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A SURVEY & EVALUATION METHOD FOR SPEECH INTELLIGIBILITY OF FIREFIGHTING RADIOS CONSIDERING THE ENVIRONMENT OF THE FIRE SITE

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ABSTRACT

In a firefighting site, the firefighter's radio plays a very important role in not only responding to the situation quickly but also in maintaining the life of the firefighter. In order for firefighters to communicate smoothly using the radio, they must be able to clearly deliver their voices and deliver them to the other firefighters. However, there are various noise sources at the firefighting site, as well as the influence of the main firefighting water, making it difficult to communicate using the radio. In this study, we conducted a survey on the level of speech transmission of radios used at firefighting sites and on-site noise. Firefighters mainly used radios and handy microphones, and responded that it was difficult to hear speech due to various noises at firefighting sites and howling phenomena of several radios in the same place. The main sources of noise at the site were the sirens of fire trucks and equipment noise such as pump cars. The siren sound transmitted into the interior of fire trucks was investigated to be very high at about 83 to 93 dB. In addition, it was investigated that the radio speech sound was affected by the main water supply for firefighting.

Keywords: *speech intelligibility, fire fighting, radio transmission, fire truck noise*

1. INTRODUCTION

In large-scale firefighting operations, swift fire suppression and successful rescue efforts heavily rely on rapid and clear communication between firefighters on the ground and the commanding staff. Communication at the fire site is primarily carried out through radios. Therefore, the radios used by firefighters must be capable of transmitting clear voice messages with sufficient volume. Recently, firefighter radios have evolved to resemble smartphones, incorporating various information and communication functions. There are various noise sources at the firefighting site, as well as the influence of the main firefighting water, making it difficult to communicate using the radio.

This study explores methods for developing information and communication radios that enable clear communication for firefighters at the fire site, focusing on evaluating speech intelligibility considering the noise conditions at the site.

To achieve this, the study first conducted a survey to assess the current state of speech intelligibility in firefighter radios. Secondly, the noise levels and characteristics of key firefighting equipment were investigated. Finally, the study proposes a method for measuring the speech intelligibility of radios by applying the widely used Speech Transmission Index (STI), as s standardized as IEC 60268-16[1] and ISO 3382-3[2], and by simulating the noise characteristics of a firefighting environment.

2. SURVEY ON THE NOISE OF FIRE SITE

A survey was conducted on the satisfaction with the transmission and reception of messages through radios used by firefighters, the causes of poor audibility, and the major noise sources in fire ground environments. The survey was carried out from June to July 2024, involving approximately 500 firefighters. The survey method included both paper questionnaires and an online response option.

Regarding the extent of message transmission through the radios, only 9.8 % of the respondents reported that all messages were successfully transmitted. Furthermore, in terms of satisfaction with the reception of speech, only 39 % of the firefighters expressed satisfaction with the

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clarity of the received sound. The most commonly selected reasons for poor audibility of radio messages were the background noise at the scene and the sounds of other firefighters. This suggests that issues related to environmental noise and acoustic phenomena, such as howling, are the main causes of poor reception.

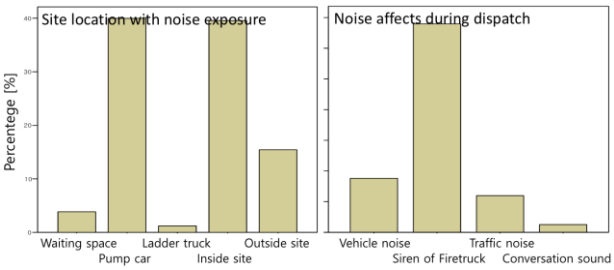


Figure 1. Results of a survey on noise at fire site

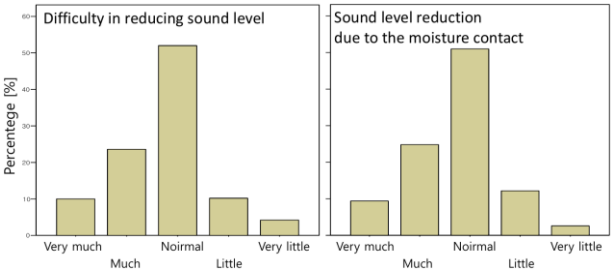


Figure 2. Survey results on difficulty in reducing level and sound level reduction due to the moisture contact

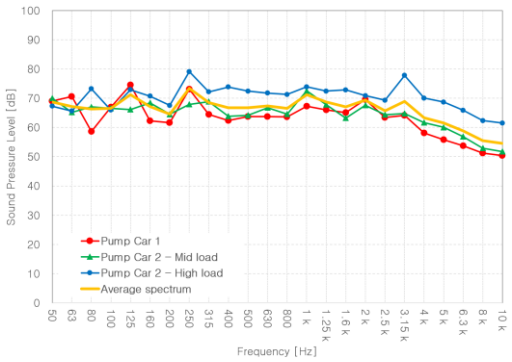
When asked about the locations and equipment that generate the most noise at fire ground operations, the results, as shown in Figure 1, indicated that pump trucks and the interior of fire scenes are the noisiest areas. During the dispatch phase, the siren of the fire truck was identified as the primary source of noise.

