Polarisation of microwaves (Item No.: P2460203)

Curricular Relevance

Area of Expertise:	Education Level:	Topic:	Subtopic:	Experiment:
Physics	University	Electricity and Magnetism	Maxwell's Equations, Magnetism, Electromagnetic Waves	Polarisation of microwaves

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Intermediate	20 Minutes	10 Minutes	1 Student

Additional Requirements:

Experiment Variations:

Keywords:

Microwaves, electromagnetic waves, transverse waves, polarisation, Malus' law

Introduction

Overview

Electromagnetic waves impinge on a grating whose transmissivity depends on the rotation plane of the waves.

Fig. 1: Experiment set-up.

Equipment

Position No.	Material	Order No.	Quantity
1	Microwave set II, 110...240 V	11743-99	1

Overview of the parts of the microwave set.

Tasks

To determine if the electromagnetic waves produced by the transmitter are polarized, and to determine the direction of oscillation.

Set-up and procedure

First part – rotation of the transmitter

Set the experiment up as shown in Fig. 2.

Fig. 2: Set-up of the system.

Connect the microwave transmitter, receiver, and loudspeaker to the power supply via the three ways cable, and connect the receiver and the loudspeaker with the receiver - loudspeaker connection cable (Fig. 3).

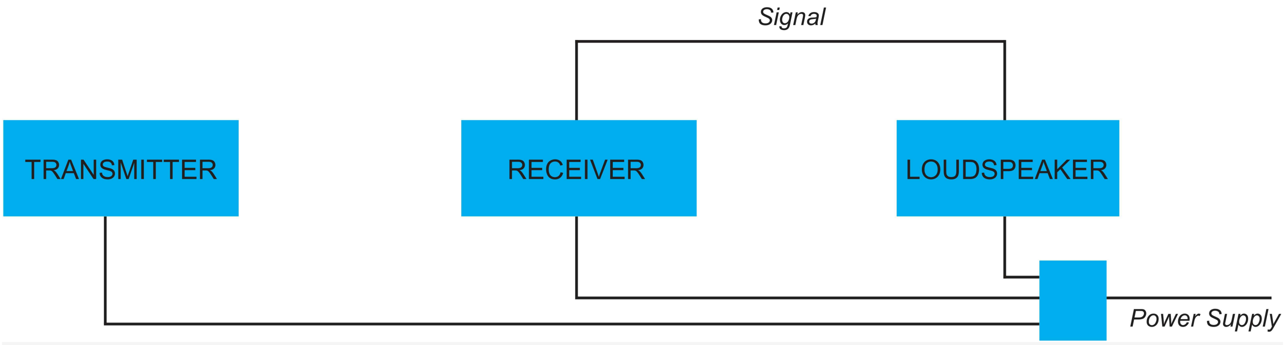

Fig. 3: Set-up of the experiment connections.

To assemble the articulated track with protractor, (1) first hook the short arm (having connection flange) to the long one (having pivot). (2) Then put the washer in the pivot. (3) Insert the protractor on the pivot at 0°, and (4) screw the black PVC yoke onto the pin (Fig. 4).

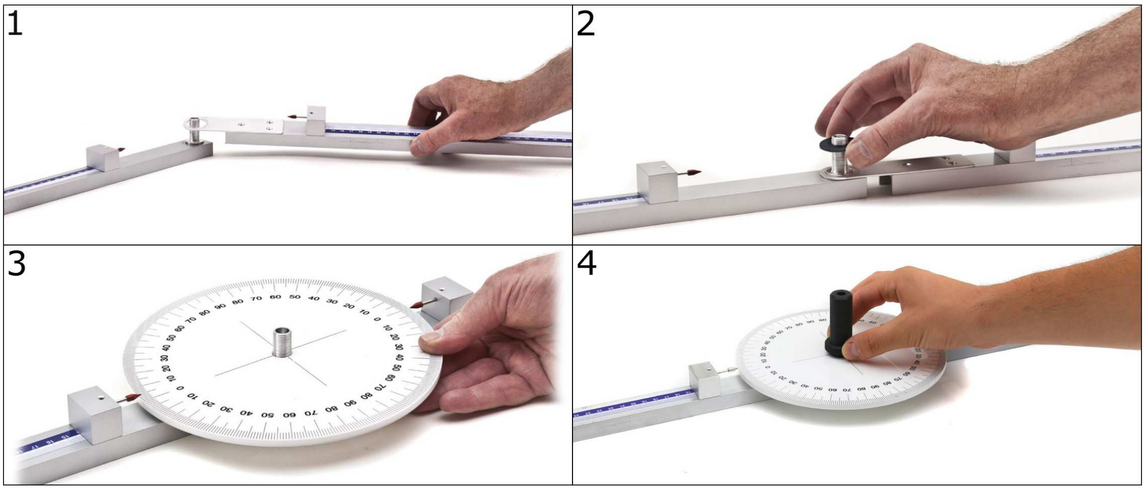

Fig. 4: Set-up of rail.

Fig. 5: Rotated transmitter.

At the back of the transmitter there is a protractor (see Fig. 5). To rotate the transmitter, slightly unscrew the handwheel, then the transmitter is able to be rotated 90° in both directions.

Now arrange the system as shown in Fig. 6, set the internal modulation and adjust the volume of the received signal to a medium value. Rotate the transmitter slowly, and record what happens to the signal as the transmitter slowly goes from the upright position (0°) to a perpendicular position (90°) to that of the receiver.

