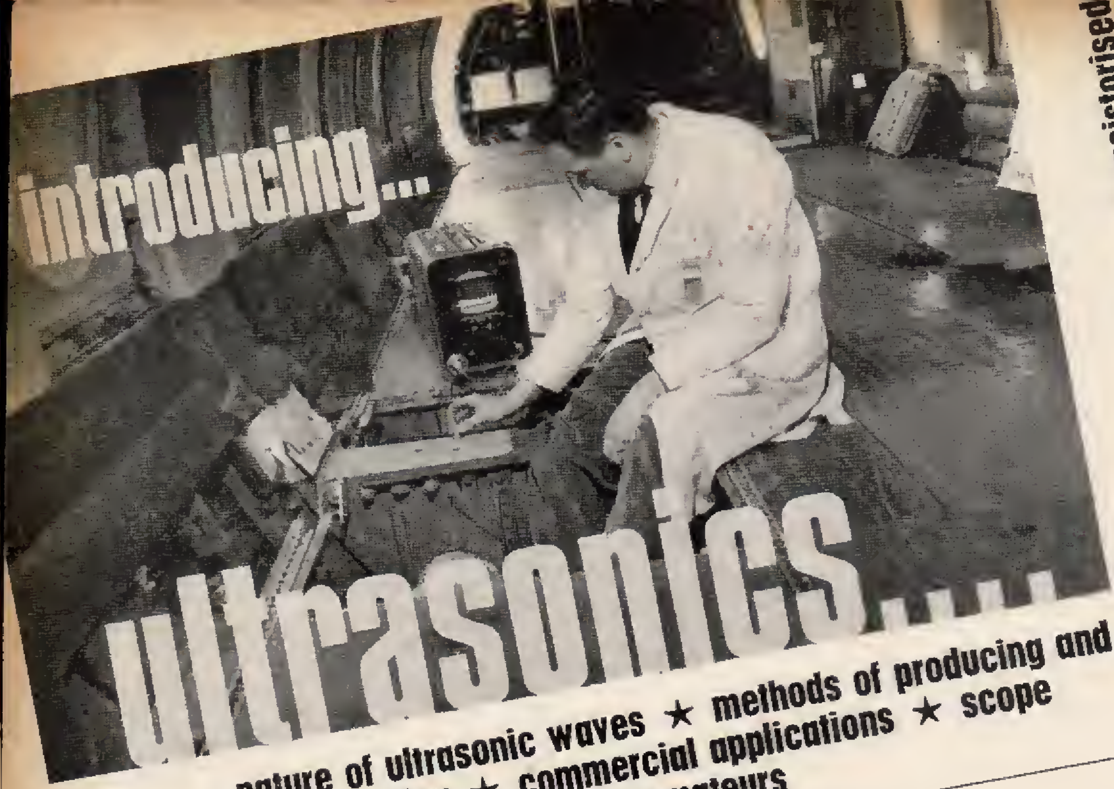


introducing... ultrasonics....

The Ultrasonoscope transistorised flaw detector being used for checking structural parts of an aircraft

nature of ultrasonic waves ★ methods of producing and detecting ★ commercial applications ★ scope for amateurs

ULTRASONICS IN NATURE

In the year 1793 Lazzaro Spallanzani established after a long series of experiments that the common bat could navigate and detect its prey without being able to see. After establishing that any loss of acuteness in the bat's hearing resulted in a loss of ability to navigate, he put forward the hypothesis that they were able to navigate and detect their prey by emitting and receiving a vibration of the same nature as that of sound but with such high frequency that it was inaudible to the human ear.

The scientific minds of the day rejected this suggestion, and Spallanzani joined the ranks of those scientists whose reward for systematic investigation and logical thought was ridiculed.

It is now quite firmly established that these ideas were correct and that other creatures, including the porpoise are able to use ultrasonic emission and reception for various means.

The definition of an ultrasonic wave is very simple, being a pressure wave whose frequency is higher than that to which the human ear will respond. It is generally accepted that 20kc/s is the lowest usable ultrasonic frequency, although in fact human audibility does not reach this high level.

The properties of an ultrasonic vibration are, since they are fundamentally the same as sound vibrations, identical with the properties of sound. They may be propagated in gas, fluid or solid, may be absorbed by soft surfaces, reflected by hard surfaces and refracted by changes in temperature and pressure of the medium in which they are propagated.

PRODUCTION AND DETECTION OF ULTRASONIC VIBRATIONS

There are three main techniques by which ultrasonic vibrations may be produced.

1. Magnetostrictive methods.
2. Piezo-electric methods.
3. Oscillation of air or fluid jets.

The first of these methods uses the fact that certain materials when subjected to a varying magnetic field undergo very slight changes in dimensions. A nickel rod is usually used as the core of a coil through which a high frequency current is flowing. The result of this is that the nickel rod is subject to a slight length change with the same frequency as the current through the coil.

