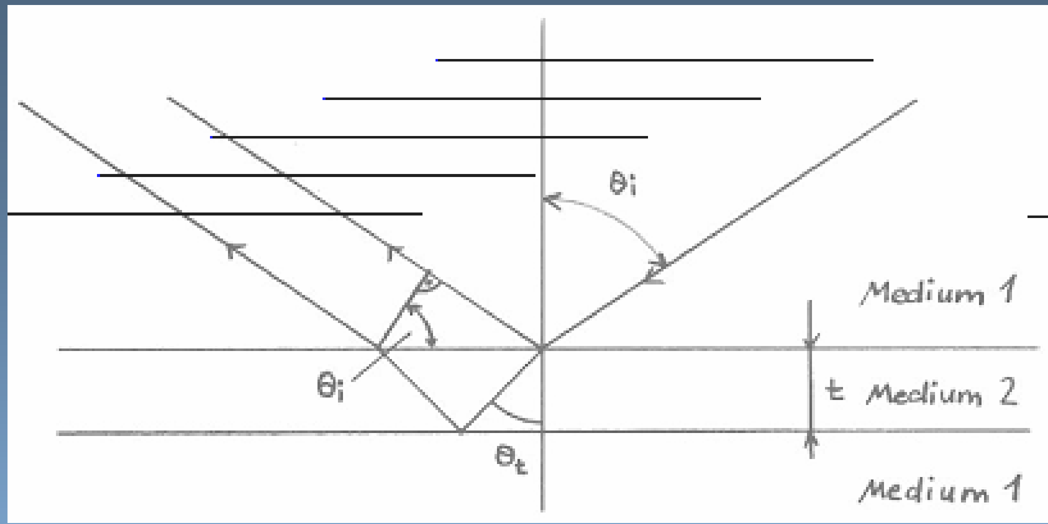


Ellipsometry Theory

The technique is based on the principle that the state of polarization of an electromagnetic wave changes on reflection from a surface. The change in polarization can then be related to the dielectric properties of the reflecting surface through the Fresnel reflection coefficients.



Ellipsometry Theory



Expression of the Reflected Electric Field

$$E_r = E_{ry} * \cos(\gamma) + E_{rz} * \sin(\gamma)$$

$$E_r = -E_i * \cos(\beta - \alpha) * \cos(\beta) * \cos(\gamma) * R_p - E_i * \sin(\beta - \alpha) * \sin(\beta) * \cos(\gamma) * R_p * e^{-j*\pi/2}$$
$$+ E_i * \cos(\beta - \alpha) * \sin(\beta) * \sin(\gamma) * R_s - E_i * \sin(\beta - \alpha) * \cos(\beta) * \sin(\gamma) * R_s * e^{-j*\pi/2}$$

Reflection Coefficient
Perpendicular component

$$R_s = \frac{E_{rs}}{E_{is}} = \frac{r_{s12} + r_{s23} * e^{-2*j*\beta*l}}{1 + r_{s12} * r_{s23} * e^{-2*j*\beta*l}}$$

Reflection Coefficient
Perpendicular component

$$R_p = \frac{E_{rp}}{E_{ip}} = \frac{r_{p12} + r_{p23} * e^{-2*j*\beta*l}}{1 + r_{p12} * r_{p23} * e^{-2*j*\beta*l}}$$

