

A study on Visual Expression to express Sound Characteristics of Public Places

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Abstract

The causes of noise generation according to the classification of indoor spaces are very diverse. Individual happiness is infringed by this noise. In this paper, We tried to visualize the spatial sound characteristics of public places using sound color to express them so that anyone can sympathize. The noise inside a conference room of a medical device company was measured for 100 minutes, and the frequency band was divided into three different types of existing sound pressure expression units. Because the size of the noise is expressed differently depending on the situation, There are cases where there is a difference of opinion between the measurer and the researcher. This noise measurement experiment was conducted, and the sound color was applied to classify it on a log scale considering auditory characteristics. As a result of comparing this with the result expression for different loudness expression units, A specific table in different units yielded almost similar results. In addition, the sound source section for 100 minutes was divided into three analysis sections, the analysis sections were different, and the size of the energy ratio for each analysis section was divided in the form of an envelope. The characteristics of the low-frequency region of the space have a high energy ratio, and the decrease in the energy ratio according to the increase in frequency is constant and regular. You can see that conversations are possible.

Keywords: Meeting Room Of Medical Device Company, Volume Expression Unit, Sound Color, Envelope Shape, Analysis Section

1. Introduction

There are many causes of noise that exists in the interior of a building, and personal happiness is infringed upon by this noise. When equipment such as a fan, cooling tower, and air handling unit (AHU) located inside a building is operated, various types of noise are transmitted to the room, and such HVAC noise is It interferes with conversation and a quiet living environment depending on the indoor use of conference rooms, performance halls, offices, etc. A study on the actual noise condition of an indoor space with a karaoke accompaniment installed as a prior study on the actual condition of indoor noise and improvement measures, the effect of noise from the machine room facilities in a university dormitory, a study on the evaluation of the sound environment of the indoor environment of an elementary school, and renovation of an indoor gym A study on acoustic performance evaluation for medical equipment, from this point of view, this study was to

measure the noise of a conference room of a medical device company and to identify the acoustic characteristics. The composition of this thesis is the volume expression unit, A7NB (acoustic 7 narrow bandwidth), the noise and measurement of the conference room of a medical device company, and conclusion.

2. Volume expression unit

2.1. dB(A). It is a volume unit that simply embodies human hearing characteristics and is most commonly used in real life including noise units. The formulas for the dB reference unit are the ANSI (American National Standards Institute) technical standard [6].

$$R_A(f) = \frac{12200^2 \times f^4}{(f^2 + 20.6^2) \sqrt{(f^2 + 107.7^2)(f^2 + 737.9^2)} (f^2 + 12200^2)} \quad (1)$$

2.2. dB(B). It has a frequency characteristic that is halfway between dB(A) and dB(C). It is rarely used for measuring very loud sound pressure [15].

$$R_B(f) = \frac{12200^2 \times f^6}{(f^2 + 20.6^2) \sqrt{(f^2 + 158.5^2)} (f^2 + 12200^2)} \quad (2)$$

$$B(f) = 0.17 + 20 \log_{10}(R_B(f)) \quad (3)$$

2.3. dB(C). It has a flat characteristic from 100Hz to 6 octaves. Used for frequency analysis. In the audible range, it has almost the same frequency characteristics as Dbspl [15].

$$R_C(f) = \frac{12200^2 \times f^2}{(f^2 + 20.6^2)(f^2 + 12200^2)} \quad (4)$$

$$C(f) = 0.06 + 20 \log_{10}(R_C(f)) \quad (5)$$

2.4. dB(D). dB(D) is a type of aircraft noise measurement unit when measured with a sound level meter with a built-in circuit, and ICAI recommends that it be used for monitoring aircraft noise in the vicinity of airports [7].