The second method relies on the fact that certain naturally occuring materials such as Rochelle Salt or Quartz and certain man-made materials such as ceramics, including Barium Titanate and Lead Zirconate Titanate, are subject to a change in dimensions with a directly applied voltage.

If an oscillatory voltage is applied to the opposite faces of such a slab of material the material will execute vibrations at twice the frequency of the applied voltage.

The reason for the frequency doubling effect is that the domains, i.e. groups of molecules, which are normally random in their orientation change direction according to the polarity of the applied electric field. Hence both the positive and negative peaks of the applied voltage will cause the corresponding expansion or contraction which results in the frequency doubling effects.

If the material is originally polarised, i.e. all the domains are arranged to lie in approximately one direction by means of application of a large electric field in the early stages of manufacture, then the fact that these domains are not completely free results in the piezo-electric vibration being of the same frequency as the applied oscillatory voltage.

The third method of production is only of interest where very high power is required, usually for emulsification of suspensions, and relies on the principle of a high powered jet of gas or fluid impinging on a blade. Under these conditions the blade will execute ultrasonic vibrations, assuming due care has been given to the dimensions of the blade, which will be transmitted through the gas or fluid.

APPLICATIONS OF ULTRASONIC VIBRATIONS

Among the first fully developed applications of ultrasonics were the fields of cleaning, drilling, welding and soldering. In each of these cases the ultrasonic techniques have certain advantages over conventional techniques.

The advantage of cleaning, by immersing the object concerned into a tank of fluid in which ultrasonic vibrations are produced, is twofold: firstly, the tremendous reduction in time when compared with manual cleaning; secondly, the advantage that very delicate and complex assemblies, such as internal parts for valves or components, may be cleaned without the risk of physical damage which is present when using conventional cleaning methods.

By using an ultrasonic vibration in a solid rod one can drill through materials for which standard drilling methods are not very satisfactory, examples being crystals or glass, or other such brittle material. A second advantage when using this method for drilling is that one has dispensed with the necessity for a rotating bit, hence one can drill holes of any desired shape.

In the case of welding and soldering, the obvious advantage is that the tremendous production of heat which can destroy or impair the efficiency of delicate assemblies is avoided, and in the case of soldering the use of any form of flux becomes unnecessary. A further advantage to the soldering technique is that it can be used to solder materials not solderable by previous methods, for instance aluminium.

The third method of producing ultrasonic energy, the jet method, is used in the textile and food industries among others; a characteristic example of products which require a process of emulsification being peanut butter.

MEASUREMENT BY ULTRASONICS

Apart from applications involved in the field of production or manufacturing, such as those previously described, ultrasonic vibrations may be used for performing scientific measurements.

Examples of these are ultrasonic thickness gauges and flow meters.

If an ultrasonic vibration is propagated through a solid material, any change in the nature of the material will result in some reflection. By measuring the attenuation or the time taken for an ultrasonic wave to cover the total journey it is possible to estimate very accurately the thickness of the material. One example of the use of ultrasonics in this respect is the measurement of the thickness of fat on certain animals, such as pigs, and in this context has an obvious superiority over any other methods which might be devised.

By launching an ultrasonic vibration into a moving fluid and using the Doppler effect, i.e. apparent change in frequency with velocity, it is possible to measure the flow rate of the fluid concerned. Although there are simpler methods for flow rate measurement, this technique has the advantage that it may be used with either corrosive or very dangerous fluids. An example of the use of this technique lies in the measurement of the flow rate of molten sodium which is used for heat transfer in certain atomic reactors.

Although it is not a scientific measurement, the similar technique to that for thickness may be used to detect flaws in factory-made products without the necessity of destroying the product in the process of inspection. An ultrasonic vibration introduced at one face of perhaps a complicated plastics moulding will be reflected by any small voids or cracks in the material.. These reflections may be compared with the pattern which is the result of a flawless product, hence inspection may be carried out very rapidly and without any destruction of the items concerned.

Probably the most dramatic use of ultrasonic energy is in the field of echo sounding. This is an extension of the thickness measurement technique by which a ship may launch an ultrasonic wave and establish the time taken for reflection from the ocean bed. This is a direct and continuous indication of depth.

Apart from indicating depth this technique may, of course, also be used to detect the presence and position of either ships or shoals of fish.

ULTRASONICS IN AIR

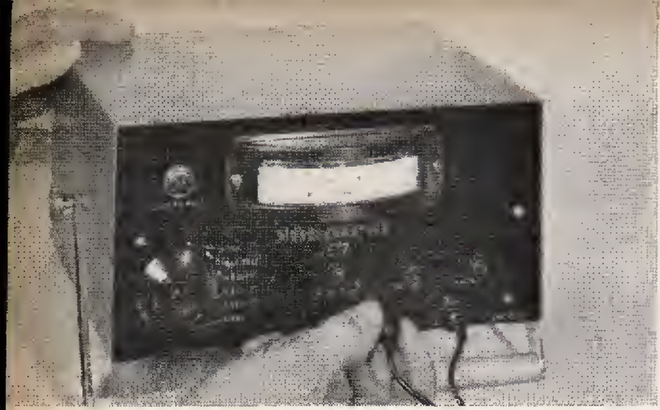
There are a number of ways in which the properties of an ultrasonic wave in air may be used to perform useful tasks. Probably the four main applications are in object detection, distance measurement, remote control and communications.