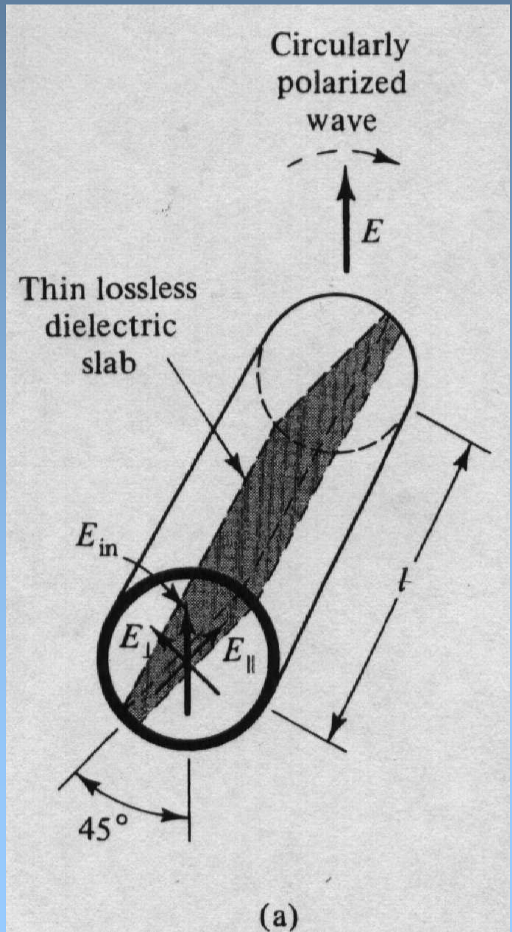
Phase
Difference

$$\beta * l = \frac{2 * \pi * t * \cos\theta_t}{\lambda_0} * \sqrt{\frac{\varepsilon_2}{\varepsilon_1}}$$

The Design of a Circular Polarizer.

This is the main part of the system.

Quarter-wave plate

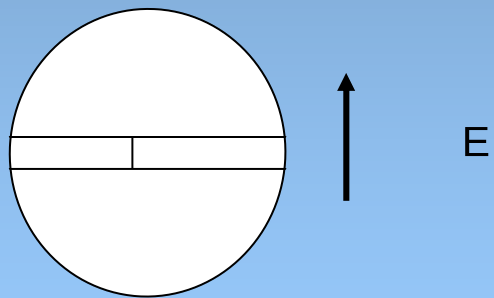


The material used is polystyrene. Three dielectric slabs of 1 mm, 0.5 mm and 3mm of thickness.

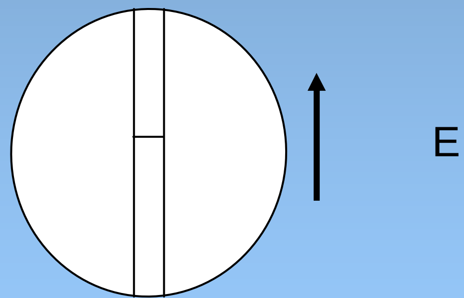
Measurements of the Circular Polarizer

Wiltron Model 360 Network Analyzer.
Wiltron Model 3621 Active device under test set 40 Mhz to 40 Ghz.

$$\Delta\theta = \theta_{\perp} - \theta_{\|}$$

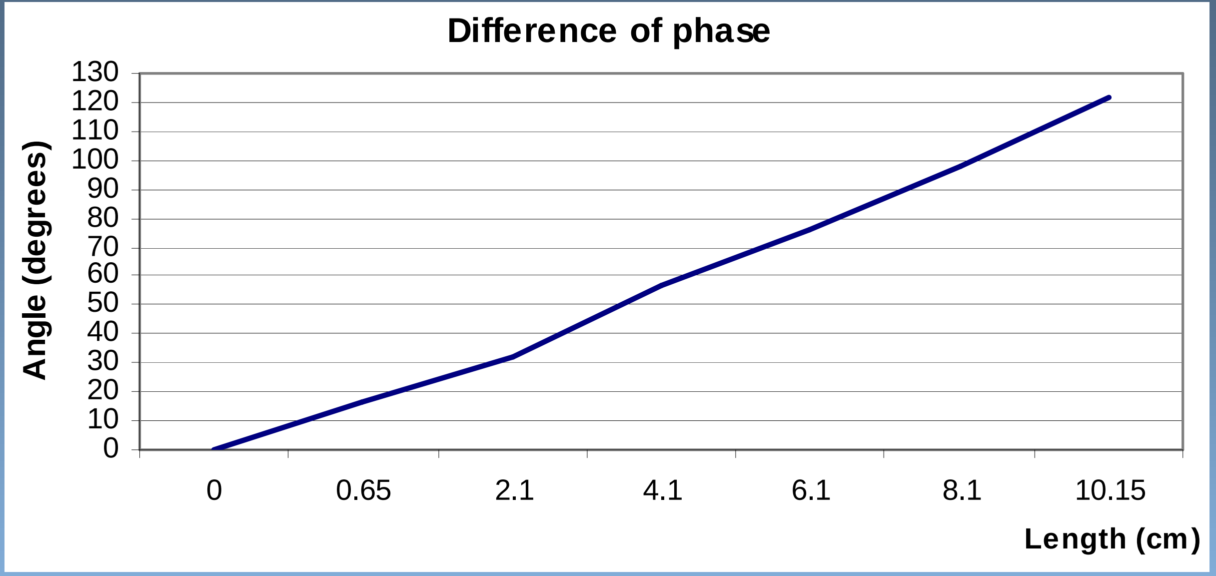


Dielectric slab at Horizontal Position produces little effect to the electric field. The phase of S_{21} is denoted by $\theta_{\perp}$. The electric field is perpendicular to the piece.



