is usually that of the mains voltage and contains only those frequencies that are multiples of the fundamental. The intensity of these multiples decreases as their frequencies increase. Noises referred to as 'complex' or square waves are similar in that they are composed of a fundamental frequency and components that are multiples of it.

White noise is a noise containing all frequencies in the audible spectrum at approximately equal intensities. However, the spectrum is limited at the ear by the frequency response of the earphone, which may essentially be flat to 6000 Hz and may drop rapidly beyond. An excellent complex masking noise can be obtained by using the thermal or random electronic emission from a semiconductor diode, since it generates all frequencies simultaneously and with equal amplitude over a frequency range wider than the response of the ear.

Narrow-band noise has been used by a number of investigators in audiometric studies. It is produced by selectively filtering white noise. It has been found that narrow band noise is the most efficient masking noise in pure-tone audiometry. The masking audiograms for normal hearing subjects and the clinical results for hearing-impaired subjects show that for equal intensity levels, narrow band noise produces greater threshold shifts than do either of the other two types and thereby provides greater protection from false responses due to cross-over of the test tone.

17.4 PURE TONE AUDIOMETER

A wave in air, which involves only one frequency of vibration, is known as pure-tone. Pure-tone audiometry is used in routine tests and, therefore, it is the most widely used technique for determining hearing loss. Pure-tone audiometers usually generate test tones in octave steps from 125 to 8000 Hz, the signal intensity ranging from –10 dB to +100 dB.

Pure-tone audiometry has several advantages, which makes it specifically suitable for making threshold sensitivity measurements. A pure-tone is the simplest type of auditory stimulus. It can be specified accurately in terms of frequency and intensity. These parameters can be controlled with a high degree of precision. Speech audiometry normally allows measurements to be made within the frequency range of 300–3000 Hz. Some patients may have impaired high frequency response due to high intensity level occupational noise at 4000 or 6000 Hz. Pure-tone measurements at these frequencies prove to be a more sensitive indicator of the effect of such noise on the ear than speech tests. Changes in threshold sensitivity associated with various middle ear surgical procedures can be monitored more accurately with pure-tone than speech tests.

A pure-tone audiometer basically consists of an LC oscillator in which the inductance and tuning capacitance are of close tolerances for having a precise control on the frequency of oscillations. The oscillator is coupled to an output current amplifier stage to produce the required power levels. The attenuators used in these instruments are of the ladder type, of nominal 10 Ω impedance. The signals are presented acoustically to the ear by an earphone or small loudspeaker. The available sound pressure levels in a typical audiometer are given in Table 17.1.

17.5 SPEECH AUDIOMETER

Besides tonal audiometry, it is sometimes necessary to carry out tests with spoken voices. These tests are particularly important before prescribing hearing-aids and in determining the deterioration

• **Table 17.1** ***Test Tones and Signal Intensity in Audiometers***

Frequency	*Pure-tone (head-phones)*	*Pure-tone (bone conduction)*	*Balance channel*	*Narrow band masking (head-phones)*	*Narrow band masking (bone conduction)*
125	70	–	–	–	–
250	90	45	90	80	50
500	110	60	110	90	60
1000	110	60	110	90	60
1500	110	60	110	90	60
2000	110	60	110	90	60
3000	110	60	110	90	50
4000	110	60	110	90	50
6000	90	–	–	80	–
8000	90	–	–	80	–
Speech	110	–	110	–	–

of speech understanding of patients. Specially designed speech audiometers are used for this purpose. They incorporate a good quality tape recorder, which can play recorded speech. A double band tape recorder is preferred to interface the two channel audiometer units. Masking noise is supplied by the noise generator. The two channels supply the two head-phones or the two loud speakers which are of 25 W each.

The tape recorder has a capacity for recording a limitless variety of test material and a consistency of speech input, which cannot be obtained for live-voice audiometry in relation to test-retest repeatability. Another advantage of the tape recorded material is that the test words and sentences can be selected to cater for the widely differing needs of age, intelligence, dialect and language.

In speech audiometers, live-voice facilities are incorporated primarily for communication purposes as the inherent unreliability of live-voice speech tests may lead to serious errors. The microphone amplifier used for this purpose is a simple two stage amplifier. The frequency response characteristics of a live-voice channel should be such that with the microphone in a free sound field having a constant sound pressure level, the sound pressure level developed by the earphone of the audiometer in the artificial ear at frequencies in the range 250 to 4000 Hz does not differ from that at 1000 Hz by more than 110 dB. Also, it shall not rise at any frequency outside this band by more than 15 dB, relative to the level at 1000 Hz.

17.6 AUDIOMETER SYSTEM BEKESY

George Van Bekesy, a Hungarian scientist, designed an automatic audiometric testing method for plotting the hearing threshold based on the patient's signal. A principal feature of the method, differentiating it from conventional pure-tone audiometric techniques, is the interdependence of the patient's response and stimulus intensity: responses govern intensity and are affected by