UNILAB®

Notes for use No. 1

3cm. ELECTROMAGNETIC WAVE APPARATUS

LIST No. 044.571, 045.671, 042.871, 045.673 etc.

GENERAL DESCRIPTION

THE TRANSMITTER 044.571 incorporates a reflex klystron and this is adjusted to produce a wave length of 3.2cm. at approximately 25mW.

POWER SUPPLY 042.871 is normally supplied for use on 220/240v 50Hz mains supply and provides heater, resonator, (+ve 300v) and reflector (variable -ve 150/250v approx.) potentials for the transmitter and these are interconnected by a multiway plug and cable.

Modulation of the 3.2cm. wave at 100Hz or approximately 1kHz is obtained by setting the 'int mod' switch to the appropriate setting. The off position disconnects the internal modulation and provides a steady output from the transmitter, more suitable for when meter indicators are used with the receiver or probe detector.

An external modulator may be connected via the normally linked 'ext mod' sockets when the socket 'r' is the side going directly to the klystron reflector. Any external modulator must provide a D.C. path of not more than about 5K ohms impedance and the 'int mod' switch set to off.

Note:— The socket marked with an earth symbol is provided for use with the pulse modulator designed for the Nuffield 'A' level Physics' Velocity of EM Wave experiment and details of this will probably be published by the Nuffield Science Teaching Project in due course.

The 'adjust for klystron' control varies the klystron reflector potential and this should be adjusted with care to a point where oscillation takes place. There may be two or more of these 'resonance' positions and the more clockwise one will give the greatest output from the transmitter.

RECEIVER 045.671 incorporates a silicon microwave diode mounted in a resonant cavity across the waveguide and the rectified signal is indicated directly on the built-in 100uA moving coil meter. This latter may be used for other work such as with the 045.673 probe type receiver by removing the white panel link and making connection to the 4mm. insulated sockets.

The alternative **PROBE RECEIVER 045.673** makes use of the same silicon diode and resonant cavity as the horn type receiver 045.671 but without the horn and waveguide assembly the rectified signal is reduced by a factor of 10 approximately. However its 360° field of reception makes the Probe type receiver more suitable for many of the interference experiments. The Probe receiver may be connected directly to a 50uA or 100uA meter (as in the 045.671 receiver) or if the Unilab 081.115 230mm. 1mA Demonstration meter is available this may be operated by making use of the battery driven **METER EXPANDER 083.611.**

Another very effective method is to connect **THE GENERAL PURPOSE AMPLIFIER 042.841** to the Probe or Horn Receiver and drive any type of D.C. demonstration meter from the low impedance output sockets with an 0A 91 or similar diode in one lead.

It is also often convenient to modulate the 3.2cm. wave and use an audio amplifier and loudspeaker to indicate points of maximum and minimum as wave patterns come in and out of phase. See power supply note re. 'int mod' switch position and check 'adjust for klystron' control.

Suitable amplifier/loudspeaker units are the Unilab **053.842 300mW TRANSISTOR** type and the 042.841 3.6w General Purpose type, both of which have screened input leads which plug directly into the Horn or Probe type of receiver.

PUTTING INTO USE

In the horn type transmitter and receiver the electric field is across the short dimension of the waveguide and is vertical when the instruments are standing upright. In the probe receiver the electric field is also vertical or in line with the resonant cavity long dimension.

This equipment should be used on a non metalic surface and nearby metal objects can effect its performance considerably.

Some users have found it helpful to cover the working surface with a sheet of white paper or card about 1 metre square on which to later mark optimum positions for the transmitter, receivers, reflectors etc. in the various experiments and in some cases draw in with a large pair of compasses the actual wave patterns once the free space $\frac{\lambda}{2}$ has been found by experiment. Alternatively the horn type units may be mounted in heavy retort stands well above the bench top by using the screw-in plastic handles provided.

Where the received signal is too large for the meter in a Horn type receiver, set 'int mod' switch on power unit to 100Hz and use one of the more anti-clockwise settings of the 'adjust for Klystron' control, alternatively a small 5 to 10K ohms resistor can be substituted for the white panel link on the receiver front panel.

