Chapter 6
Directional Band and Spectral Cue

Abstract Blauert (ACUSTICA 22: 205–213, 1969/70) performed sound localization tests, in which 1/3 octave band noise was presented randomly from the front, above, and rear in the median plane and reported that there was a band that was perceived in a specific direction, regardless of the direction of the sound source. This band is referred to as the directional band.

6.1 Directional Band

Figure 6.1 shows the relative frequency of the subjects, the number of responses in one of the front, upper, or rear direction is considered to be greater than the number of responses in the other two directions at a significance level of 5%.

The open square in the figure indicates a directional band, which can be regarded as having more subjects, who perceived a sound image to be in that direction at a significance level of 10%. The hatched square indicates a quasi-directional band.

These results show that a 1/3 octave band with center frequencies of 315–500 Hz and 3.15–5 kHz is perceived as being forward, with center frequencies of 800–1.6 kHz and 10–12.5 kHz as being backward, and with a center frequency of 8 kHz as being upward.

Furthermore, Blauert analyzed the HRTFs and reported that the energy in the directional band was large as compared to other directions. He referred to this band as the boosted band.

6.2 Individual Differences in Directional Bands

Itoh et al. (2007) reported that there exist individual differences in directional bands. The directional bands obtained for each of the seven subjects are shown in Table 6.1. Here, "All" indicates the directional band obtained from the responses of all of the subjects. The directional band obtained by Blauert (1969/70) is also shown.

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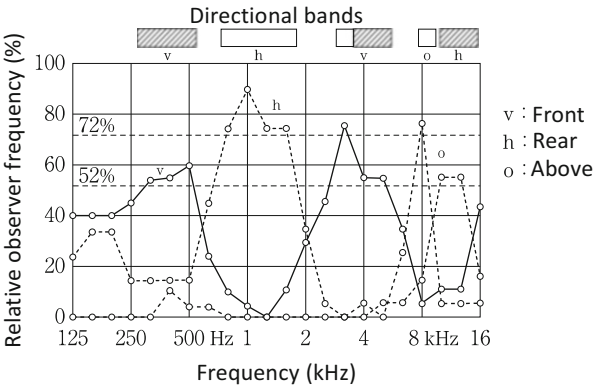

Fig. 6.1 Directional bands. (Blauert 1969/70)

It is common that the directional band changes as the center frequency becomes higher in any of the subjects: rear → front → above → rear. However, there is a difference in the frequency. That is, there are individual differences in the directional band. On the other hand, no significant difference is observed between the 1/3 octave band noise and the 1/6 octave band noise.

6.3 Band Widths of Directional Bands

The band widths in which directional bands occur have also been examined. Table 6.2 shows the directional bands for the 1/6 octave band noise for four subjects.

For the three types of center frequencies, in which directional bands occurred (rear: 1250 Hz, front and rear: 4000 Hz, above and rear: 7100 Hz), sound image localization tests were conducted using stimuli (1/6, 1/12, and 1/24 octave bands and pure tone), for which the band width was narrowed.

Table 6.3 shows the results. With some exceptions, by narrowing the bandwidth, even for pure tones, directional bands similar to 1/6 octave bands occurred.

Furthermore, sound image localization tests were performed using stimuli, in which successive directional bands of 1/6 octave bands occur in the same direction, were connected. The results are shown in Table 6.4.

Directional bands occurred in the direction same as the 1/6 octave bands for four of five types of stimuli for Subject SKG. However, for the stimuli having a center frequency from 11,224 Hz to 16,000 Hz, a directional band occurred in the rear, whereas that for the 1/6 octave band occurred in the front. For Subject NMR, the same directional band as the 1/6 octave band occurred for all three types of stimuli.

These results infer that, even for the case in which the band width of the stimulus is widened by connecting consecutive directional bands, which are perceived in the same direction, the directional bands are preserved.

Table 6.1 Directional bands for seven subjects. (Itoh et al. 2007)

(a) 1/3 octave band

: Front :Above : Rear

Subject	Center frequency (kHz)												
	0.8	1	1.25	1.6	2	2.5	3.15	4	5	6.3	8	10	12.5
A													
B													
C													
D													
E													
F													
G													
All													
Blauert													

(b) 1/6 octave band

Subject	Center frequency (kHz)																								
	0.8	0.9	1	1.12	1.25	1.4	1.6	1.8	2	2.24	2.5	2.8	3.15	3.55	4	4.5	5	5.6	6.3	7.1	8	9	10	11.2	12.5
A																									
B																									
C																									
D																									
E																									
F																									
G																									
All																									

Table 6.2 Directional bands for the 1/6 octave band

Subject	Center frequency (Hz)																		
	250	280	315	355	400	450	500	560	630	710	800	900	1000	1120	1250	1400	1600	1800	2000
SKG																			
KMG																			
MYM																			
NMR																			

Subject	Center frequency (Hz)																	
	2250	2500	2800	3150	3550	4000	4500	5000	5600	6300	7100	8000	9000	10000	11200	12500	14000	16000
SKG																		
KMG																		
MYM																		
NMR																		

Table 6.3 Directional bands for the narrow band

: Front :Above : Rear

(a) 1,250 Hz

Subject	Band width			
	1/6 octave	1/12 octave	1/24 octave	pure tone
SKG				
KMG				
MYM				
NMR				

(b) 4,000 Hz

Subject	Band width			
	1/6 octave	1/12 octave	1/24 octave	pure tone
SKG				
KMG				
MYM				
NMR				

(c) 7,100 Hz

Subject	Band width			
	1/6 octave	1/12 octave	1/24 octave	pure tone
SKG				
KMG				
MYM				
NMR				

Table 6.4 Directional bands for connecting consecutive bands

: Front :Above : Rear

(a) Subject SKG

	Frequency (Hz)				
	250 - 1000	1120 - 3150	4000 - 4500	6300 - 9000	11200 - 16000
1/6 octave band					
Connected Band					

(b) Subject NMR

	Frequency (Hz)		
	450 - 2500	2800 - 5600	7100 - 10000
1/6 octave band			
Connected Band			

6.4 Relationship Between Directional Band and Spectral Cue

As described in Sect. 6.3, even for pure tones or the directional bands of continuous 1/6 octave bands, the narrow-band signals are localized at a specific direction.

Then, what kind of sound image will be perceived if the energy of the directional band of the broad-band signal is boosted? As described above, when 1/3 octave band noise is presented from the median plane, most of the subjects localize a sound image above, regardless of the vertical direction of the sound source.

One sound image was localized at the direction of the loudspeaker when broad-band noise, in which the sound pressure in the 1/3 octave band of 8 kHz is boosted (up to +18 dB), was presented from a loudspeaker placed at the front or rear direction. Beyond a boost of +18 dB, only the boosted band spatially separates and is localized above, and the other band is localized at the direction of the loudspeaker.

This ear input signal has information on the sound source direction (front or back) as a notch and has information on the above direction as a boosted band. Therefore, this experimental result suggests that the notch functions more strongly than the boosted band as a spectral cue of vertical angle perception.

Middlebrooks (1992) proposed that the auditory system has the knowledge of the directional information filter by the pinna and the sound image occurs in the direction of the filter that the ear input signal best fits. Based on this proposal and the above experimental results, it is reasonable to consider that, "For vertical angle perception, the auditory system collates the ear input signal with the knowledge of the spectrum of HRTF. The auditory system uses the notch frequency as a stronger cue, and when the notch frequency is not available (such as narrow band signals), the auditory system uses the boosted band".

References

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