Dielectric slab at Vertical Position produces maximum effect to the electric field. The phase of S_{21} is denoted by $\theta_{//}$. The electric field is parallel to the piece.

Measurements of the Circular Polarizer



$$difference\ of\ \ phase\ lenghts \Rightarrow \ (\,Phase_{8.1cm}) - (\,Phase_{4.1cm}) = 98.17^{o} - 56.32^{o} = 41.85^{o}$$

$$\frac{(\,Phase_{8.1cm}) - (\,Phase_{4.1cm})}{length(8.1cm) - length(4.1cm)} = \frac{41.85^{o}}{40mm} = 1.04^{o}/mm$$

$$Phase\ required - Phase\ obtained_{4.1cm} = 90^{o} - 56.32^{o} = 33.68^{o}$$

$$Length\ required \Rightarrow \frac{33.68^{o}}{1.04^{o}/mm} + 4.1cm \approx 7.33cm$$

Implementation of the System

Receiver: Circular Horn connected to the Circular waveguide 1.

Test Area where materials are allocated.

Transmitter: Circular Horn connected to the Circular waveguide 2.

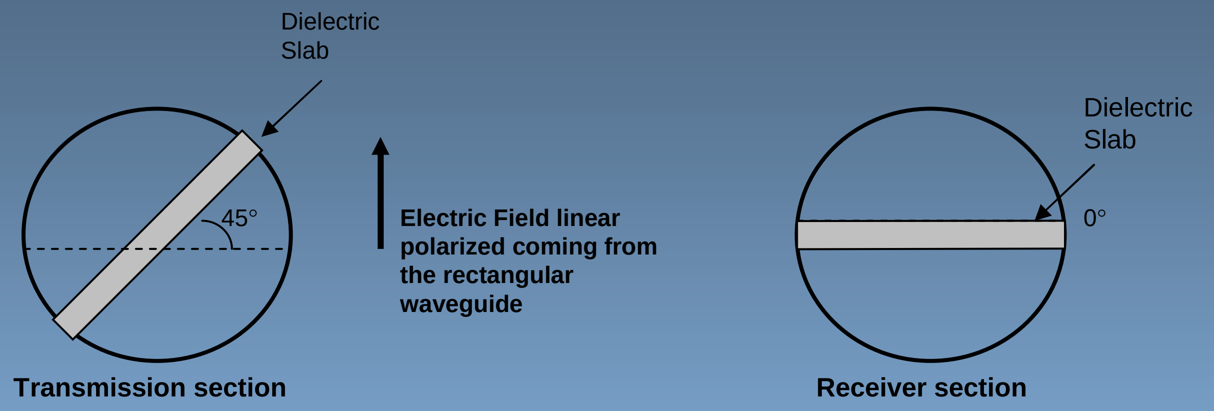
Receiver Section

Transition Section rotating from 0° to 180°. This is going to provide the rotation angle when there is extinction.