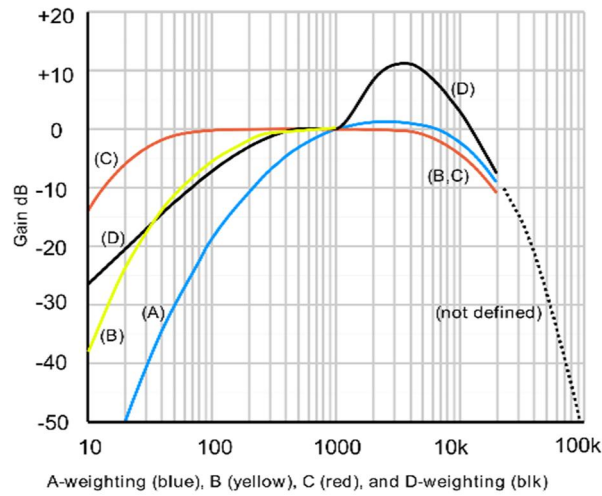


Figure 1. Frequency waiting curve in dB

$$R_D(f) = \frac{f}{6.8966888496476 \times 10^{-5}} \times \sqrt{\frac{h(f)}{(f^2 + 79919.29)(f^2 + 1345600)}} \quad (6)$$

$$D(f) = 20 \log_{10}(R_D(f)) \quad (7)$$

The figure below shows the frequency weighting characteristics according to the units of dB(A), dB(B), dB(C), and dB(D). dB(D) is based on A7B [15]. and the weighting of the mid- and high-pitched tones has been

increased up to 11dB [8].

3. A7NB(acoustic 7 narrow bandwidth)

A7B divides the frequency band according to the human hearing range into 7 bands with consistent energy per octave. wide bandwidth) covers the research area beyond the general audible limit.

Table 1. Energy ratio of pink noise according to A7B frequency segmentation criteria[10]

classification		scale band	frequency band[Hz]	center frequency [Hz]		energy ratio [Ttoal: 100%]	
infrasound		0 octave do # under	17 under	-		20	
ultra-bass	~A7WB	0octave do# ~	17 ~ 29	31	22	11.5	5.7
	~A7NB	0Octab ra# ~	29 ~ 49		38		5.8
bass		1Octave Sol ~	49 ~ 139	83		11.5	
bass		3 octave do# ~	139 ~ 392	233		11.5	
midrange		4 Octave Sol ~	392 ~ 1109	659		11.5	
alto		6octave do# ~	1109 ~ 3036	1835		11.5	
treble		7 Octave Sol ~	3036 ~ 8870	5189		11.5	
ultra-treble	~A7NB	9octave do# ~	8870 ~ 14917	14917	11503	11	5.8
	~A7WB	9Octab ra# ~	14917 ~ 25088		19345		5.2
ultrasonic wave		10Octave Sol more	25088Hz more	-		-	

A7B basically targets the human audible range, but in this measurement, the energy of the infrasound band outside the human audible range is summed together as a ratio. As a result, it can be confirmed that 20% of energy is concentrated in the infrasound band, which is a band that is inaudible to humans. This is a very large number, about 1.75 times the energy of the other individual 7 bands. When calculating the energy of the band below the A7NB band that directly affects hearing, it corresponds to more than 25% of the energy. A7B is the theoretical background of sound color with duration.

In frequency analysis, human hearing recognition ability for frequency changes plays an important role in low frequency and high frequency analysis. If a person reacts sensitively to a frequency change of a low frequency, a detailed analysis is required as it goes to a low frequency. However, human auditory characteristics are sensitive to frequency changes in the low frequency band and insensitive in the high frequency band. Therefore, the analysis section should be determined by finely dividing the band in the low frequency band and broadening the frequency band in the high frequency band. To analyze in detail means to analyze the frequency band narrowly, and to analyze broadly means to analyze the frequency band broadly.

There is a need for a method of analyzing a narrow frequency band as it goes down to a lower frequency and a wider band as it goes up a high frequency. This concept is octave analysis. Octave analysis means that in dividing the band, the center frequency of the upper band is twice the center frequency of the lower band. The center frequency of the next band of the band having 250 Hz as the center frequency becomes 500 Hz, and the center frequency of the next band becomes 1000 Hz, so it can be seen that the bandwidth increases proportionally as the frequency increases. can be expressed as In this case, the standard is 1000 Hz. Therefore,

the center frequency of every octave band is equal to the power of 1000.

In general, the speed of sound is 344 m/s (344 m/s) at room temperature of 20°C, and increases by 0.6 m/s as the temperature increases by 1°C. However, since the frequency of a sound multiplied by the wavelength of the sound is the speed, the speed of sound is the product of the frequency of the sound and the wavelength of the sound. From the table above, it can be seen that the value obtained by multiplying the frequency of the sound by the wavelength of the sound is constant at about 344 m/s.

