"Infra-red—Its Problems and Possibilities"

THE FOLLOWING IS AN EXTRACT FROM THE SYNOPSIS OF A LECTURE GIVEN TO THE RADAR ASSOCIATION ON NOVEMBER 14th, 1956

THERE is a well-known saying which goes "I shall not believe it until I see it with my own eyes." The eye is, of course, a very well designed receiver of electro-magnetic radiation working on a narrow band of wavelengths around 1/2,000th of a millimetre, i.e., 0.5 microns (1 micron is one-millionth of a metre). It sees each particular wavelength as a colour : for example, at 0.4 microns it sees violet and at 0.75 microns it sees red. Beyond 0.75 microns, where the eye ceases to respond, and up to 1,000 microns lies the infra-red. The region immediately beyond 1,000 microns, or 1 millimetre, is the radar spectrum well known to the Radar Association, and although the first wavelength to be used for equipment works on 8 millimetres (high resolution airfield radars) this is only because techniques are as yet insufficiently developed on wavelengths below 8 millimetres.

The main advantage of short radar wavelength is that it gives high resolution with a small aerial size. The resolution of a radar act is proportional to D/λ where D is the diameter of the scanner and λ the wavelength. Thus on X band (wavelength 3 cm.) a radar with a 1ft. diameter scanner can separate out two aircraft at 5 miles range if they are 1 mile apart. On a wavelength of 8 millimetres it could distinguish between them if they were ¼ mile apart. In the infra-red on a wavelength of 1/500 millimetre (2 microns) an infra-red receiver even with a 3in. diameter scanner could resolve the separate engines on a single aircraft at a range of 5 miles.

Transmission

All warm bodies transmit infra-red radiation, the amount and wavelength depending on the temperature of the body and on its surface. The amount transmitted depends on the fourth power of the temperature, i.e., $P \lambda T^4$. Thus a body at 1,000°K (°K = °C + 273), say, a jet engine, transmits more than 250 times as much power as a kettle of boiling water with a temperature of 373°K. In addition, the band of wavelengths transmitted is also a function of the temperature, the wavelength λ max. on which maximum power is transmitted being given by the simple formula

$$\lambda \text{ max.} = \frac{3{,}000}{T^\circ K} \text{ microns.}$$

Thus we see that for the following bodies the λ max. is as follows

Radiating Body	Temperature °K	λ max. in microns
Sun	6,000	0.5 (visible light)
Jet aircraft engine ...	1,000	3.0
Piston-engined aircraft	750	4.0
Kettle with boiling water	373	8.0
Human body ...	300	10.0

Thus, theoretically, we have only to make a receiver to work on the various wavelengths and we can detect the body concerned—the hotter the body the easier the problem is because the more power it transmits.

Reception

Broad-band receivers which receive all infra-red wavelengths equally well have been known for many years. These are the thermal detectors known as radiation thermo-couples and bolometers. They rely for their action on the warming-up effect of the incoming radiation and in general they are too sluggish in their response-time to detect rapidly moving objects, although they are still widely used for laboratory measurements.

The modern infra-red detector is one based on a German war-time development—photo-conductivity in the infra-red. In this type of detector a semi-conductor is used—the same class of material as is used in transistors. A semi-conductor, as its name implies, is a material that lies between a conductor and an insulator as far as its electrical properties go. In a photo-conductor infra-red detector the semi-conductor is in the form of a thin layer between the electrodes, across which a potential is supplied. The resistance of the layer is usually fairly high (in excess of 1,000,000 ohms) and when infra-red radiation is allowed to fall on it the resistance drops, and this is in turn indicated by a fall in the applied potential. This type of detector does not require that the temperature of the layer shall change—the effect is caused by the *absorption* of radiation in the layer. Thus each unit of infra-red radiation absorbed releases an electron in the layer which would not normally have been free, and these freed electrons flow across the layer and add to the steady leak current caused by the applied voltage. The effect causes measurable changes in voltage for very small amounts of infra-red radiation, and, what is very important, the change takes place in a few micro-seconds. Thus even the Fairey Delta II will only have gone about 2in. in the time that it takes a photo-conductor to respond !

Selective Devices

These photo-conductor detectors only work over certain wavelengths ranges, i.e., they are selective, and the particular semi-conductor material must be chosen to suit the required wavelength. The most common materials for the layers are lead sulphide which responds to about 3 microns, lead telluride, which responds to 4.5 microns, lead selinide to 6 microns, indium antimonide to 7 microns, and germanium which responds out to very long wavelengths—possibly 100 microns. All these materials must be specially treated to give them infra-red sensitivity, and all of them with the exception of lead sulphide and possibly lead selinide need to be kept cool, i.e., refrigerated, to make them sensitive.