

Related topics

Fresnel zones, Huygens' principle, Fraunhofer diffraction, diffraction at the slit.

Principle and task

Microwaves impinge on a slit and the edge of a screen. The diffraction pattern is determined on the basis of diffraction at these obstacles.

Equipment

Microwave transmitter w. klystron	11740.01	1
Microwave receiving dipole	11740.03	1
Microwave power supply, 220 VAC	11740.93	1
Screen, metal, 300×300 mm	08062.00	2
Multirange meter with amplifier	07034.00	1
Measuring tape, l = 2 m	09936.00	1
Meter scale, demo, l = 1000 mm	03001.00	2
Tripod base -PASS-	02002.55	1
Barrel base -PASS-	02006.55	3
Right angle clamp -PASS-	02040.55	1
Support rod -PASS-, square, l 250 mm	02025.55	1
G-clamp	02014.00	2
Adapter, BNC-plug/socket 4 mm	07542.26	1
Connecting cord, 500 mm, red	07361.01	1
Connecting cord, 500 mm, blue	07361.04	1

Problems

Determination of the diffraction pattern of the microwave intensity

1. behind the edge of a screen,
2. after passing through a slit,
3. behind a slit of variable width, with a fixed receiving point.

Set-up and procedure

The experimental set up is as shown in Fig. 1. The microwaves (9.45 GHz) used for detection are amplitude-modulated either internally with a frequency of 50 Hz or externally with any frequency (NF). With constant modulation (frequency, amplitude) the signal (e.g. 50 Hz), demodulated with a receiving diode, is proportional to the field strength and is measured with the measuring amplifier and the voltmeter. As it is an a.c.-signal no time-constant (damping) may be switched on.

For the diffraction at the edge, the screen is placed in the wave field so that it covers about half of the transmitter (direction receiving diode – transmitter). The receiving dipole is moved parallel to the screen. A distance of approx. 80 cm from the transmitter to the screen, and approx. 20 cm from the screen to the receiver, is recommended.

Fig.1: Experimental set up for determining the diffraction pattern of microwaves at the slit.

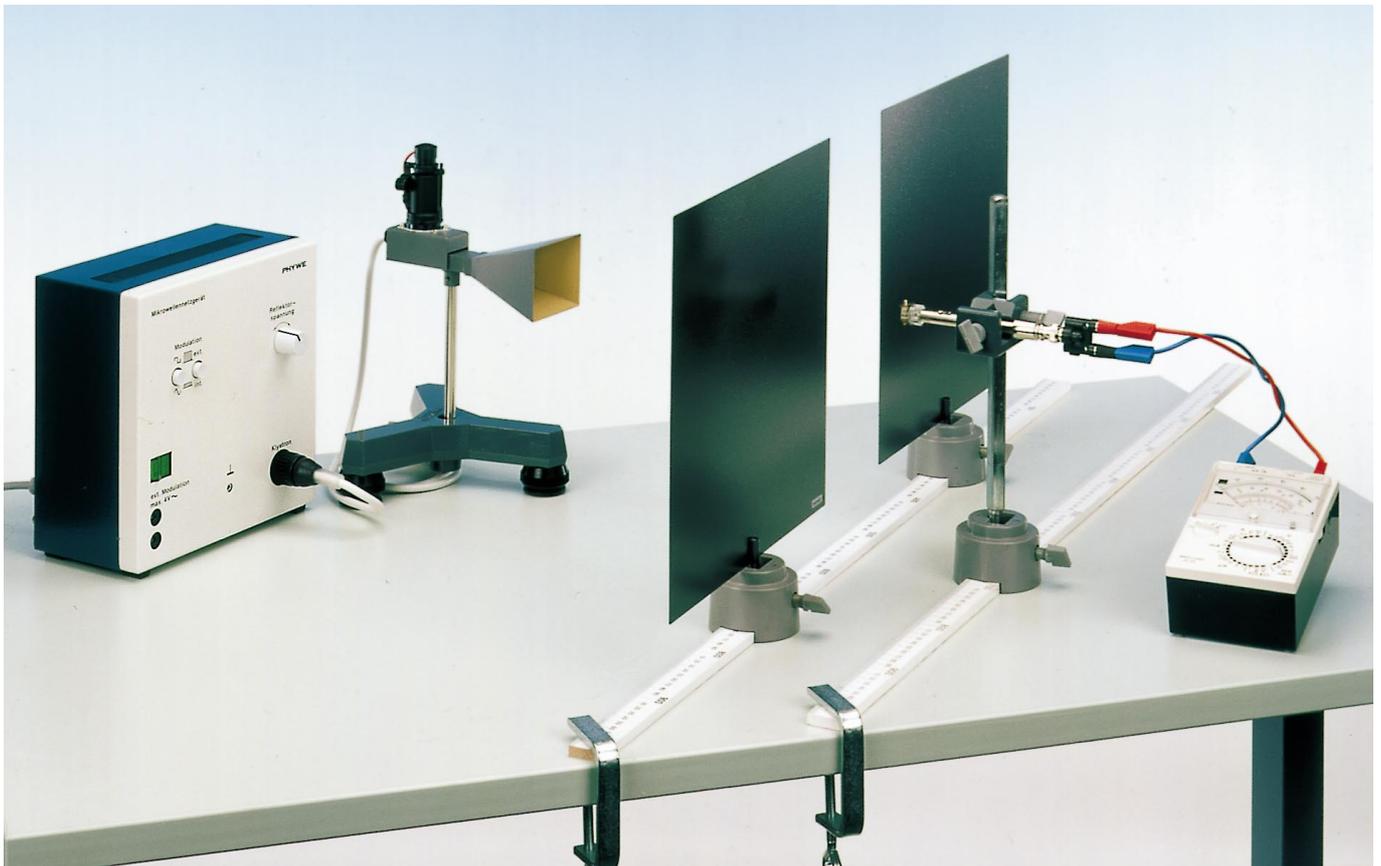
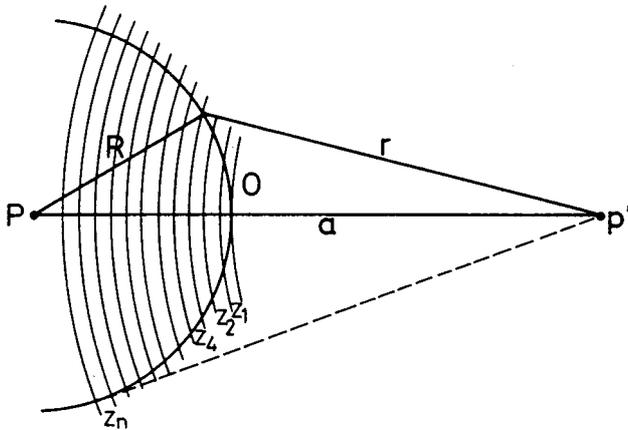