Sound Wavelength = (344m/s) Sound Frequency Speed of Sound: 344m/s And in the table above, the wavelength of color is expressed in angstroms (Å). can be compared. Considering that the wavelength of C sound and the wavelength of red color is 100, it can be seen that each sound and color has a wavelength close to the ratio value on the right side of the table. In other words, colors having almost the same ratio can be substituted for each sound, and accordingly, colors can be seen by listening to the sound.

Table 2. Representation of color bands according to frequency band classification[10].

	Persia	Mizzler (1742)	Castel (1742)	Kruger (1743)	yuller (1760)	lefebourg (1789)	Sudr (1862)	bishop (1893)	scriabin (1911)
C	blue-black	red	blue	red	purple	blue	red	red	red
C#			celadon (blue-green)					orange-red	purple
D	violet		green	goledn-yellow	red	green	orange	orange	yellow
D#			olive-green					yellow-orange	flesh
	yellow		yellow				yellow	green-gold /yellow	sky blue
F	black	green	apricot yellow-orange	green	yellow	indigo	green	yellow -green	deep red
F#			orange					green	bright blue/violet
G	bright blue		red	sky blue	green	yellow	blue	green-blue	orange
G#			crimson					blue	violet
A	green		violet	purple	blue	orange	indigo	violet-blue	green
A#			agate					violet	rose/steel
B	rose	violet	indigo	violet	violet	violet	violet	violet-red	blue

When analyzing a vibration or acoustic system, it is very difficult to represent the entire frequency band. Therefore, it is the Octave Band that divides the frequencies so that the magnification is constant. Octave Band divides frequency bands and analyzes them based on the center frequency of the band, and each time the band

goes up, the center frequency doubles. In general, 1/1 Octave Band is used, but 1/3 Octave Band is used to display more precisely.

Table 3. Color bands as pure sound frequency increases[10].

pure frequency	tone	pure tone wavelength	Share by increase	wavelength by color	Share by increase
483.5		0.703205791	1.059145674	3976	1.032193
456.5		0.744797371	1.06039489	4104	1.033382
430.5		0.789779326	1.05904059	4241	1.074039
406.5		0.836408364	1.05859375	4555	1.039956
384		0.885416667	1.060773481	4737	1.038421
362		0.939226519	1.058479532	4919	1.063834
342		0.994152047	1.060465116	5233	1.070323
322.5		1.054263566	1.057377049	5601	1.047134
305		1.114754098	1.060869565	5865	1.05098
287.5		1.182608696	1.05893186	6164	1.049968
271.5		1.252302026	1.060546875	6472	1.061496
256		1.328125	1	6870	0

Sound pressure refers to the amount of change in pressure generated at each point of the medium when a sound wave passes through the medium. Sound pressure can be measured with a microphone in air and a hydrophone in water. The unit is expressed in pascals (Pa) or the like. The sound pressure level refers to the ratio of the sound pressure to the reference sound pressure expressed on a logarithmic scale. The unit is decibel (dB).

4. Meeting room noise measurement for medical equipment specialists

It is a sound source recorded for about 100 minutes of naturally occurring indoor noise in a conference room of a medical device company. This sound source collection was performed once. IC RECORDER ICD-UX543F (SONY CORP) was used for sound source collection and recording equipment, and audition was used for sound source analysis program.

