additional devices have to be used at the receiver to minimize the disturbance.

2. *Shot Noise.* This is a noise arising from uneven emission of the electrons in a valve. If adequate emission is provided from the cathode, however, this is continually surrounded by a space charge which acts as a reservoir so that the effect is reduced considerably.

The equivalent grid noise due to shot effect can be shown to be given by

$$v_g^2 = 2keF\Delta i_a/g^2$$

where e is the charge on an electron,
i_a is the anode current,
g is the mutual conductance,
Δ is the frequency band of the receiver,
k is a constant,
and F is a factor dependent on the operating conditions.

With a temperature-limited cathode $F = 1$, but with a valve such as a triode the space charge, acting as a reservoir as already described, considerably reduces the noise, and F has a value of about 0·05.

With a pentode valve the presence of the screen overcomes the space charge to a large extent, while the random distribution of electrons between anode and screen further increases the noise. In other words, although the steady anode and screen currents bear a fixed relation for any given operating conditions, the instantaneous values are fluctuating slightly, and as a result of these various factors F increases to a figure of the order of 0·25 to 0·3.

A screened valve, therefore, produces five or six times the noise of a triode, while with a frequency changer the conditions are still worse, as explained on page 445.

The criterion of goodness, from a noise point of view, is determined, for a given class of valve, by the ratio g^2/i_a. The higher this can be made the less will be the noise.

3. *Thermal Agitation,* sometimes called *Johnson noise.* This arises from the movement of the electrons in the material of the conductors. Both this and the shot noise are only important in the first stage of the amplifier where they are followed by the full amplification of the remaining stages. In the case of thermal agitation, the impedance across the grid and cathode of the first valve develops a noise which is proportional to the effective resistance and to the absolute temperature. As is to be expected, the noise is random and is distributed over the whole frequency spectrum, so that