In terms of the reduction in radio volume and the effects of moisture, the survey results, as shown in Figure 2, revealed that 33.6% of respondents experienced difficulty due to low volume on their radios. Additionally, 34. 2% of firefighters reported experiencing difficulties due to moisture-related issues affecting the radios.

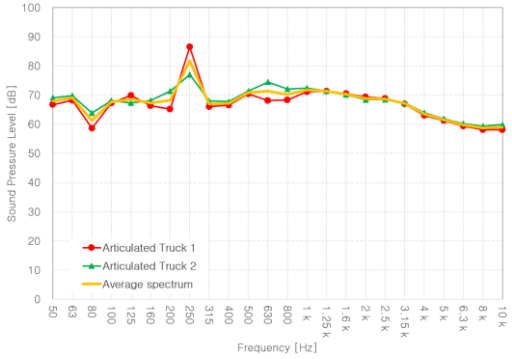
3. NOISE CHARACTERISTICS OF FIRE TRUCKS & SIREN

Based on the survey results, the noise characteristics of firefighting equipment were measured. Noise measurements were taken at several locations around the vehicles when operating pump trucks and articulated fire trucks, which are actively used by two fire stations in Gyeonggi Province. The noise from firefighting equipment was recorded throughout the entire training scenario, and noise levels were analyzed based on the operational stages and load conditions of the equipment. Figure 3 shows the firefighter training scenario and the articulated fire truck being measured.

Figure 3. The noise measurement of articulated fire trucks and firefighter training scenarios.



(a) Frequency characteristics of pump car



(b) Frequency characteristics of articulated truck

Figure 3. Sound level measurement results of fire trucks

Figure 3 presents the averaged noise measurement results for the fire pump trucks and articulated fire trucks,

categorized by each vehicle. The noise generated by the fire trucks exhibits a flat frequency characteristic, with specific noise bands occurring due to pump operation for each piece of equipment. The noise generated by a single fire vehicle typically exceeds 70 dB across most frequency bands, with noise levels around 78 dB(A) to 85 dB(A).
Figure 4 shows the frequency measurement results of the siren sound from various fire vehicles. Due to the characteristic nature of siren noise, high sound pressure levels were observed in frequency bands above 400 Hz, with a peak at 630 Hz. As the frequency increases, the sound pressure levels in the respective frequency bands decrease.

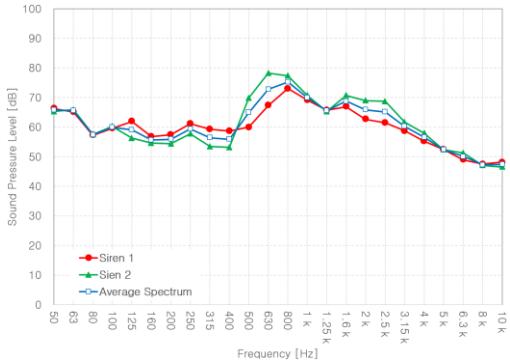


Figure 4. Sound level measurement results of sirens

The results of the firefighting equipment noise characteristics measurement were simplified for use as field sound sources when measuring the speech clarity of radios used by firefighters.

4. SPEECH TRANSMISSION INDEX MEASUREMENT OF FIREFIGHTERS RADIO

For speech intelligibility measurement of fire fighter's radio was conducted using STI (Speech Transmission Index), which is standardized in IEC 60268-16 and ISO 3382-3. The Speech Transmission Index (STI) measurement was based on IEC 60268-16. STI measurements were conducted using the NTI XL2 sound level meter and NTI Talk-Box. The sound source for the STI measurement was generated by the Talk-Box, which simulates human speech, and was then input into the transmission radio's microphone. The STI sound source transmitted through the communication network was received by the radio's speaker, and the STI of the received sound was measured.
Figure 5 illustrates the simplified measurement setup for STI measurement of the radios. The distance between the Talk-Box and the transmitting radio, as well as the distance between the receiving radio and the STI measurement microphone, was set to 10 cm, considering the actual conditions in which firefighters hold and speak into radios or listen to them. The transmission and reception of STI sound sources through the radios were conducted in a soundproofed environment to ensure adequate noise isolation.