Fig. 2: Fresnel zones.



Two metal screens, the edges of which are 6 cm apart, form a slit. The microwave beam impinges at right angles on to the slit and is adjusted parallel to the screens using the receiving diode.

In problem 3, the receiving diode and one screen are set up as for the diffraction at the edge. The other screen is now moved so that a slit of variable width is produced.

Theory and evaluation

If a spherical wave with its origin at P strikes an obstacle at O , the intensity at the point of observation P' is calculated from the Huygens' principle according to which each point around the obstacle is the origin of a new spherical wave. The space is divided up into zones, commencing in the plane of the obstacle, so that the average distances from adjacent zones (Fresnel zones) to P' differ by $\lambda/2$ where λ is the wave-length. The radii of the zones, for small radii, using the symbols shown in Fig. 2, are approximately given by:

$$r_n = \sqrt{R(1 - R/\alpha)\lambda} \sqrt{n} .$$

As the zones interfere destructively because of the phase difference adopted, only about half the intensity of the innermost zone contributes to the total intensity at P' .

The diffraction of microwaves at the edge of a screen, due to interference of the wave directly incident with the cylindrical wave produced at the edge, produces maxima and minima on a line which runs parallel to the screen. The total intensity, expressed as a function of the distance ρ from the edge of the screen to this line, is:

$$I = C' \left[\int_{-\infty}^{\omega} \cos \left(\frac{\pi}{2} n^2 \right) dn \right]^2 + \left[\int_{-\infty}^{\omega} \sin^2 \left(\frac{\pi}{2} n^2 \right) dn \right]^2 .$$

C' is a constant; the upper limit ω is given by:

$$\omega = \rho \frac{2}{\lambda} \left\{ \frac{1}{R_0} + \frac{1}{R} \right\} .$$

$R_0 + R$ is the distance between the radiation source and the receiving point, R_0 and R being the respective distances between the plane of the screen and the source and the receiving point on the line connecting P and P' .

Maxima and minima occur if the difference $r-s$ between (a) the distance and (b) the perpendicular distance between the receiving point and the edge of the screen satisfies the following condition:

$$r-s = - \left(n + \frac{3}{8} \right) \lambda \quad \text{maximum}$$

$$r-s = - \left(n + \frac{7}{8} \right) \lambda \quad \text{minimum}$$

where n is a whole number.