4.1. Medical device company conference room noise

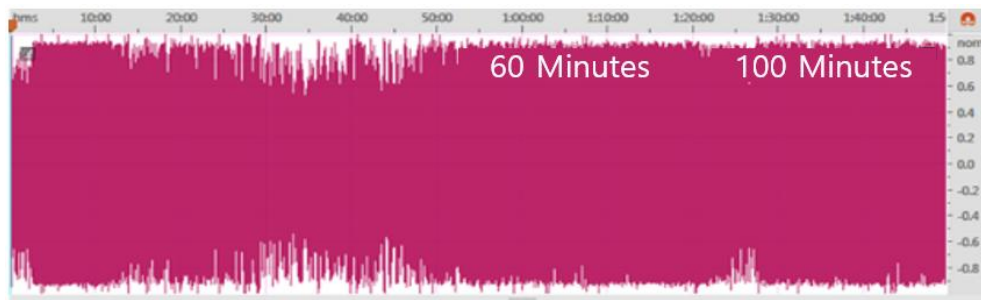


Figure 2. Medical Device specialist conference room noise waveform

Waveform The sound source from a medical device specialist company lasted for about 1 hour and 40 minutes, and the sound wave for about 30 to 50 minutes included the sound of medical device promotion, and the sound wave from the speaker for 50 to 100 minutes. The large sound pressure level of the music and the amplifier occupies a large proportion in absolute terms.

4.2. Spectral expression and sound pressure level expression of conference room noise of a medical device company

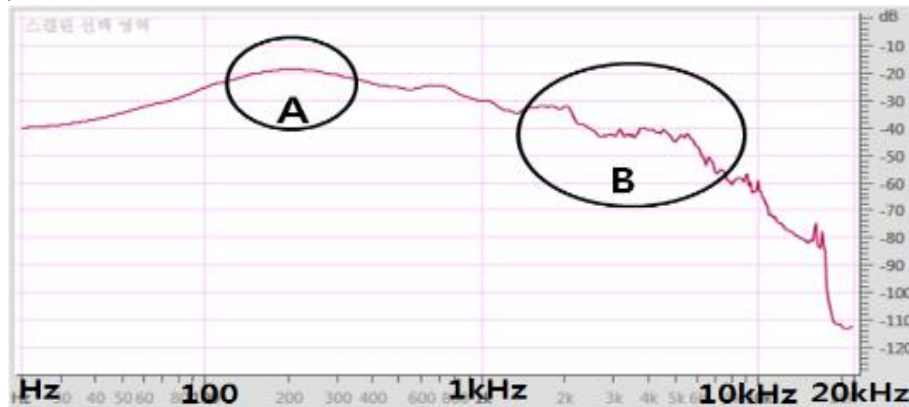


Figure 3. Medical device promotion conference room noise spectrum

The sound source from a medical device specialist company lasted for about 1 hour and 40 minutes, and the sound wave for about 30 to 50 minutes included the sound of medical device promotion, and the sound wave from the speaker for 50 to 100 minutes. The large sound pressure level of the music and the amplifier occupies a large proportion in absolute terms.

Table 4. Center frequency sound pressure level expression for each band of indoor noise in a conference room of a medical device company

Relative Response (dB)	Frequency (Hz)								
	31.5	63	125	250	500	1000	2000	4000	8000
dB(A)	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1
dB(B)	-17	-9	-4	-1	0	0	0	-1	-3
dB(C)	-3	-0.8	-0.2	0	0	0	-0.2	-0.8	-3

It expresses the sound pressure level by applying Equations (2.1), (2.2), and (2.3) to the sound pressure level of the indoor noise in a conference room of a medical device company. dB(A) is a unit expressing the degree of sound pressure level generated by human voice, and it was not suitable to express the size of the indoor noise of a conference room of a medical device company, and it appeared relatively small because there is no weight for the low sound of the space. , dB(C) is a means of measuring by setting the weight of the low-pitched area high, and is a unit expressed in terms of the low-pitched sound pressure level of the space. As a result of measuring the indoor noise in a conference room of a medical device company, the bass sound contained in the waveform in the time domain is well represented. In dB(A) and dB(C) expressions, there is a difference of about 10 times or more at the level of 30 Hz, which is the center frequency of 60 Hz.

