

The Nature of the Sound Field Surrounding the Piper in Open Air

by Alex R. Carruthers

The sound energy from the Highland bagpipe is radiated from the three drones and the chanter in a continuous manner. It spreads out from each pipe in a definite way and encounters the piper's body and obstacles as it spreads. The result of the different transmission paths is that the sound spreads unequally around the piper. This gives the piper-instrument combination an element of directivity, that is, being louder to the front and sides than to the rear. An objective knowledge of this directivity is important in recording the music with a microphone, in estimating the sound effects when the instrument is in-doors, assessing the amount of sound likely to be given off by a group of pipers and assessing how the sound is propagated out of doors.

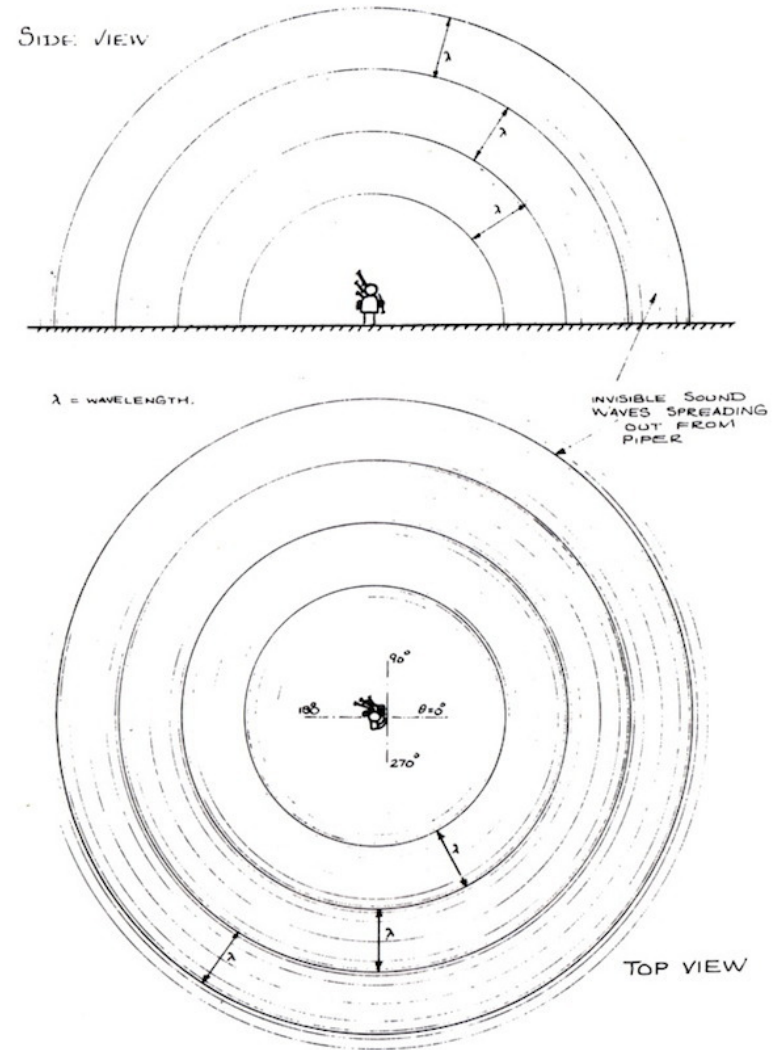
This report introduces the concept of diffraction and the wavelengths of the bagpipe notes. It proceeds to show how the sound around the piper is distributed and how this sound varies from note to note of the chanter.

Diffraction

When sound waves strike any obstacle (including the piper's body) in their path there will be some reflection from it and some absorption by it. In addition, the waves can bend around the obstacle and fill part of the space behind it. The ability to bend depends on the frequency of the sound vibrations or more specifically their WAVELENGTH and the size of the obstacle. The bending of sound waves around obstacles and corners is called DIFFRACTION. It is diffraction which allows us to hear the pipes, albeit at a reduced level, even when some large person stands in front of us or when pipers turn their backs to us. It also allows us to hear the pipes when they are around a corner or behind a wall even when there are no reflected wave paths.

