Absorption of microwaves

Objects of the experiment

- Measuring the signal received by the E-field probe as a measure for the transmitted microwave power behind a dry and a moistened foam mat.

Principles

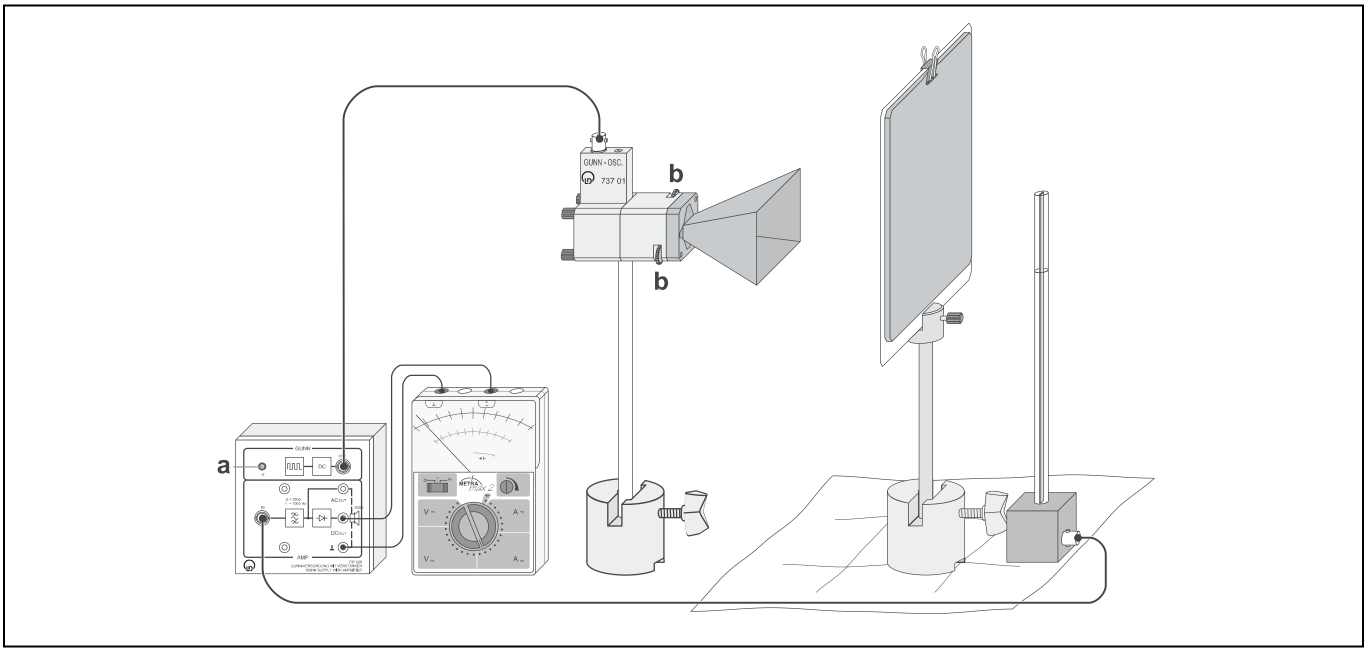
When microwaves pass through a medium, they are – like all electromagnetic waves – more or less dampened because part of the microwave power is absorbed in the medium. The proportion absorbed depends on the thickness of the medium and on the molecular structure. The warming which accompanies absorption is mainly due to inductive and dielectric effects, which are temperature and frequency dependent, i.e., the absorption of microwaves, too, depends on the temperature and on the frequency.

Inductive heating occurs above all in semiconductors and metals. Here the free electrons are accelerated in the alternating electric field, which leads to eddy currents.

In substances with polar molecules such as water or substances that contain water and polar plastics, dielectric heating takes place. Polar molecules align in the electric field thus being rotated back and forth in the alternating electric field of the microwave. Theses movements lead to internal friction and generate heat.

