CHALLENGES IN INTELLIGIBILITY ANALYSIS OF PUBLIC ADDRESS AND EMERGENCY NOTIFICATIONS SYSTEMS

Jean-François Latour[*1]
[1]SNC-Lavalin Inc., Longueuil, Québec, Canada.

1 Introduction

During the past decade, there has been an increase in the requirements for Public Address and General Alarm Systems (PAGA). They migrated from audibility criteria to intelligibility criteria. Checking simple charts showing sound levels at a distance is no longer enough and intelligibility must be evaluated. This task comes with several challenges as it requires more thorough inputs regarding the speakers and the spaces where the messages need to be intelligible. Also, an adequate methodology and the uncertainty in the evaluation tools are to be considered as the PAGA may be tested during commissioning and must show compliant results.

2 Audibility vs intelligibility

It is quite obvious that building users must be aware of the existence of an emergency situation. Awareness was historically achieved with emergency bells and sirens and assuring audibility by a minimal signal-to-noise ratio (of 15 dBA as per ISO 7731 [1] for example). Some siren systems even had different tones or rhythm/pattern to announce different emergency situation. However, to understand which situation it relates to (and react accordingly), users must be aware of the existence of different emergency signals, the audio characteristics of each one and their respective meaning. This approach was not very convenient.

Nowadays, it is common that status and/or instructions be transmitted via vocal messages through a PAGA system. Audibility is therefore not enough and it must be assured that the message is understandable, instead of just being heard.

3 Speech intelligibility criteria for PAGA

The notion of intelligibility refers to the capacity of hearing a message and understanding its meaning and content. Speech intelligibility can be objectively quantified using several metrics developed for that purpose: Speech Transmission Index (STI), Articulation Index (AI), Speech Intelligibility Index (SII), etc.

A common reference for PAGA acoustic/intelligibility requirements is NFPA 72 [2] which uses STI (or its simplified version, the STI-Public Address).

3.1 Speech transmission index

Simply put, STI is a metric that qualifies the deterioration of a modulation spectrum and which scores vary from 0.00, for no intelligibility, to 1.00, for perfect intelligibility (as per IEC 60268-16 [3]). Scores could then be compared to a subjective scale (see Table 1).

Table 1: Subjective scale of STI scores (as per ISO 9921 [4])

Subjective scale	STI score
Excellent	0.75 to 1.00
Good	0.60 to 0.75
Fair	0.45 to 0.60
Poor	0.30 to 0.45
Bad	0.00 to 0.30

It is obvious that the subjective scale would be different in the case of a non-native listener and/or speaker and also in the case of hearing impaired listeners.

3.2 STI targets as per NFPA 72

As per NFPA 72 [2], the evaluation must take place in each Acoustically Distinguishable Spaces (ADS) of a building. In each ADS, the PAGA system must have STI scores that complies with the following criteria:

- At least 0.45 within 90% of the area;
- Mean value must be equal or above 0.50.

4 Required inputs for modelling intelligibility

Floor plans and elevations are part of the primary information to assemble a 3D model in acoustic simulation software. The expected finishes are also primordial as they have an important impact on the sound field by absorbing/reflecting waves and need to be incorporated in the model (and accounted for with the proper absorption coefficient).

Expected speakers' location as well as type are also mandatory. As most models of speakers used in PAGA systems are constant-voltage and could therefore broadcast the signal at different levels, it is important to know the tap setting (assigning more or less power to the speaker). Different speakers may have different sensibilities, frequency responses and directivity patterns which all need to be accounted for in the model.

For a new building, the background noise may not be measurable. However, background noise assumptions may be accounted for in the model.

5 Possible sources of uncertainty on STI scores

The acoustic modelling of speech intelligibility can only be as precise as the inputs are. Some may have more influence

[*] jean-francois.latour@snclavalin.com

on the STI scores than others. To verify this, an input variation analysis was made in a model that consisted of an open office/lab environment (furniture not modelled) of approximately 500 m² covered with four ceiling speakers and using two receptors (see Figure 1).