Not wanting to delve too deeply into wave phenomena or acoustical theory, it is sufficient to say that the sound waves from the pipes spread outwards in all directions just like water ripples when a stone is dropped into a pond. In the case of the Highland bagpipe the sound is confined to the half space above the ground level and ripples are approximately three dimensional expanding hemispherical shells. These shells are wavefronts in which the

FIGURE 1



atmospheric pressure has been modified by the sound wave. The wavefronts move because the disturbance is passed from one air particle to another. Sound is the propagation of these pressure waves and they have crests and troughs just like the water ripple. Two adjacent wave crests are spaced one wavelength apart and is the distance travelled by the sound during one complete vibration of, for instance, the chanter reed.

The wavelength therefore depends on the frequency of the note (the number of vibrations per second) and the speed of travel of the sound in the open air. An important formula relates the wavelength to these fundamental quantities:

$$\text{Wavelength} = \frac{\text{Speed of sound}}{\text{Frequency}}$$

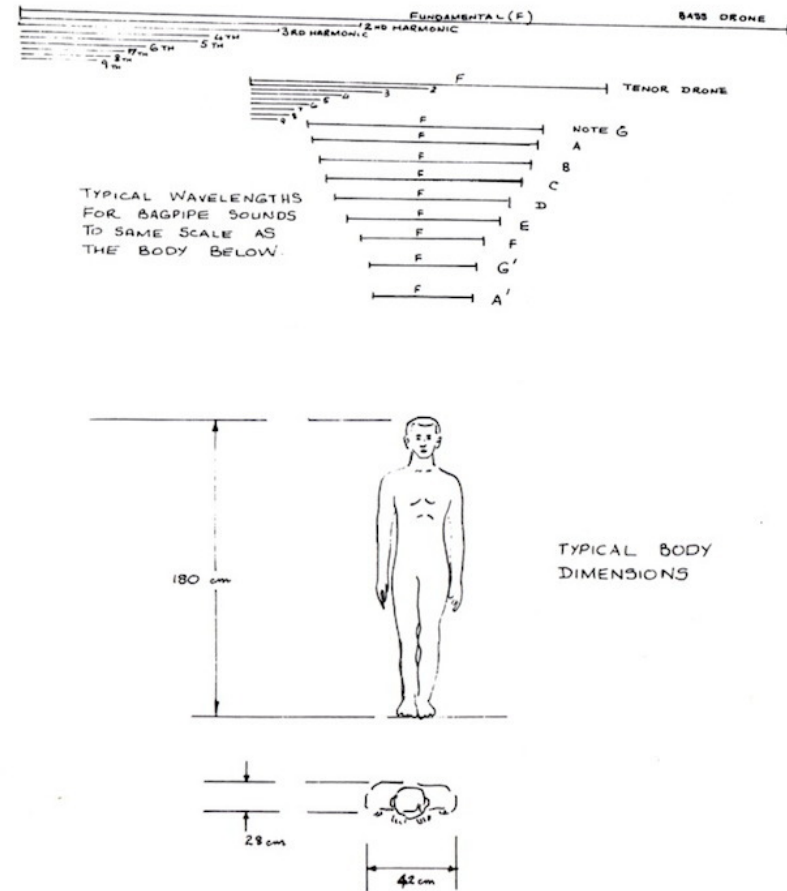
If frequency is in Hertz and speed of sound is metres per second then the wavelength is in metres.

In fig. 1 simple hemispherical wavefronts are shown surrounding the piper. This is a simplified picture of the true situation since it implies that the sound level at a given distance all around the piper is the same for any direction. This is incorrect as we will see later.

As stated above, the important factors are the dimensions of the piper and the wavelength of the note being played. If the wavelength is large compared with the body size of the piper then the sound waves are relatively undisturbed and the simple state in fig. 1 applies. However as the wavelength gets smaller (by virtue of higher frequencies) the size of the piper's body will have a large effect on the sound radiation. The situation is further complicated by the complexity of the pipe sound since it contains a mixture of frequencies for even one note. These frequencies are fixed by the pitch of the note which defines the lowest or fundamental vibration. Up to ten other frequencies of higher value accompany the fundamental vibration. Hence there is a family of wavelengths for each note, the longest being the fundamental.