In this experiment, the absorption of microwaves by a moistened foam mat is compared with the absorption by a dry one. This investigation has two interesting aspects regarding technical applications. On the one hand, absorption of microwave power by media that contain water is used for drying and, in households, for cooking. On the other hand, microwave absorbers, which are formed so that they suit the intended purpose, are manufactured with plastic foam or rubber as a carrier, which is impregnated or coated with conductive or polar compounds.

Fig. 1 Experimental setup for measuring the absorption of microwaves



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Apparatus

1 Gunn oscillator 737 01
1 large horn antenna 737 21
1 stand rod 245 mm, with thread 309 06 578

1 Gunn power supply with amplifier 737 020

1 E-field probe 737 35

1 physics microwave accessories I 737 27

1 voltmeter, DC, $U \leq 10$ V . . . . e.g. 531 100

2 saddle bases 300 11

2 BNC lead, 2 m long 501 022

1 pair of cables, 100 cm, black 501 461

additionally recommended:

1 set of microwave absorbers 737 390

Setup

Remarks:

Measuring results may be distorted by reflection of the microwaves from vertical surfaces of objects close to the experimental setup:
Choose the direction of transmission of the horn antenna so that reflecting surfaces are as distant as possible.
If possible, use microwave absorbers to build up a reflection-free measuring chamber.

If several experiments with microwaves are run at the same time, neighbouring Gunn oscillators can interfere:
Try to find a suitable arrangement of the experiments.
In this case, use of microwave absorbers is mandatory to set up separate reflection-free measuring chambers.

The varying magnetic field of microwaves can induce voltages in cable loops:
Avoid cable loops.

Safety notes

Attention, microwave power! The microwave power released from the Gunn oscillator is approx. 10–15 mW, which is not dangerous to the experimenter. However, in order that students are prepared for handling microwave systems with higher power, they should practise certain safety rules.

- Never look directly into the transmitting horn antenna.
- Before positioning anything in the experimental setup, always disconnect the Gunn oscillator.

The experimental setup is illustrated in Fig. 1.

– Attach the Gunn oscillator to the horn antenna with the quick connectors **(b)**.
– Align the horn antenna horizontally, screw the 245 mm long stand rod into the corresponding thread and clamp it in a saddle base.
– Connect the Gunn oscillator to the output OUT via a BNC lead. Connect the E-field probe to the amplifier input and the voltmeter to the output DC OUT of the Gunn power supply.
– Set up the E-field probe in front of the centre of the horn antenna.
– Set the modulation frequency with the frequency adjuster **(a)** so that the multimeter displays maximum received signal.
– Put a piece of absorbent cloth or paper under the setup, and set up the dielectric plate (3 mm) from the physics microwave accessories I at a distance of approx. 100 mm from the horn antenna.
– Look for a distance between the E-field probe and the dielectric plate so that the measured voltage is as high as possible.

Remark:
As the microwaves are also slightly reflected at the housing of the E-field probe, the measuring signal exhibits a small standing wave ratio even behind the dielectric plate.

Carrying out the experiment

– Read the received signal, and take it down.
– Clamp the foam mat behind the dielectric plate, and measure the received signal.
– Thoroughly moisten the foam mat with water, clamp it behind the dielectric plate again, and measure the received signal.
– Allow the foam mat to dry for half an hour, and repeat the measurement.

Measuring example and evaluation

Tab. 1: received signal U of the E-field probe, and absorption A calculated from it

material	$\frac{U}{\text{V}}$	A
dielectric plate (PVC)	4.1	
dry foam	4.05	1 %
wet foam	1.8	56 %
moist foam	2.5	39 %

Under the assumption that the reflection at the dielectric plate can be neglected, the proportion A absorbed in the foam mat is calculated from the microwave power P_0 measured without foam mat and the power P measured behind the foam mat. The output voltage U of the E-field probe is proportional to the microwave power P, and therefore

$$A = \frac{P_0 - P}{P_0} = \frac{U_0 - U}{U_0}$$

Result

The wet foam mat absorbs a significantly greater proportion of the microwave power than the dry foam mat.

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