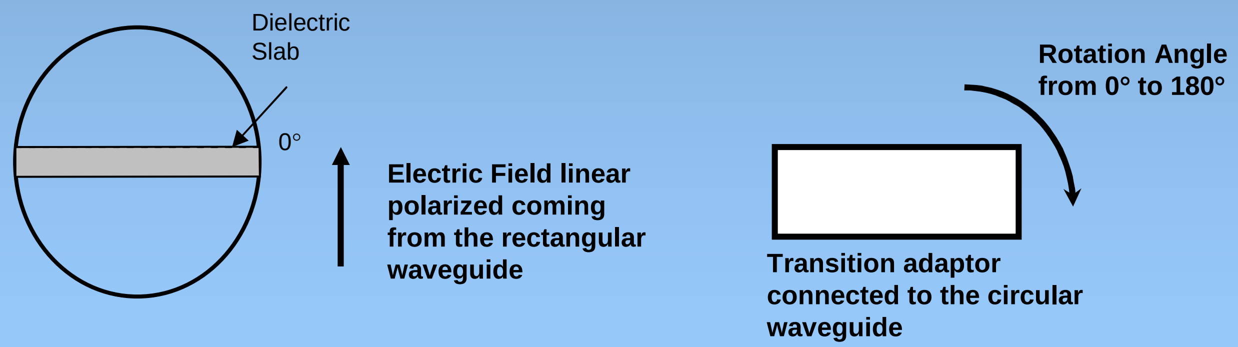
Transmitter Section

Final Measurements and Results

This view is taken looking from the input to the out put for both sections

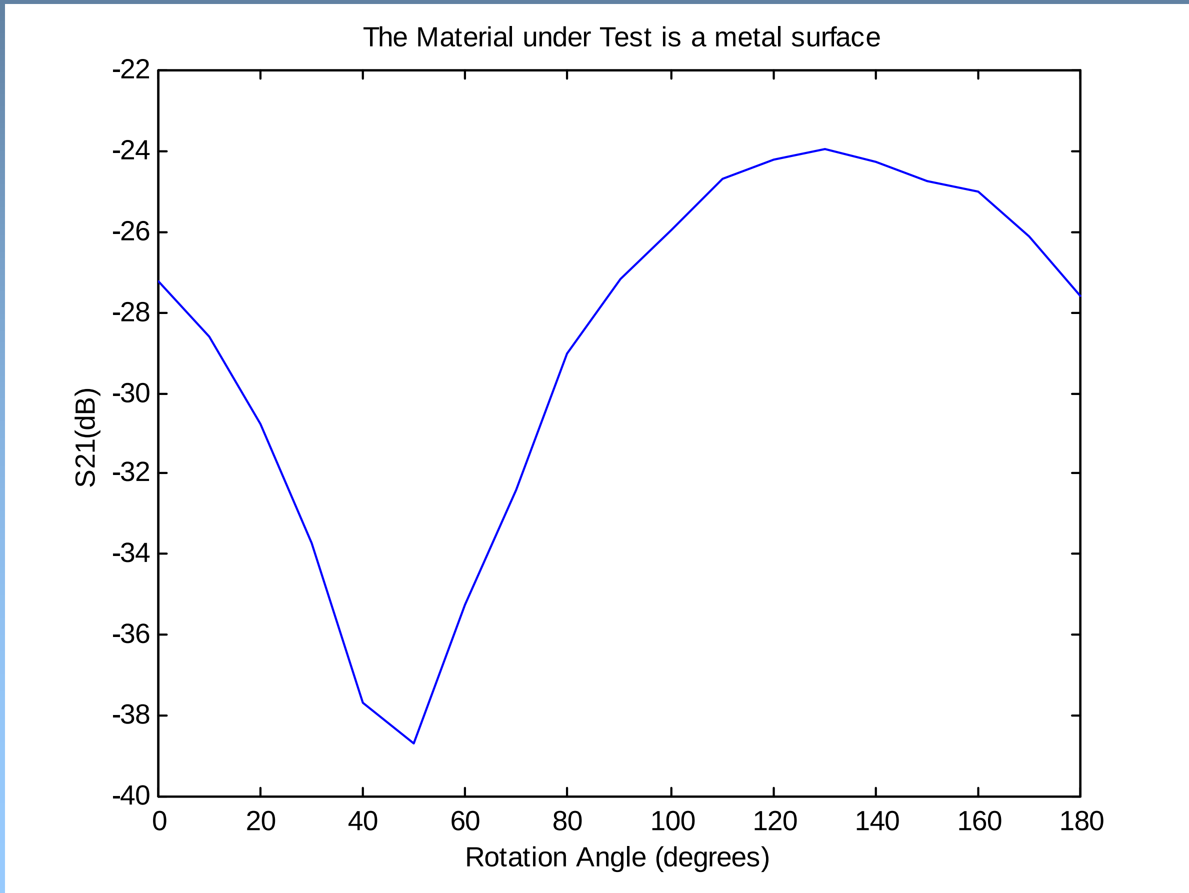