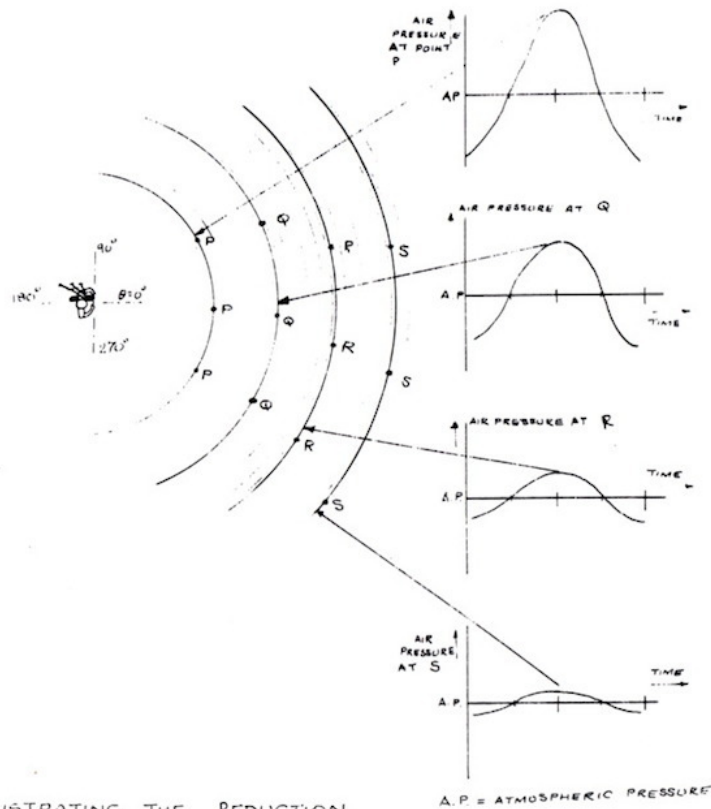
Fig. 2 is a scaled diagram to illustrate the wavelengths of the sounds of the bagpipe in relation to the size of a piper's body. Only the family of wavelengths for the drones is shown but each note of the chanter has a similar set of wavelengths diminishing in size from the fundamental. Most of these wavelengths are comparable with or smaller than the body sizes (breadth and width) and thus a

FIGURE 2



departure from the circular sound field is inevitable. Naturally the data given are only average and the picture will change for different pipers, different atmospheric conditions and different temperatures.

One final point regarding wavefronts is that they represent points in space in which the sound level is the same. As the wave expands, the air pressure disturbance gets smaller until at a far distance from the piper the pressure change is so small that the ear drum is unable to detect the sound. Fig. 3 shows the change in magnitude of the sound as it diverges from the piper.



ILLUSTRATING THE REDUCTION IN MAGNITUDE OF THE SOUND PRESSURE AT VARIOUS DISTANCES FROM THE PIPER.

FIGURE 3

Distribution of sound around the piper

The use of sound level contours to depict the sound pressure level variation (and hence perceived loudness) at a constant distance around the piper is a simple way of showing the sound radiation in the horizontal plane, i.e. parallel to the ground. To simplify the understanding of the radiation phenomenon we will consider only the sound contour at the air-ground interface and thus avoid the more complicated contours above the ground. These latter contours incorporate the effects of direct and reflected sound.

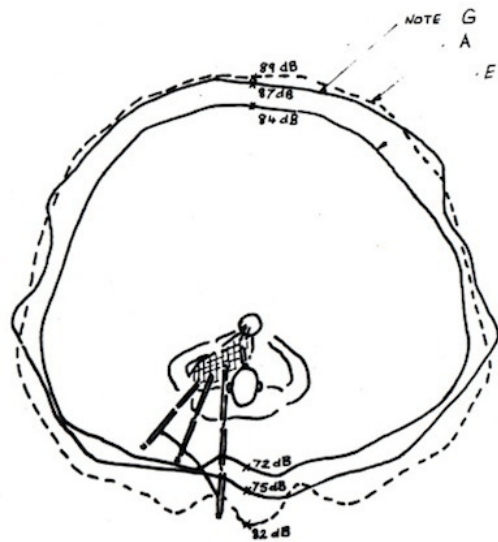
The sound radiated from the bagpipe out of doors depends on many factors. The amount of sound absorbed by the ground, the strength of the reeds, the clothing worn by the piper, the wind and temperature fluctuations can all affect the outward sound level.

