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Introduction

Any material medium, whether in its fluid (i.e. gaseous or liquid) or its solid (or condensed) state, is capable of carrying acoustic waves. This kind of mechanical disturbance occurs when the elementary building blocks of matter are, by some cause, displaced out of their equilibrium position and try to return to this position under the influence of restoring forces. In this respect, acoustic waves differ from electromagnetic waves in that the latter can also be present *in vacuo* (i.e. in the absence of matter), whereas the former cannot. In the present part of the *Handbook*, the investigation of the properties of acoustic waves in fluids is our main concern; the properties of elastic waves in solids are discussed in Part 2.

When following an acoustic wave on its course, we start with its *excitation* by an acoustic source or transmitting device (the human voice, a musical instrument, a loudspeaker, a vibrating machine, an ultrasonic transducer). Once it has been generated, the wave *propagates* along a certain, more or less confined, path from the source to the receiver. Depending on the properties of the medium through which the wave passes, this propagation can lead to continuous *refraction* by spatial and/or temporal changes in the medium (for example, the atmosphere), to *reflection* against and *transmission* across interfaces between different media, or to discontinuous *scattering* or *diffraction* by objects whose acoustic properties show a contrast with those of their surroundings. Finally, the wave motion is *received* by an acoustic receiving device (the human ear, a microphone, a hydrophone, a geophone, an electronic transducer). Figure 1.1 illustrates these different aspects.

Each of these aspects is the subject of extensive theoretical and experimental investigation. Usually, when the attention is focused on a particular detail, the remaining circumstances are chosen as simply as possible. For example, when one wants to investigate the directional characteristics of an acoustical source, the surrounding medium will be taken to be of the utmost simplicity as far as its acoustic properties are concerned, and of infinite extent. When studying refraction phenomena during the propagation of an acoustic wave, the source will be taken to be a simple one (mostly a point source, i.e. a source whose dimensions are negligibly small compared to the other characteristic dimensions of the configuration under investigation), while the influence of the receiver will be neglected altogether (by taking it to be a point receiver). When studying the influence of a scattering configuration, both the surrounding medium and the kind of excitation will be taken to be very simple ones. All these simplifications are dictated by the impossibility of accounting for the influence of all parameters simultaneously, even with present-day, large-capacity, high-speed computers. It is the task of the acoustician to put the

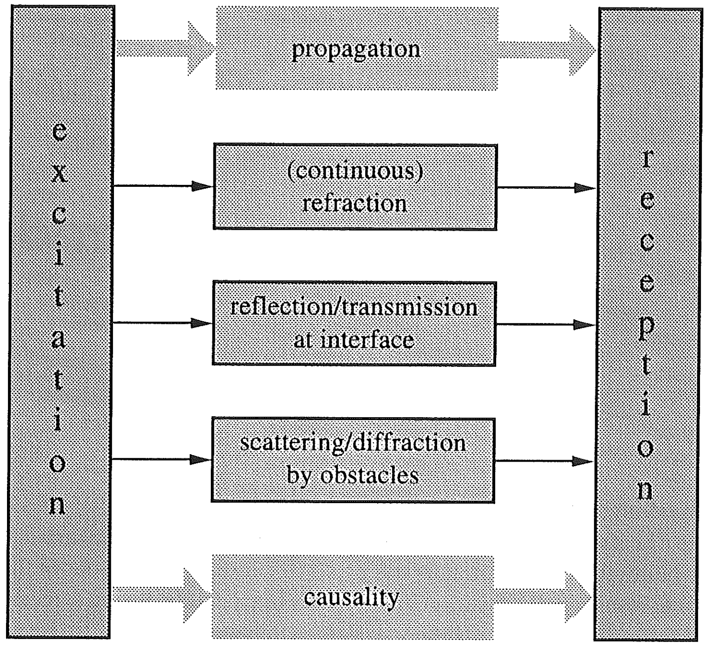

Figure 1.1 Acoustic wave phenomena on their course from source to receiver.

results of the partial model studies together in a judicious way in order to compose a judgement of the behaviour of acoustic waves and vibrations in the more complicated situations met in practice.