This view is taken looking from the input to the out put



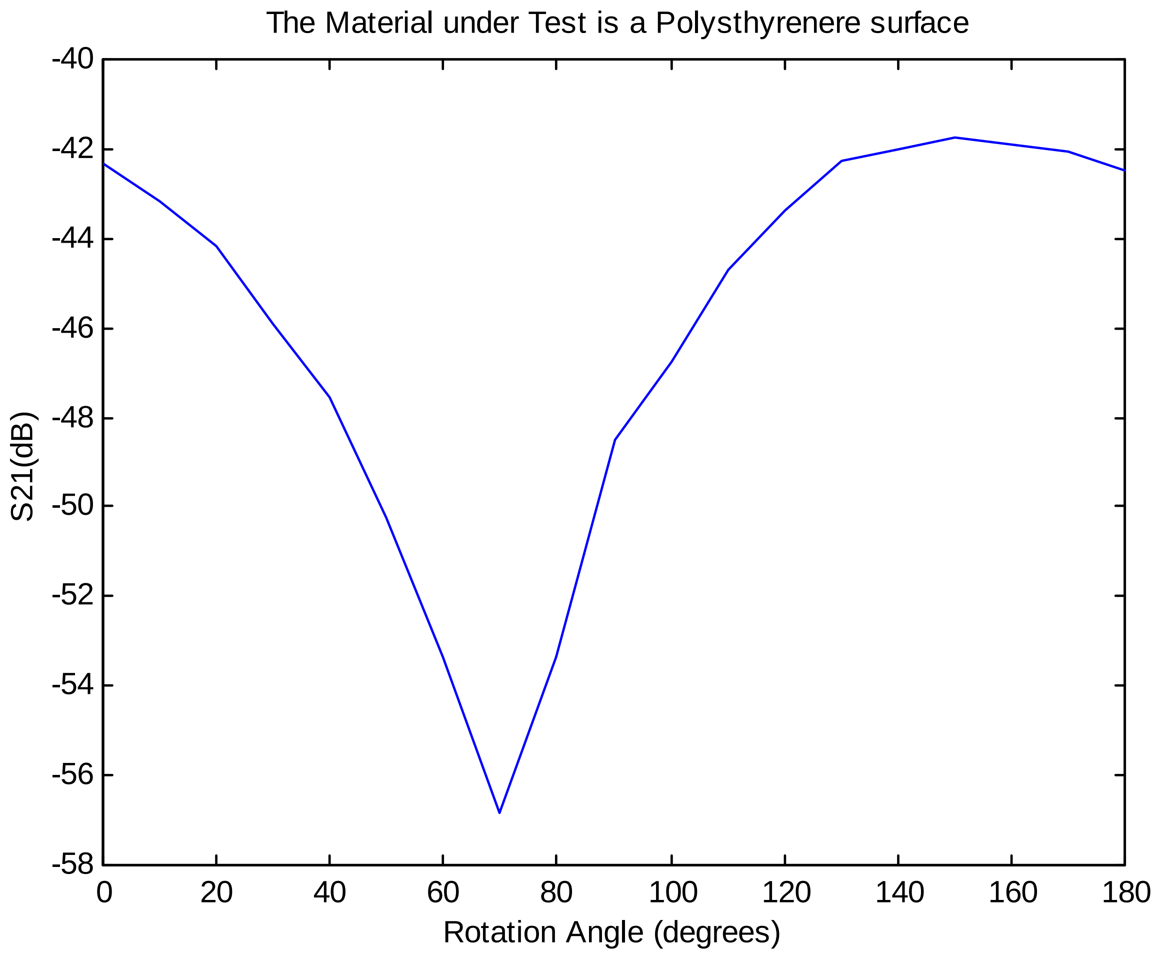
Final Measurements and Results

S_{21} magnitude versus the rotation angle when there is a metal surface under test of width = 2mm. E_r(50º)=0