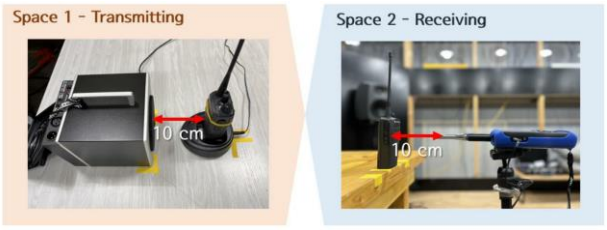


Figure 5. Speech intelligibility measurement set-up for fire fighter's radio

In addition to the STI measurement setup in Figure 5, the simplified noise characteristics of firefighting equipment were reproduced using two loudspeakers to measure the STI of firefighter radios. The noise level of firefighting equipment in the field was approximately 85 dB(A), but considering the test environment and the sound pressure levels generated by the firefighting radios, it was set to from 52 dB(A) to 72 dB(A) for the experiment.
STI measurements were conducted on three types of firefighter radios and one normal radio, comparing the values obtained in a quiet environment without firefighting equipment noise and the values obtained in conditions where firefighting equipment noise was present.

Table 1. STI measurement results of normal radio

BGN condition	STI	STI class
Low-noise	0.78	Excellent
52 dB(A) noise	0.76	Excellent
62 dB(A) noise	0.75	Excellent
72 dB(A) noise	0.42	Bad

Table 2. STI measurement results of fire fighters radio 1

BGN condition	STI	STI class
Low-noise	0.89	Excellent
52 dB(A) noise	0.54	Sufficient
62 dB(A) noise	0.31	Bad
72 dB(A) noise	0.22	Incomprehensible

Table 3. STI measurement results of fire fighters radio 2

BGN condition	STI	STI class
Low-noise	0.78	Excellent
52 dB(A) noise	0.75	Excellent
62 dB(A) noise	0.41	Bad
72 dB(A) noise	0.33	Bad

Table 4. STI measurement results of fire fighters radio 3

BGN condition	STI	STI class
Low-noise	0.92	Excellent
52 dB(A) noise	0.89	Excellent
62 dB(A) noise	0.84	Excellent
72 dB(A) noise	0.78	Excellent

The STI measurement results for the general radio (Type 1) and three types of firefighting radios are shown in Table 1 to Table 4. During the STI measurement, the volume of the receiving radio was set to its maximum. In the case of the general radio, the STI value did not change significantly as the surrounding noise level increased. However, under the 72 dB(A) condition, the STI value decreased to 0.42.
For the two types of firefighting radios, as shown in Tables 2 and 3, an increase in background noise level was found to correlate with a decrease in the STI value. However, for firefighting Radio 3, as shown in Table 4, although the STI value slightly decreased with the increase in background noise level, the evaluation grade remained "Excellent."
The different changes in STI values across the radios with increasing background noise levels are believed to be influenced by the sound pressure levels generated by the radios and the frequency characteristics of the radio microphones and speakers.

5. CITATIONS

In order to ensure rapid response and firefighter safety at fire situation, clear communication through firefighter radios is essential. However, measurement method for speech intelligibility has not been proposed that targets the entire system, including the hardware such as the transmitting radio's microphone and the receiving radio's speaker, as well as the software. Additionally, it is necessary to specify the measurement environment considering the field conditions of radio usage.

This study aimed to establish a method for evaluating speech intelligibility of firefighter radios by identifying the noise sources at fire scenes through a survey. The noise characteristics of selected firefighting equipment were measured and simplified, then presented as background noise during the speech intelligibility evaluation.
The speech intelligibility (STI) of the radios was measured and compared. Differences in speech transmission index (STI) and sound pressure levels between radio models were identified. It was found that the degree of change in speech intelligibility varied across radio models depending on the reproduction of background noise from the fire scene.
In the future, it is necessary to standardize the speech intelligibility (STI) measurement methods for radios and various products, considering the noise environments specific to their intended use.

6. ACKNOWLEDGMENTS

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7. REFERENCES

[1] IEC 60268-16:2020, Sound system equipment - Part 16: Objective rating of speech intelligibility by speech transmission index.

[2] ISO 3382-3:2022, Acoustics — Measurement of room acoustic parameters — Part 3: Open plan offices