The body of the piper is our main concern. The piper usually stands or marches during a performance and the chanter is held at waist level. Sound from the chanter radiates to the front and to the sides with negligible obstruction. The remainder of its sound energy is absorbed and reflected from the piper's body and a portion bent, by diffraction, around the player. The obstruction is the hips, waist and chest of the player and since these are comparable in size to the chanter sound wavelengths then irregularities in the sound radiation are inevitable. Fig. 4 shows some actual sound contours for three notes of the chanter. These were taken at 6 metres from the piper for reasons which we will see shortly. These contours are the pressure levels at a constant distance all around the piper. A few actual sound levels are given on the contours. Contours of equal sound pressure show the different distances from the piper at which the sound level is the same. They have the same basic characteristics as fig. 4. In both cases the contours are not circular all around the player. To the front and for an arc of about 250 degrees the contours are almost circular. At the back of the piper the contours depart markedly from the circular pattern and show a reduction in the sound level of typically 10 decibels (10 dB directly behind the player. The contours also become bumpy (known as lobing) at the rear.

Fig. 5 shows the sound level contours for note G of the chanter for a set of fixed distances from the player.

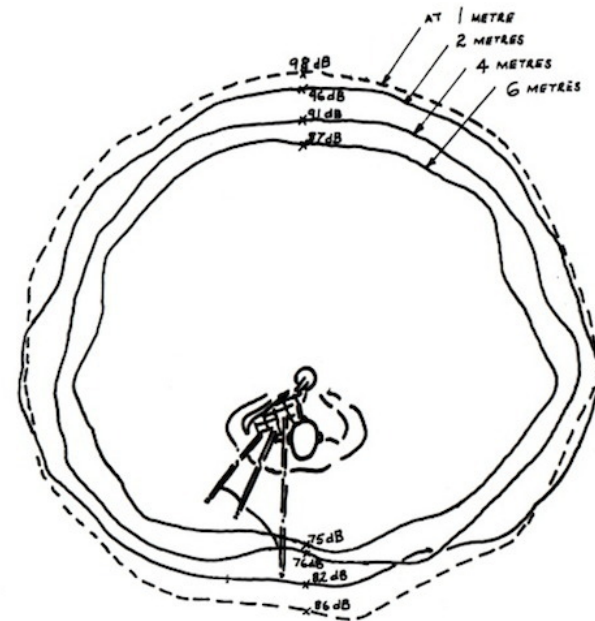
The drones are supported by the shoulder with the bass drone protruding above the piper's head and the tenor drones on a par with the head. The bass drone has negligible obstruction by the body and is free to transmit its sound in all directions unimpeded. It also

FIG 4-



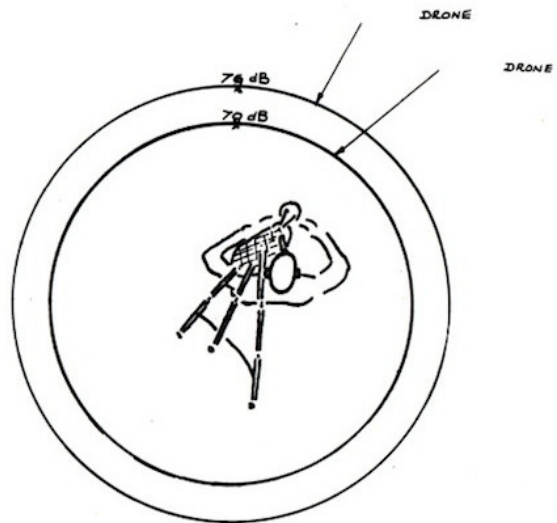
HORIZONTAL SOUND CONTOURS FOR NOTES G, A AND E AT 6 METRES FROM PIPER.

FIGURE 5



HORIZONTAL SOUND CONTOURS FOR NOTE G AT VARIOUS DISTANCES FROM PIPER.