EXPERIMENTS

POLARIZATION. Rotating the electric field of either the Transmitter or Receiver 90° with respect to the other will produce a zero indication at the Receiver, giving proof of polarization. Further proof can be obtained by using the Polarization Indicating Grille 041.174. With the Transmitter and Receiver erect, placing the Grille between them with its rods also erect almost all the energy is absorbed but with the Grille rods at 90° to the electric field, little or no current flows in them and attenuation is almost zero.

ROTATION OF PLANE OF POLARIZATION

Arrange the Transmitter and Receiver on retort stands above the bench with their electric fields at 90° i.e. zero signal. Introducing the Grille between them with its rods at 45° will produce a rotated component.

OPTICAL ACTIVITY ANALOGUE

Arrange as above, preferably with the Receiver vertical so that its meter can be seen. Introducing between the Transmitter and Receiver a quantity of small copper wire Spirals, with Left Hand

or Right Hand 'threads' will produce a Left Hand or Right Hand rotation of the Plane of Polarization as in quartz crystals. The Spirals may be suspended in a regular form as in 141.174 or in random form using separate Spirals 141.176 each suspended in an expanded polystyrene Sphere 2cm. to 3cm. in diameter. 120 Spirals in either form will produce a rotation of about 10° and it is helpful to build an expanded polystyrene sheet 'table' to support the spheres in a cardboard box or plastic bag or other arrangement.
See Foxcroft & Crumpler, School Science Review, November, 1966.

REFLECTION & PENETRATION

Placing various materials directly between the Transmitter and Receiver will indicate the degree of Penetration and directing a signal from the Transmitter onto a surface and reflecting it to the Receiver will indicate Reflecting properties. It will be found that for example glass, Perspex, hardboard etc. reflect and also allow penetration and may be considered as 'half silvered' mirrors at these wavelengths.

MEASUREMENT OF $\frac{\lambda}{2}$

Method 1

Stand the Probe Receiver about 75cm. in front of the Transmitter horn. Indicate the received signal by connecting an Audio Amplifier/ Loudspeaker 053.842 or 042.841 and modulate the Transmitter or for a more precise indication connect a sensitive meter and switch off modulation. Place a Metal Reflector 041.171 or 041.172 behind the Probe Receiver and move this slowly between say 15cm. and 30cm. from the Probe, causing it to receive a direct and a reflected signal. Mark carefully on the bench top, positions of the reflector which produced minimum signal, these being where the direct and reflected signals are in anti phase. $\frac{\lambda}{2}$ is an average of the spacings.
See Fig. 1.

Method 2

Stand the Transmitter about 50cm. in front of and facing a half silvered reflector, e.g. 141.173 with a Probe or Horn type Receiver slightly behind the Transmitter to receive the reflected signal. Behind the 'half silvered' reflector move a metal reflector 041.171 and note minimums or anti phase position as in method 1.
See Fig. 2. THIS EXPERIMENT MAY ALSO BE CONSIDERED AS AN ANALOGY TO THIN FILM INTERFERENCE.

STANDING WAVES

With the Transmitter signal directed towards a metal reflector at a distance of about 50cms., use a Probe type Receiver to explore the region between them, indicating a stationary wave pattern.

LONG DISTANCE RADIO

With the Transmitter modulated at say 100Hz and a Horn type Receiver connected to an Audio Amplifier/Loudspeaker place them about 1 metre apart and pointing towards each other. Tilt the horns upwards by resting the units on the plastic handles provided and hold a metal plate to reflect the transmitted signal down to the Receiver as from an ionised layer in the atmosphere.

RADAR

Arrange as before but place the Transmitter and Receiver side by side with the horns pointing in the same direction. Again use a metal plate to represent an aircraft.

DIFFRACTION

Using one or more metal plates placed vertically with their surfaces facing and at right angles to the Transmitter at a distance of 20cm. to 30cm. and in the path of a signal to a Horn or Probe type Receiver, most diffraction experiments can be shown, for example 'At a straight edge' – use one large metal plate 041.171 covering half the radiated field. The Receiver will show signal spread into the 'shadow' area. 'At a single 'slit' – use two large metal plates with a 1.5cm. to 2cm. 'slit' between them. A narrow metal plate 041.172 placed directly in front of the Transmitter and at a distance of about 30cm. produces an interference pattern in its 'shadow' and this can be plotted by either type of receiver.
See Fig. 3.