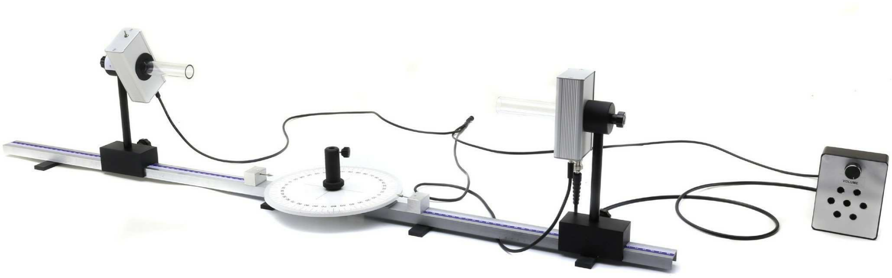

Fig. 6: Set-up with rotated transmitter.

Second part – rotation of the grating

With the following experiment, the direction of oscillation can be determined. Set up the system as shown in Fig. 2. Make sure internal modulation is activated, and adjust the intensity of the acoustic signal to an average value.

Now place the 11 slits grid between the transmitter and the receiver as shown in Fig. 7.

Fig. 7: Grating in horizontal position.

Turn the grid by 90° to a vertical grating as shown in Fig. 8.

Fig. 8: Grating in vertical position.

Take note of the acoustic signal based on the different rotation of the grating.

Note

During the experiment, do not stand in the direct vicinity of the beam path. The human body reflects microwaves so that the measurement result may be invalidated. The same applies to all types of metallic objects. If several experiments are performed simultaneously in a laboratory, ensure sufficient distance between the experiment stations in order to avoid interference signals caused by reflected radiation and/or scattered radiation from the other set-ups. Stay in the direct vicinity of the set-up only for adjusting the angle.

Theory and evaluation

Theory

Electromagnetic waves, i.e. also microwaves, can be described by an electric part, a magnetic part, and their respective directions of propagation, which are perpendicular to one another (see Fig. 9). The direction of propagation is described by the wave vector $\vec{k}$.

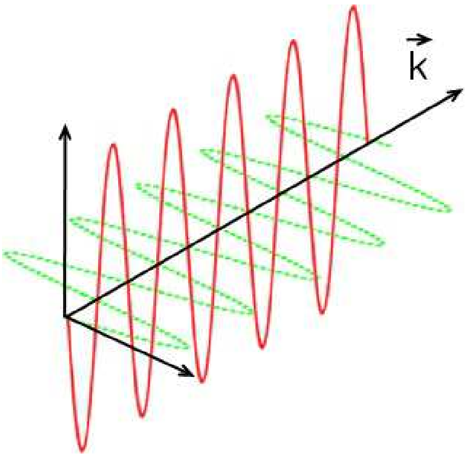

Fig. 9: Electromagnetic wave (schematic representation).

The direction of the oscillation is known as the *polarisation*. A distinction is made between linear polarisation in which the oscillation planes do not change, and circulation polarisation in which the respective oscillation plane rotates.

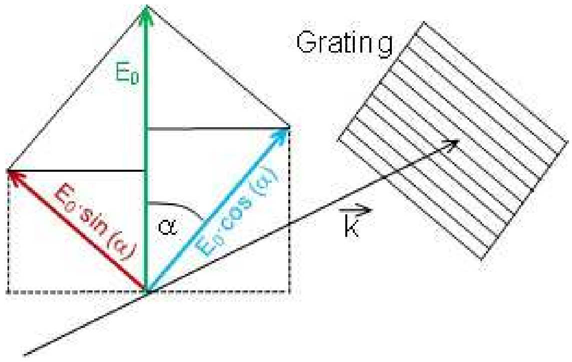

Fig. 10: Projections of the electric field vector.

When a polarised wave impinges on a grating, this grating is either transmissive, non-transmissive or partially transmissive, depending on the direction of polarisation. Looking at the projection of the electric field vector in the direction of the grating (see Fig. 10), there is the transmitted part $E(\alpha)$, depending on the angle α under which the polarised waves impinge on the grating.

$$E(\alpha) = E_0 \cdot \cos(\alpha) \tag{1}$$

An object that is transmissive with regard to electromagnetic waves depending on the angular alignment, is referred to as a *polariser*. Actually, the diode that is used for the experiment acts as a second polariser, which means that a second projection in the direction of reception of the diode must also be taken into consideration.
This is why the following applies to the measured intensity $I(\alpha)$:

$$I(\alpha) = I_0 \cdot \cos^2. \tag{2}$$

This relationship is known as "Malus' law". (The amplitudes E_0 are incorporated in the intensity measurement in a square manner.)

For a better understanding, the following analogy from the field of mechanics should be taken into consideration: If a rope is fed through a grating and tensed, and if then one of the ends of the rope is caused to oscillate, the wave will either pass through the grating or be blocked, depending on the direction of excitation.

Please note: Polarisation exists solely for transverse waves (oscillation perpendicular to the direction of propagation). Longitudinal waves (oscillation parallel to the direction of propagation), e.g. like in the case of sound propagating in the air, *cannot* be polarised.

Results

First part – rotation of the transmitter

It is found that slowly rotating the transmitter (when it is placed perpendicular to the receiver) results in the signal to be extinguished, as the receiver includes a polarization filter. If the speaker output is connected to a tester (not provided) and set for alternating voltage measurements, it can be verified that the intensity of the received signal is proportional to the cosine of the angle of rotation.

This experiment shows that the electromagnetic wave produced by the transmitter is linearly polarized, i.e. both the electric and the magnetic vector oscillate always in the same direction.

Second part – rotation of the grating

For the second part of the experiment, the direction of ocillation is able to be determined. It should be found that the acoustic signal maintained its intensity with the grating in the horizonal position. Upon rotation of the grating to a vertical position, the acoustic signal is extinguished. It is possible to conclude that the electric vector of the wave produced by the transmitter oscillates in a horizontal plane, as described in the theory section above.