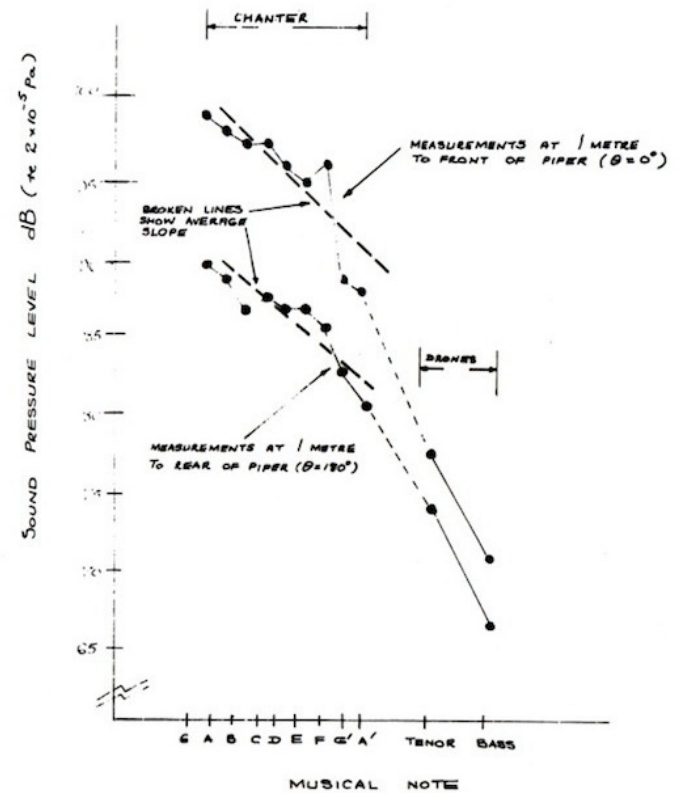
has very long wavelengths for most of its significant frequency harmonics. The sound contours for this drone can be taken as circular with a centre at the air hole. Fig. 1 becomes more of a



APPROXIMATE SOUND CONTOURS FOR DRONES ;
AT 1 METRE FROM PIPER.

reality in this case. The tenor drones have the head as the main obstacle. The size of the head is about the same dimension as the 8th harmonic wavelength of the drone note. Most of the sound is again

FIGURE 7

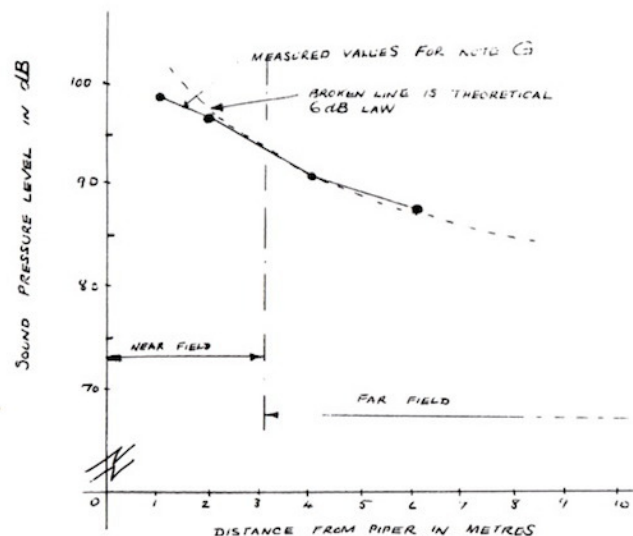


almost unimpeded and so a circular contour provides a useful approximation. Fig. 6 shows the sound radiation models which approximate to the drones. It is seen that the tenor drones are 5 or 6 dB higher than the bass drone.

Sound level of different notes

It was observed in Fig. 4 that different notes of the chanter have different sound levels. High notes are noticeably quieter than the low notes. The change in the sound level of note low G to high A' including the drones is shown in fig. 7. Only the front and rear axis values are shown. The best straight line drawn through the points