If a wave field impinges on a slit of width d , and if $G(y)$ is the amplitude of the waves arriving at the slit, then a secondary wave is emitted from each point.

If the primary waves arriving at the slit and the waves measured at P' can be regarded approximately as plane waves (Fraunhofer diffraction), the radiation intensity produced at P' , by vectorial summation of all amplitudes, is:

$$I = \left\{ \int_C^d G(y) \exp \left(i \cdot \frac{2\pi}{\lambda} y \sin \alpha \right) dy \right\}^2$$

where α is the receiving point angle. If $G(y)$ is constant, this reduces to

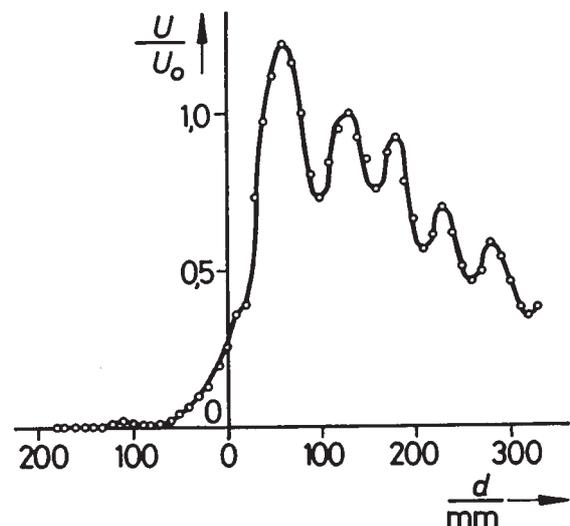


Fig. 3: Intensity distribution in the diffraction of the microwaves at the edge of a screen, parallel to the plane of the screen.

Fig. 4: Intensity distribution in the diffraction of microwaves at the slit as a function of the position along a straight line parallel to the plane of the slit.

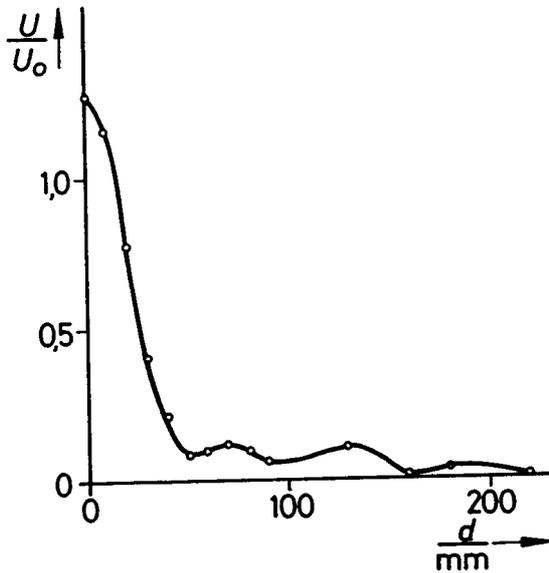
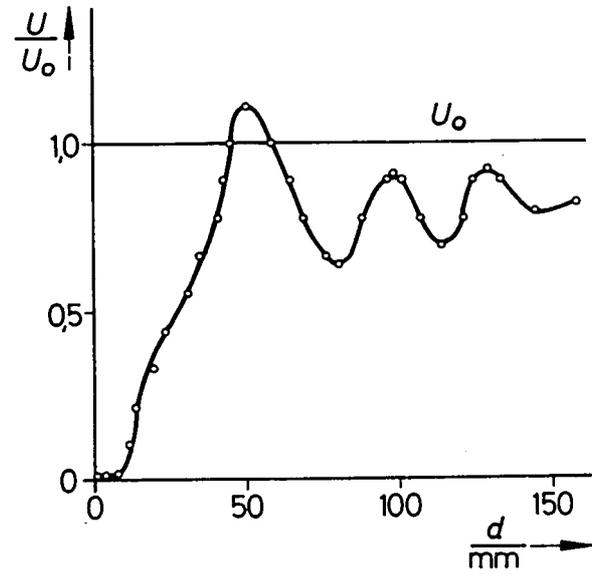


Fig. 5: Intensity distribution in the diffraction of microwaves at the slit as a function of the slit width.



$$I = \left(\frac{\sin \xi}{\xi} \right)^2$$

where

$$\xi = \frac{\pi d}{\lambda} \sin \alpha .$$

Minima for I are thus produced for

$$\sin \alpha = n \frac{\lambda}{d} .$$

In order to obtain a minimum, d must be greater than or equal to λ , i.e. $d \geq \lambda$.