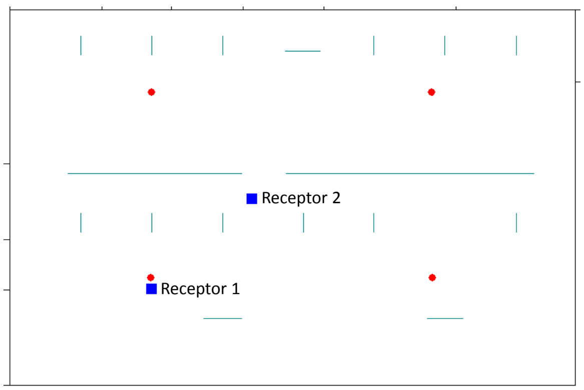

Figure 1: Plan showing the PAGA speakers (red dot) and receptor (blue square).

5.1 Expected vs real background noise

For new projects, it may be difficult to predict the background noise with accuracy. The HVAC system may be designed to a specific NC, but in reality it may easily vary. The addition of user equipment and other non-building mechanical system sources may also increase the background noise. Figure 2 shows how background noise may influence STI scores.

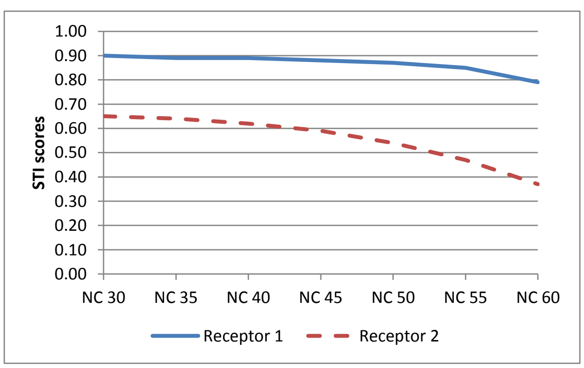

Figure 2: STI scores vs background noise

It may be noted that the relation is not linear between background noise and STI scores. The effect of increased background noise appears to be of greater magnitude for receptors that have a lower score to begin with. In the current case, the STI scores may be reduced by as much as 0.10 when background noise is increased by only 5 points.

5.2 Absorption coefficient discrepancy

In the current case, the ceiling is modelled with a NRC 0.70 acoustical ceiling tiles. Three other selections of tiles have been modelled (NRC 0.60 to 0.75) and it appears that their respective STI scores remained in close agreement with the one of the original tile selection (± 0.02).

5.3 PAGA speaker variation

Directivity variation

Despite being of a similar type (ceiling speaker in this case), from one speaker model to another the directivity pattern could be significantly different (especially at higher frequencies). In the current analysis, different directivity pattern could introduce STI score variations up to 0.10.

Sensibility and frequency response

Speakers will have different sensibilities and frequency responses. As those speaker characteristics may influence significantly the STI scores, slight tweaks at the commissioning stage are possible to some extent by adjusting the speaker tap as well as the audio signal volume and equalization (adjustments must not, however, increase distortion as this could be detrimental to the intelligibility).

5.4 Effect of furniture

For practical reason, all equipment, furniture, office screen/work stations or other elements not part of the base building are typically not modelled. However, the effect of such elements could either be insignificant, beneficial or detrimental on the STI scores. The effect on STI scores is difficult to predict as it depends on many factors related to the room finishes, the speakers' placement, height of screens in an open plan area for example, etc. and could therefore only be established on a case-by-case basis.

6 Conclusion

The current paper summarizes typical PAGA requirements and the required inputs to perform intelligibility analysis through acoustic modelling. Possible uncertainties on the STI scores are also identified and discussed.

Acknowledgments

The current study has been made possible through funds provided by SNC-Lavalin Inc. (SLI). The author would like to thank all members of the acoustics and vibration team of SLI for their help and support during the study with a special thanks to Mrs. Céline Lefebvre for her assistance in assembling the figures.

References

[1] ISO 7731:2003 International Organization for Standardization, *Ergonomics -- Danger signals for public and work areas -- Auditory danger signals*, 2003.

[2] NFPA 72 National Fire Protection Association, *National Fire Alarm and Signaling Code*, 2016.

[3] IEC 60268-16:2011 International Standard, *Sound system equipment – Part 16 Objective rating of speech intelligibility by speech transmission index*, 2011.

[4] ISO 9921:2003 International Organization for Standardization, *Ergonomics - Assessment of speech communication*, 2003.