A DIFFRACTION GRATING can be made by the student, using strips of aluminium foil pasted to a sheet of hardboard or Perspex. C. Pirt of Barnet College has suggested about 15 strips 2.5cm. wide by 30cm. high with 1cm. spacing to give a first order diffraction of 55°

See also Dr. R. Diamond School Science Review, November, 1962.

INTERFERENCE

The Probe type Receiver connected to an Audio Amplifier/ Loudspeaker is very suitable for most interference experiments. Set modulation switch on power supply to 1000Hz or 100Hz. For YOUNG'S EXPERIMENT, place in line one 21cm. 041.171, one 6cm. 041.172 and a further 21cm. metal plate with a 1cm. to 2cm. spacing between each to form the 'slits'. Position the Transmitter about 35cm. away, behind the slits and on a centre line between them. Move slowly a Probe Receiver in an arc of about 50cm. radius in front of the slits to investigate the interference pattern.

See Fig. 4.

A LLOYD'S MIRROR EXPERIMENT is quickly set up. Use one 21cm. metal plate facing the operator. Place the Transmitter in front and to the left with its horn directed to the centre of the metal plate at an angle of 30° with respect to the plane of the reflecting surface and 30cm. to 40cm. away. From the right hand edge of the reflecting metal plate move forward in a straight line a Probe type Receiver connected to an Audio Amplifier/Loudspeaker to show the points of reinforcement and cancellation of the direct and the reflected wave.

See Fig. 5.

A form of **MICHELSON'S INTERFEROMETER** can be set up using a hardboard plate 041.173 as the 'half silvered' mirror. Either the Horn or Probe type Receiver is suitable and a path correcting plate is not necessary at these wavelengths. Position the 'mirrors' as in a normal Michelson with the Transmitter as the light source and a Receiver as the eyepiece and both 30cm. to 40cm. from the 'half silvered mirror'

See Fig. 6.

FRESNEL ZONES

These again can be student made from aluminium foil but Unilab have produced a ready made kit comprising a Perspex Sheet 35cm. x 35cm. Zone A is a disc of 18 s.w.g. Aluminium 16.5cm. diameter. Zone B 16.5cm. ID x 23.3cm. OD, Zone C 23.3cm. ID x 28.5cm. OD and Zone D 28.5cm. ID x 32.6cm. OD and all listed 141.173. Raise the Transmitter and Horn Receiver on support blocks 141.172 (65mm. above the bench) facing each other with the zone plate midway between. Zones B or D should increase the meter reading by about 2:1 and B and D together about 3:1 with the Transmitter and Receiver horns 80cm. apart. At this 80cm. spacing Zone C will greatly reduce the signal but on increasing the Transmitter and Receiver spacing to 104cm. Zone C will produce a 2:1 magnification and the disc A a slight gain of 7:5. See Dr. R. Diamond, School Science Review, November, 1963.

REFRACTION Fig. 7.

3cm. waves are refracted by blocks or prisms of wax, plastic or the hollow perspex vessels filled with paraffin or carbon disulphide. Examples of the latter are 041.175 60° and 041.176 45° prisms and 041.177 semi circular lens. Glass lenses also converge these waves. Unilab have a 27cm. diameter mounted wax lens 041.179 with a focal length of 50cm. designed particularly for a Bragg diffraction type experiment.

TRANSITION FROM TOTAL INTERNAL REFLECTION TO TOTAL TRANSMISSION EXPERIMENT

Using two 45° prisms 041.176, a Horn type Receiver to indicate the reflected wave and a probe type Receiver with Audio Amplifier/ Loudspeaker to indicate the total transmission wave, arrange as Fig. 8. With the prisms separated by 5cm. or more a full reflected signal is indicated on the Horn Receiver meter and there is no signal at the Probe. On bringing the prisms close together the reflected signal becomes almost zero and the wave passes fully to the Probe as though through a solid dielectric. Intermediate spacings produce a gradual transition from total internal reflection to total transmission. See Dr. R. Diamond, School Science Review, November, 1963 for full mathematical treatment, a reprint of which is available from Unilab, Clarendon Road, Blackburn, England.