The practical applications of acoustic waves are widespread, and the number of fields in which they are used is ever increasing. In everyday life, acoustic waves are the carriers of *sound*, be it wanted (music, some speech) or unwanted (noise, other speech). In the field of medicine, *acoustic tomography*, i.e. the imaging of an object (foetus, tumour) inside the body, is of growing importance, the more so since acoustic radiation in the applied dosages is either non-hazardous or much less hazardous than the X-ray radiation used in X-ray tomography. The same idea of acoustic imaging underlies the use of acoustic waves in *exploration geophysics*, be it in surface seismics, vertical seismic profiling, cross-borehole seismics, or borehole acoustics. Here, acoustic waves are used to map the subsurface structure of the Earth in the search of fossil energy resources (coal, oil, natural gas). Furthermore, the *non-destructive evaluation* of materials and of mechanical structures makes use of acoustic waves to a large extent. The scattering of these waves by interior defects (inclusions, bubbles, cracks) makes the presence of these defects detectable at the surface of the structure, which surface is accessible for carrying out the necessary measurements. For underwater locations, *SONAR* (SOund Navigation And Ranging) acoustic systems are installed on almost any vessel. Finally, *earthquake engineering*, i.e. the design of earthquake-resistant structures, requires the knowledge of the properties of acoustic waves in the Earth's crust. These different applications are listed in Figure 1.2.

We shall develop the theory of acoustic radiation on a *macroscopic scale*. This implies that in all acoustic wave interactions a large number of elementary building blocks of matter are

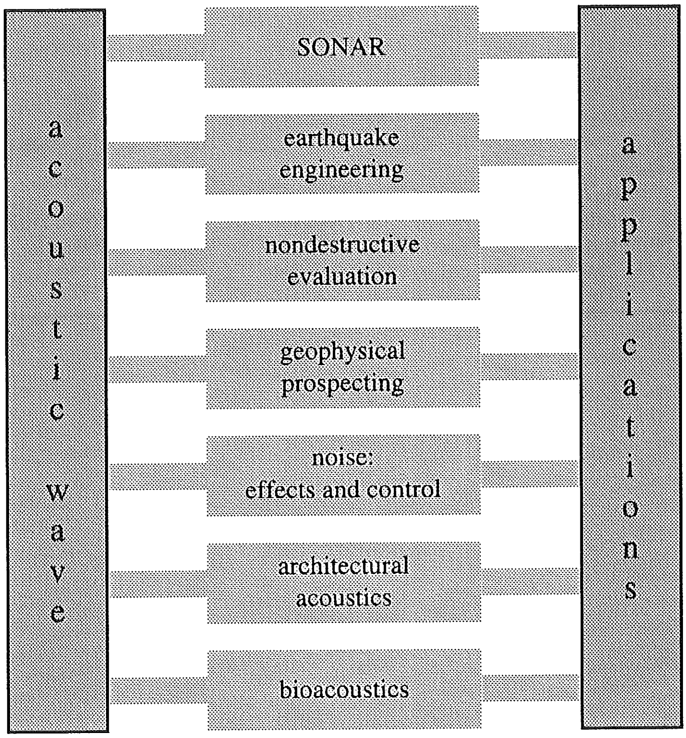

Figure 1.2 Applications of acoustic waves.

involved and that the exchange of energy between these building blocks takes place through large numbers of energy quanta. Occasionally, we shall use microscopic considerations to elucidate the underlying physical picture of the macroscopic phenomena. Classical treatises on the subject are those by Lord Rayleigh (Strutt, 1945), Love (1959), Lamb (1952), Morse (1948), Morse and Ingard (1968), Mason (1964), and Friedlander (1958).

As in any kind of wave motion, the physical quantities that describe the acoustic wave motion depend on position and on time. Their time dependence in the domain where the source is acting is impressed by the excitation mechanism of the source. The subsequent dependence on position and time elsewhere in space is governed by the pertaining propagation and scattering laws, together with the principle of causality.

Exercises

Exercise 1.1

Make a list of the names and the SI-units (written in full and with the corresponding symbols) of the acoustic wave-field quantities occurring in the chapters of Part 1. (*Hint*: Consult the General Introduction for the pertaining international standardisation.)

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