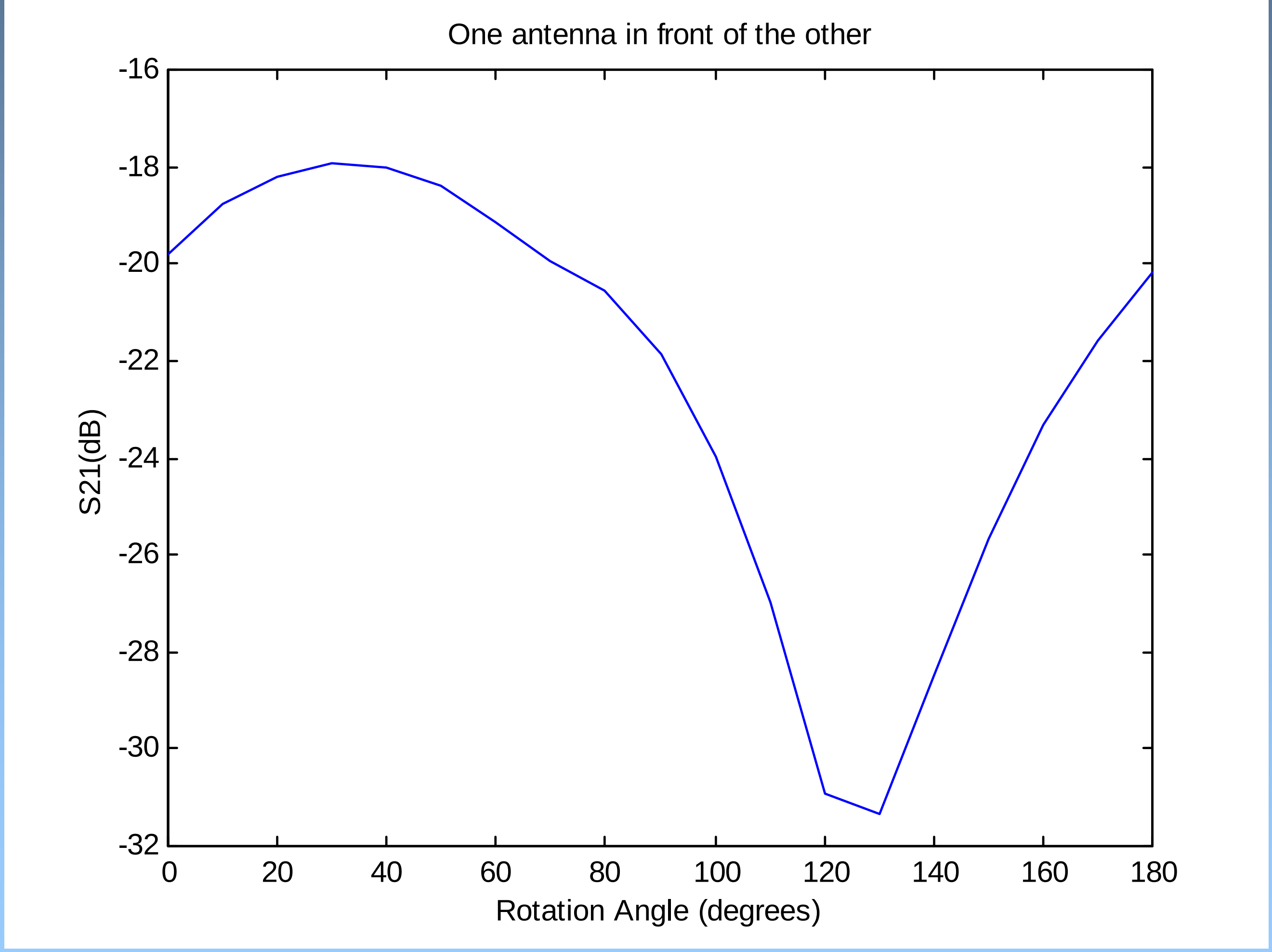
Final Measurements and Results

S_{21} magnitude in function of the rotation angle when there is a polystyrene surface under test of width = 3mm. E_r(70º)=0



Final Measurements and Results

S_{21} magnitude in function of the rotation angle when the transmitter antenna is placed in front of the receiver. E_r(135º)=0



Conclusions

The conclusion of this project is that the aims have been achieve with success. Bearing in mind that with this project was pretended to implement a microwave ellipsometry system using microwave technology to the well established optical techniques, it can be confirmed that the system is responding as it was expected from the theory.

Although this technique is not well developed it can be assure that microwave ellipsometry could have a more important role in the future, in research applications, such the study of the dielectric properties of the material used in microstrip circuits. And also to other systems that at the moment are implemented exclusively with optical devices and techniques. Because of the cost of this technology compared to optic technology it gives another advantage to the use of this techniques and technology compare with optical technology.