BRAGG SCATTER. Fig 9 shows a layout in which a 'crystal' made from metal spheres embedded in expanded polystyrene sheet is used in an exact analogy to the diffraction of X rays by a crystal. Alternatively solid expanded polystyrene spheres 3 to 4cm. in diameter and arranged in the required form may be rotated on the turntable to produce a satisfactory result.

The crystal 141.175 in Fig. 9 was designed by P. S. Coles of Loughborough College. 120 aluminium foil spheres 12.5mm. in diameter and spaced in a 4cm. cubic form give a typical first order diffraction at 48° (2θ) on the turntable when investigating the 1.0.0 face. In the Bragg equation $2d \sin \theta = n\lambda$, $d = 4$cm., $\theta = 24°$ $\lambda = 3.2$cm. approximately.

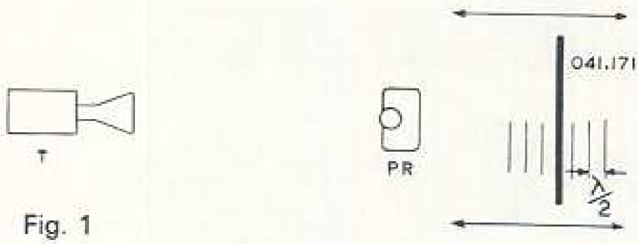

Fig. 1

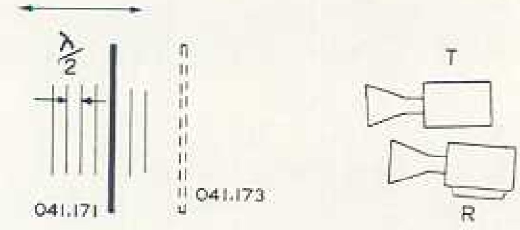

Fig. 2

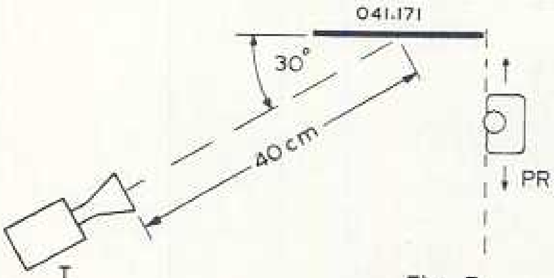

Fig. 5

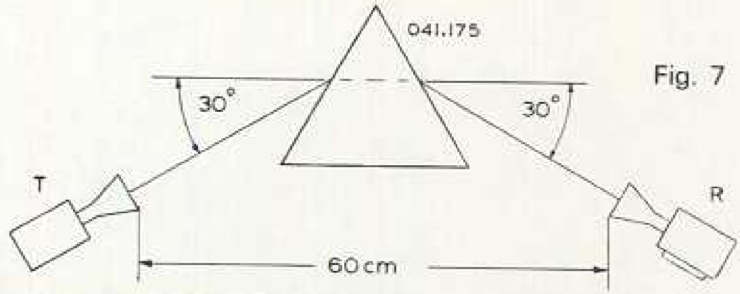

Fig. 7

Fig. 3

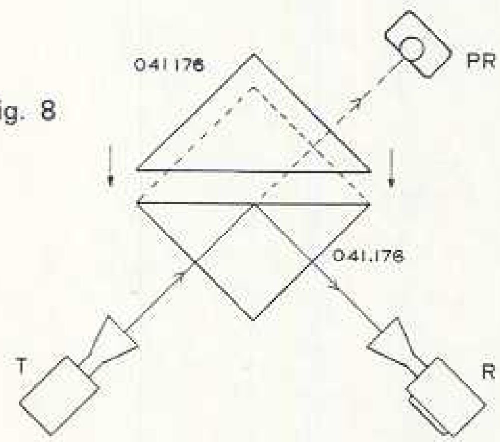

Fig. 8

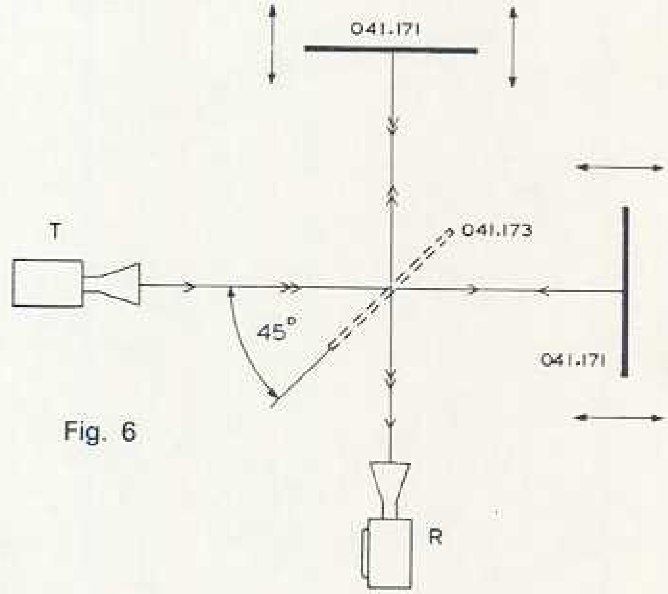

Fig. 6

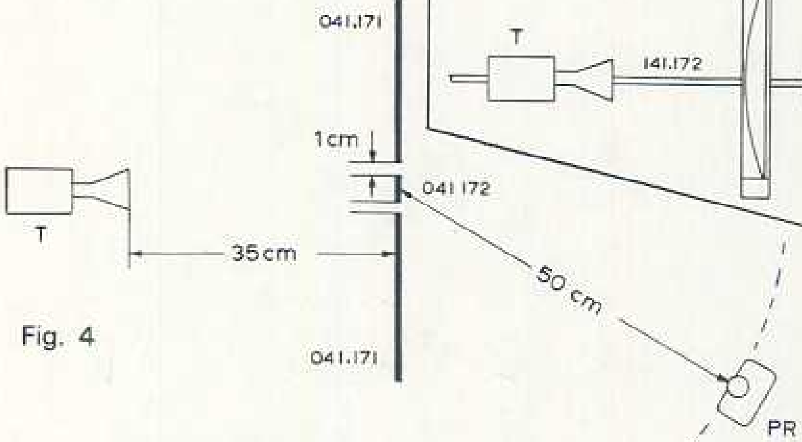

Fig. 4

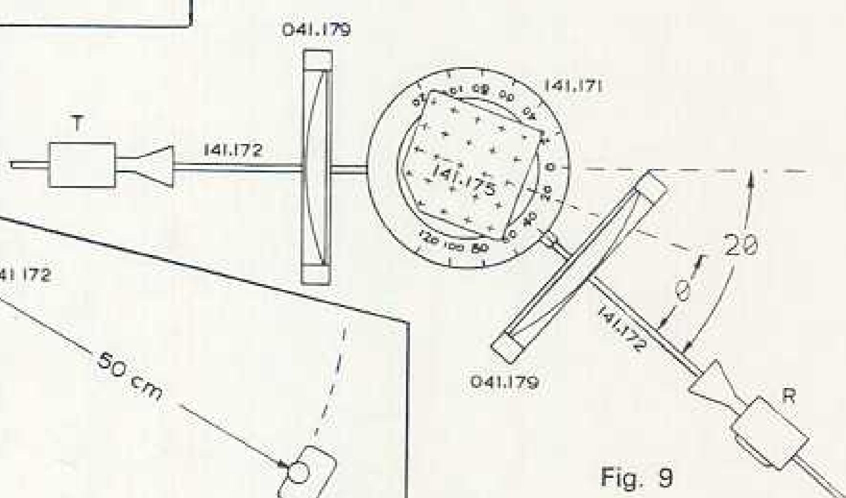

Fig. 9