FIGURE 8



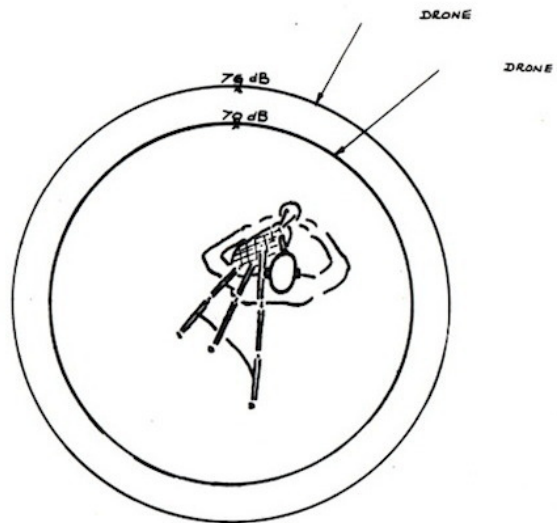
has a slope of approximately -7 dB per octave. The minus sign indicates that the sound level falls off as the higher notes (of higher frequency) are played. The actual sound level is not constant for all bagpipes. The level depends on the ground below the piper and the surroundings and the atmospheric conditions. It further depends on the condition of the reeds in the pipes. A soft wet reed can usually be sounded with very little pressure in the bag and can emit a soft sound. A hard dry reed on the other hand requires a larger amount of operating pressure in the bag and when its vibrations are coupled to the chanter, the sound can be much greater in level.

In fig. 5 the change in the sound level of the note low G at different distances from the piper is shown. Transferring the front axis points to fig. 8 we observe that the sound pressure level falls off at the rate of approximately 6 dB for a doubling of the distance. Very close to the piper this 6 dB law does not apply because of what is known as the near field effect. This deviation is the result of anomalous propagation from the chanter and movements of the piper. At 4 metres or so, the 6 dB law begins to become valid. It should be noted that the measurements were taken on a concrete surface which absorbed very little of the sound. Had the surface been grass or soil, some absorption would have taken place and the measured values would have been lower with perhaps a 9 or 12 dB per doubling of the distance.

Conclusion

It is possible to assume that the drones approximate well to a simple hemispherical sound radiator to the front and to the rear of the piper. For the chanter this approximation cannot be justified for the whole space around the player. The circular sound pattern can be approximated only for the front 180 degree semicircle. The greatest irregularities in the pattern and the greatest attenuation are to the rear of the piper.

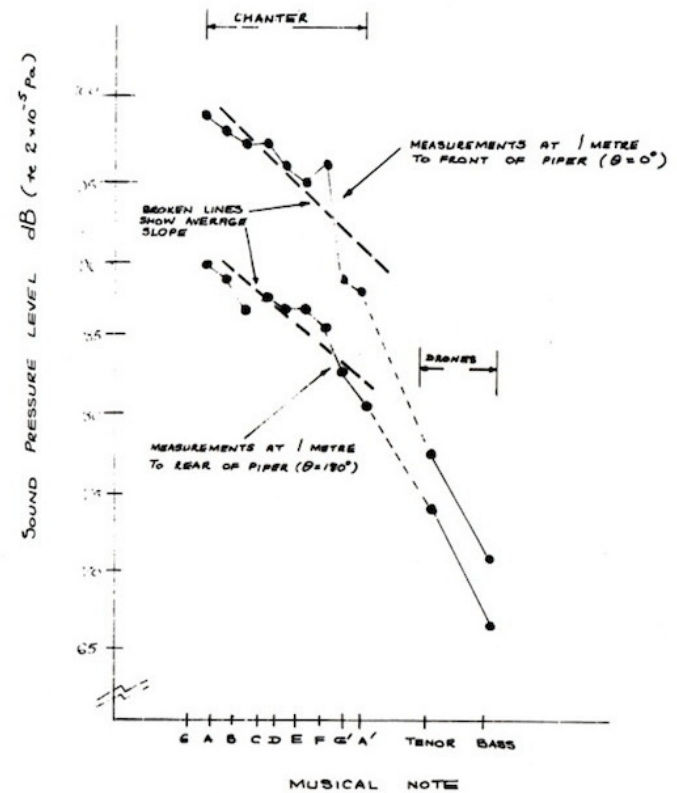
The total sound of the Highland bagpipe is the summation of the sound energies of the three drones and the chanter. It seems reasonable, therefore, to adopt the directivity pattern of note E or D of the chanter as representative of the piper-bagpipe combination and take into account the extra sound from the drones. To the front of the piper this amounts to a total sound level of about 95 dB and to the rear, about 85 dB. One consequence of the directivity effect is that sound from the front can travel further than sound from the back. A simple calculation gives a distance of 65.5 km in front and only 16.4 km to the rear (assuming no noise in the background).