4.3. Meeting room noise amplitude statistics for medical device companies

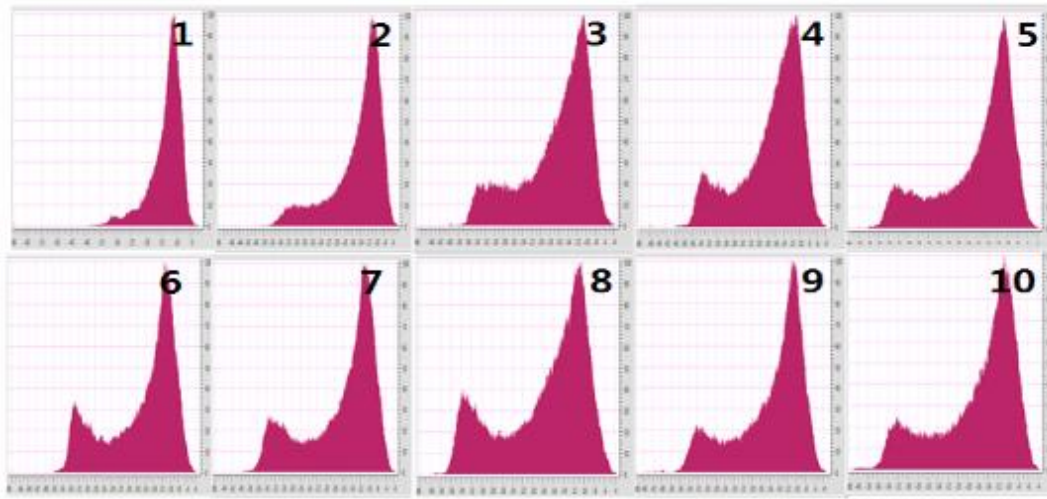


Figure 4. Medical device specialist conference room noise amplitude statistics

In the medical device promotion conference room, it is shown that the highest amplitude maintains almost the same value because the voice of the host by the microphone is the main sound source. As can be seen from the envelope of the zero-interval amplitude statistics, the shape of the energy distribution does not change according to the interval. This contrasts with the characteristics of other sound sources.

Table 5. Table of changes in noise amplitude statistics in conference rooms for medical equipment specialists

	1 range	2 range	3 range	4 range	5 range	6 range	7 range	8 range	9 range	10 range	average
maximum amplitude	0.00	0.00	0.00	0.00	-0.18	0.00	0.00	0.00	0.00	0.00	-0.018
average energy	- 13.42	- 14.81	- 16.71	- 17.11	- 16.31	- 16.94	- 16.63	- 17.79	- 16.06	- 16.32	-16.21
dynamic range	62.61	44.65	43.73	45.53	38.74	45.56	42.74	38.15	42.72	38.07	44.25

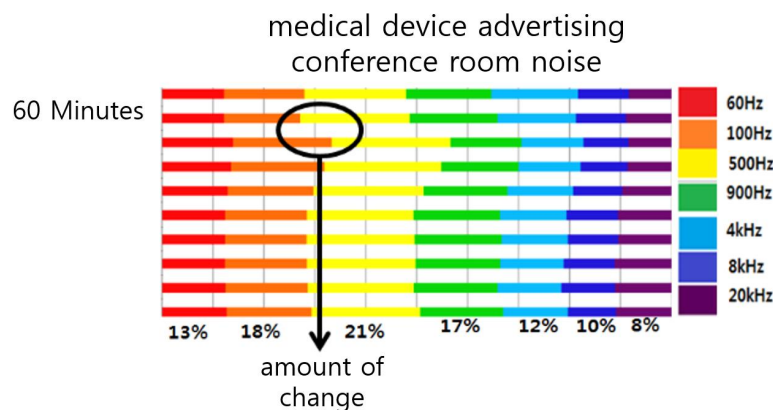
As can be seen from the envelope of the zero-interval amplitude statistics, the shape of the energy distribution does not change according to the interval. This contrasts with the characteristics of other sound sources.

Table 6. Noise measurement in the conference room of a company specializing in medical equipment

Relative Response (dB)	Frequency (Hz)						
	60	100	500	900	4000	8000	20000
dB(A)	-15.7	-12	-11.5	-13.3	-16.4	-18	-19.9
dB(B)	-17.5	-14.7	-13.3	-15.2	-18.2	-19.8	-21.7
dB(C)	-17.6	-14.8	-13.4	-15.3	-18.3	-19.9	-21.8

The table above is based on the noise measurement in the conference room of a medical device company. As a preparatory stage for individual expression, the human auditory By dividing the frequency section on a log scale according to the gender, It is expressed as a percentage of energy.