The property of reflection may be used in air, as it is in water, to measure the distance to a given object.

An ultrasonic spot welder for welding thin ductile materials such as aluminium and copper

This is exploited in devices which are available for the measurement of height of such things as hovercraft, helicopters and possibly light aircraft when flying at very low levels.

When used for detecting objects the largest application is that of the burglar alarm. If a transmitter and receiver are set up some distance apart, and the incoming wave of ultrasonics to the receiver used via an amplifier to hold over a relay, anybody interrupting the beam will cut off the input to the amplifier, hence cause the relay to change position. This is used directly to indicate presence of intruders in factories, warehouses, etc.



This ultrasonic thickness meter incorporates a moving coil meter which indicates directly the thickness of metals being examined. It is fully transistorised and operates from dry cells

The Omega threadless stitcher. This uses a novel spot welding technique and is used in garment production with man-made fabrics

A similar system may be used for remote control or communication, but in this case the ultrasonic wave is directly controlled at the transmitter.

Since a pressure wave of this sort may be modulated in much the same way as a radio wave, with sufficiently sophisticated electronic equipment the transmitted ultrasonic wave may be either amplitude modulated, frequency modulated or pulse code modulated in order to transmit information or instructions over short distances.

Concerning the remote control of model boats, it must however be noted that control may be effected over much longer distances if the wave is transmitted through the water, since the attenuation of ultrasonic waves is considerably less in a liquid medium than in air.

The transmission of ultrasonic waves in air is a field which is very suitable for the experimenter as suitable transducers for transmitting and receiving are available commercially at comparatively low prices. Although the range of control is a little limited, something of the order of 100 to 300ft being the maximum practical at the moment, an ultrasonic system for remote control has certain advantages over radio control. The most obvious of these being the fact that the ancillary amplifiers are usually cheaper to make and considerably more simple. There is, of course, the added advantage that a transmitting licence is not required, as in the case of radio wave propagation.

ULTRASONIC TRANSDUCERS

When transmitting ultrasonic energy through air the direct use of a vibrating crystal is not the most satisfactory method since, although great power is available from such a crystal, the dimensions of the change in size are so small that the range would be very limited.

In order to improve this range a technique is used whereby the movement of the crystal is mechanically amplified to get a greater degree of movement from the transmitting element.

Fig. 1 shows the technique which is used to achieve this mechanical amplification. A thin crystal is cemented to a small thin round plate mounted on a central stem. As the crystal is energised it attempts to change its dimensions in the plane of its two parallel faces. Since it is securely cemented to the metal plate the latter is forced to bend with the movement of the crystal, and this results in an oscillatory bending movement of the metal plate at the frequency of the applied voltage—hence the transmission of a pressure wave into the air.

Correspondingly, a pressure wave impinging on the plate will cause very small movement of the plate which is sufficient to generate across the crystal a signal corresponding to the frequency of the incoming pressure wave.

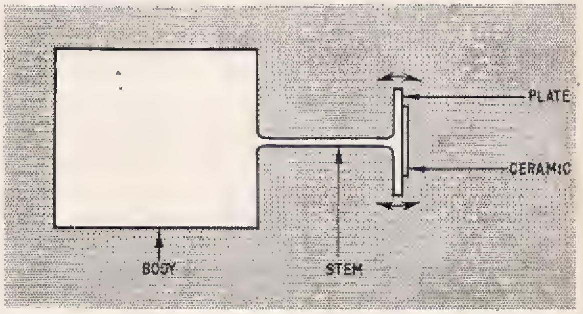


Fig. 1. Mechanical amplification of the transducer crystal is achieved by use of a small metal plate

THE EXPERIMENTAL APPLICATIONS OF ULTRASONIC ENERGY

Most amateurs, or indeed small industrial users, are limited to the application of ultrasonics directly in air, as this is the only application for which the general purpose transducers are available on the market.

There are a number of aspects of ultrasonics which are certain to capture the imagination of the enthusiastic amateur, especially in the field of remote control and voice communication.

The fact that in this medium the experimenter is free from the necessity to acquire transmitting licences is a major attraction of these techniques.

In the case of amateurs or small industrial users who feel sufficiently confident to manufacture their own transducers from fundamental ceramic materials which are freely obtainable, the field of underwater transmission could be particularly exciting. This has the previously mentioned advantage of considerably greater range and would offer at least one immediate application, this being the facility of direct voice communication between aqualung divers.