APPROXIMATE SOUND CONTOURS FOR DRONES ;
AT 1 METRE FROM PIPER.

reality in this case. The tenor drones have the head as the main obstacle. The size of the head is about the same dimension as the 8th harmonic wavelength of the drone note. Most of the sound is again

FIGURE 7



Appendix

The sound contours given for the Highland bagpipe are for the complex musical notes transmitted through the air. If the distinct harmonic components, which make up the notes, were sounded separately, the contours for each component would depart markedly from the near circular pattern if they were of a high frequency.

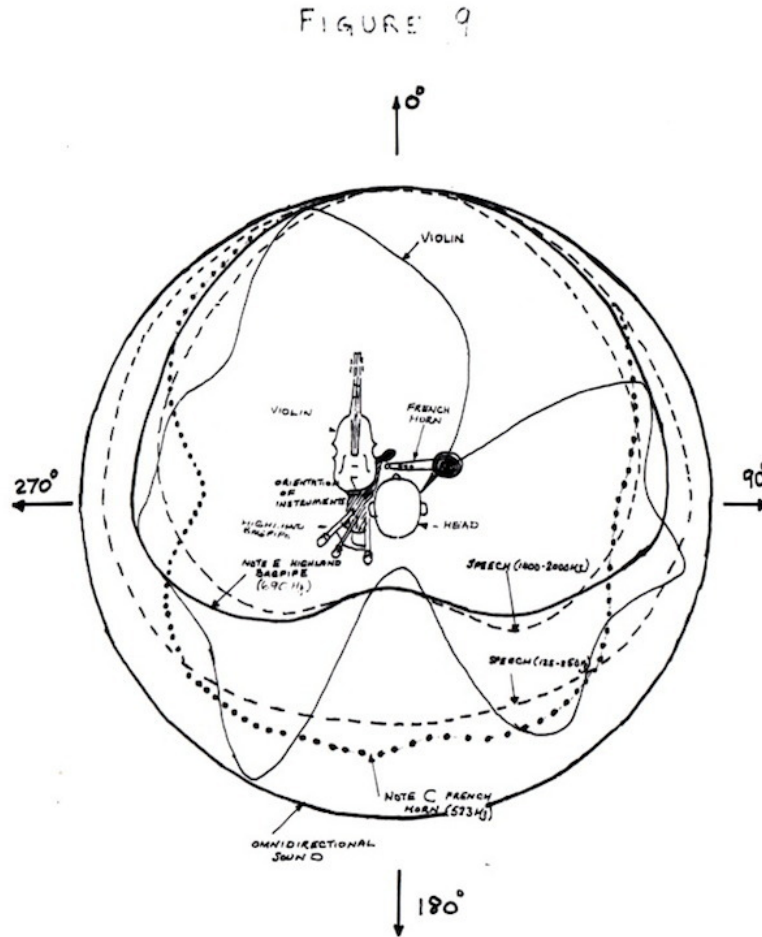


FIG. 9 APPROXIMATE DIRECTIONAL DISTRIBUTION OF SOUND IN THE HORIZONTAL PLANE FOR DIFFERENT SOURCES.

The contours are different for different notes and different distances from the piper. They also depend on the orientation of the instrument with respect to the listener or measuring device.

As these remarks apply equally to most musical instruments it is difficult to compare them with any great precision. However the directive properties of some musical instruments are compared with the Highland bagpipe in fig. 9. These drawings are only pictorial approximations to provide a platform for the reader to gauge how sound can spread around musical sound sources.

For Sale: Robertson drones and stocks, circa 1930, ivory and plain silver mounts, superb tone, excellent condition. Enquiries to Malcolm McRae, Kerrow House, Strathglass, Inverness-shire. Phone: Cannich 243

The Piobaireachd Society

announces the publication of a new book
"Sidelines on the Kilberry Book of Ceol Mor"
 Edited by James Campbell, Kilberry.

This consists of a collection of papers of Archibald Campbell, Kilberry, including musical illustrations and comments.

Price £7.00 plus postage

Obtainable from

The College of Piping

or the usual agents.