4.4. Sound color marker

**Figure 5. Sound color marker**

As shown in the previous table, Unlike performance, the ratio of energy to each frequency domain is Since it is expressed as an absolute value, the sound color is A visual representation of the noise level is not shown between unit types. It can be seen that can also include all Viewpoints. In the waveform, frequency spectrum, and duration of this sound source, only average changes at low frequencies are shown. In order to express this clearly at a glance, we suggest the following sound bands.

Table 7. Medical device advertising conference room noise

classification	frequency band	center frequency	energy ratio
Red	0 ~ 60	30	13%
Orange	61 ~ 100	80	18%
yellow	101 ~ 500	250	21%

green	501 ~ 900	750	17%
blue	901 ~ 4000	2000	12%
Indigo	4001 ~ 8000	4000	10%
purple	8001 ~ 20000	10000	8%

The experimental space recorded the sound source from the first floor of a four-story building. This space can accommodate a relatively large number of people. The characteristics of the measured indoor noise vary according to time. The cause of noise is the sound source coming out through the microphone of an employee of a medical device company for 30 to 50 minutes of the sound source, and the sound source between 50 and 100 minutes is because the amplified sound of the amplifier is reproduced through the speaker. For each frequency band, noise due to speaker nonlinearity and noise due to amplifier nonlinearity are predominant. However, since this is a state in the time domain, it is only possible to visually confirm whether the change in the sound pressure level reaches the peak point, and other room noise characteristics cannot be distinguished.

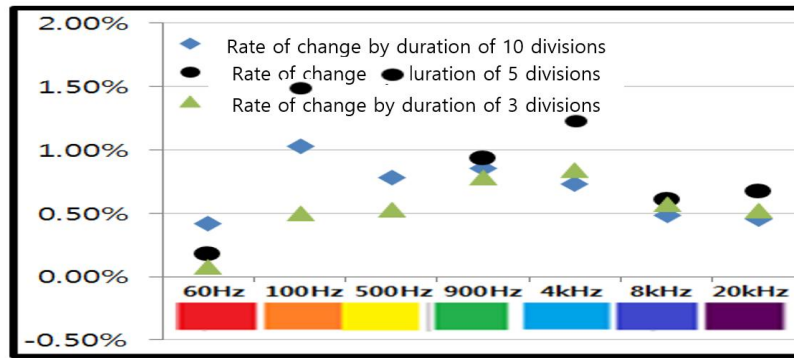


Figure 6. Rate of change by duration of medical device specialized companies

Since the visual expression of noise is calculated as the energy ratio for each frequency band regardless of the different sound pressure level measurement units, it can be used equally regardless of the measurement unit. If the unit of the sound pressure level selected by different measurers is different, the noise level may change, so it may cause differences in opinions and conflicts when understanding the actual noise level in a specific space.

Therefore, the visual expression of noise becomes a means to fundamentally block such conflicts. Another characteristic implied by the above figure is that, unlike spectrum analysis, which divides spatial characteristics into short sections, this researcher analyzed three types of time waveforms for 100 minutes and expressed energy ratios for each frequency by dividing the sections. This shows that the spatial acoustic characteristics of a medical device company are similar to the log scale, which is a characteristic of human hearing. This can confirm a kind of sound masking effect that does not disturb the person next to you even when several people are talking to each other in a conference room of a medical device company.

5. Conclusion

Various noises exist in the indoor space in a building due to various noise sources, and the happiness of individuals is infringed by these sounds. When performing acoustic measurement of a space, it is not easy to

understand the characteristics of the entire space because previous researchers only consider changes in the sound pressure level in a relatively short time through spectral analysis focusing on the size of the sound pressure level.

This study measured the noise in a conference room of a medical device company and analyzed it by applying sound pressure level expression, spectrum analysis, amplitude statistics, and sound color. Frequency sections were divided on a log scale representing human hearing characteristics, and the sound pressure level in that area was expressed as an absolute value of energy ratio. For different sound pressure levels, the criteria for analyzing the noise level may vary depending on the point of view of the measurer. On the other hand, for the room noise characteristics to which sound color is applied, the same level of room noise was expressed even when several volume measurement level units were applied.

This has the effect of preventing differences of opinion that may occur between different measurers in advance. In addition, when analyzing sound sources by applying sound color, the analysis section was divided into three sections to analyze the acoustic characteristics of the space over time. You can also check the masking role.

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