Split Air-conditioner Noise Source Identification through Sound Intensity Mapping

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Split Air-conditioner Noise Source Identification through Sound Intensity Mapping

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Abstract. As the global warming takes place in years, the electrical appliances such as air-conditioner have been installed in most residential, industrial, or even in the education institution to provide better air quality and ultimately reduces the heat transfer in the ambient. Common use of split air-conditioner system to give maximum capacity in a space is responsible to the accumulated noise generated by the outdoor unit of the system. Therefore, an experimental study has been done to identify the noise rating and location of the highest noise level emitted by the system through different temperature and fan speed. The sound intensity mapping together with the sound power level will be applied to ensure the reliability of the data for the study purposes. Generally, the results indicated that the noise were concentrated at the compressor and fan blades whereas the level were observed to be higher with the lower temperature and higher fan speed operated. The highest noise level also reported as high as 99.08 dB(A) which located at the compressor. Hence it can be concluded that mitigation action is needed since considerable noise are generated by the application of air-conditioner particularly at the compressor and condenser fan.

1. Introduction

Global warming and climate changing caused by the human activities primarily due to burning fossil fuels like coal, oil and gas has been acknowledged since the early 2000's [1]. These issues have driven the technology to reduce the dependency of fossil fuels in the automotive industry by replacing with the usage of biodiesel [2]. Meanwhile, to adapt this climate changes, the heating, ventilation, and air-conditioning systems are developed to provide comfort in human thermal and better air quality [3]. Purposely designed to raise and lower the temperature in a space, the system components were identified as the source of noise emission, thus, gives a detrimental effect to the acoustical environment [4].

Explained by Crocker et al. [5], the noise emitted by the air-conditioning and heating unit probably generated by the mechanical and aerodynamic processes including the vibration of compressor shell, electric motor, and fan noise. Therefore, it is critical to understand the mechanisms of the components that can derived to the higher extent of noise level so that the amelioration can successfully be made. Stated by Manivasagam and Sethilnathan [6], the application of compressor in the air-conditioner is recognized as the major noise source due to the pressure pulsations and mechanical vibration generated to the compressor housing which consequently producing the direct and indirect noise. Meanwhile, a study by Bo et al. [7] presented that the expansion valve could also be one the noise sources due to the throttling effect and refrigerant flowing in two-phase. For these reasons, they

suggested a designated pipeline muffler that ideal to the high-pressure pipelines use to compensate the transmitted sound energy and to reduce the size of bubbles in the two-phase flow.

On the other hand, the contribution of the fan in the system is not negligible since considerable levels of noise was generated by the motor, bearing housing, shaft seals and improper design of fan blades [8]. Not only that, the dust and materials that are trapped at the fans also tend to introduce the additional noise to the overall noise level. Thus, several improvements were made through the fan casing, silencers, acoustic guards as well as shaft sealant to improve the acoustic characteristics of a fan. The same problem has been acknowledged by Sun et al. [9] which show that there is a linear relationship between sound power level and cooling capacity as the higher cooling capacity delivers the higher sound power level. Nevertheless, different units of air-conditioner do not maintain the relationship since it depends on the specific model, dissimilar design of fan blades and fan power.

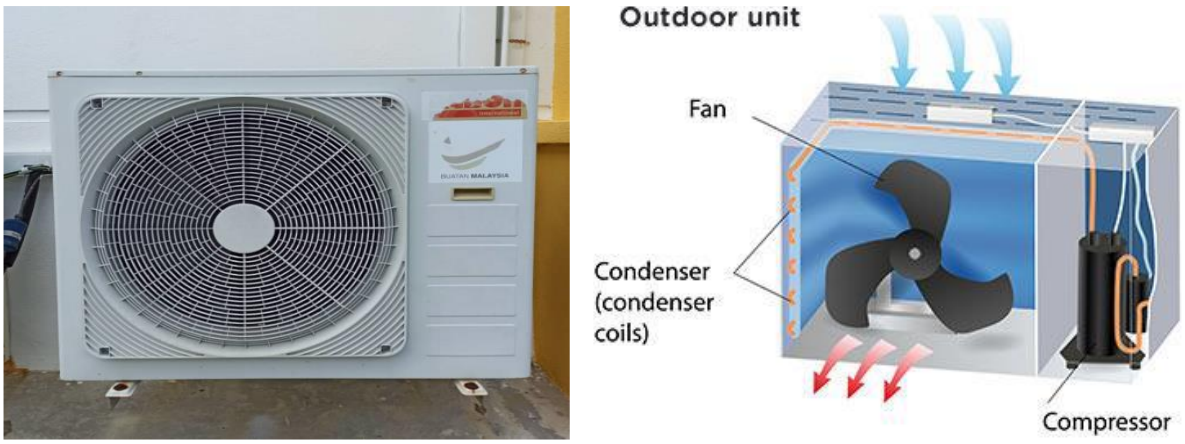
Regarding on the indoor unit of the air-conditioning system, Kamada et al. [10] asserted that the fan blades and scrolls are responsible to determine the blowing performance and noise level. They also added that the design shapes may depend on many variables, and it is arduous to optimize all the variables simultaneously. In different study by Tomozei et al. [11], it can be concluded that the noise values of indoor unit are varied according to the operational frequency along with the distance of blowing. On top of that, the temperature of an indoor space is found to be influenced by the outdoor ambient temperature which indirectly forcing the longer cycle to reach the desired temperature.

Identically to Crocker et al. [5], Sani et al. [12] and Zikri et al. [13] utilized the sound intensity measurements to investigate the noise level generated by the outdoor unit of air-conditioner. The author revealed that generally the sound power level will increase with the higher fan speed together with the lower temperature. This shows the correlation between the sound power and sound intensity as the results indicated that the highest noise levels were concentrated at the fan and compressor. However, the lowest temperature is restricted to 20°C only, where in most cases, for a big space, the temperature is even brought down to 16°C to shorten the heat elimination duration. Thus, in this paper, the study will be conducted at the outdoor unit by the varying the fan speed and temperature from the lowest with the increment of 4°C. The noise results are analysed by using the sound power level and sound intensity measurements according to the standard of ISO 9614-1.

2. Method

2.1 Test Section

The test section is the outdoor unit of split air-conditioning system that is located outside of a building which close to the office area where it possibly yielding the annoyance and uncomfortable environment. The outdoor unit and its components are illustrated in Figure 1 (a) and (b) where it contains the compressor, condenser coil, expansion valve and fan. Knowledge of these components is important as it will describe the phenomenon that might take place in the noise evaluation.



(a) Outdoor Unit (b) Components in the outdoor unit

Figure 1. Air-conditioner test section

2.2 Sound Intensity Measurements

For the measurement purposes, the Brüel and Kjær handheld analyser together with the sound intensity probe Type 2270 are used since it possesses the ability to host number of applications including frequency analysis, logging, FFT, building acoustics and signal recording apart from simultaneously measuring with two microphones. All the measurements being done according to the ISO 9614-1 standards which uses point as measurements and the noise being measured by 1m distance. The distance and measurement process are depicted in Figure 2 (a) and (b) where the results are analysed in both the sound intensity and sound power terms so that the noise hotspots and rating could be determined. The intensity mapping scale is presented in Figure 3 where the colour code shows the direction of the sound either forward or backward.

(a) Distance (b) Measurement process

Figure 2 Data measurements

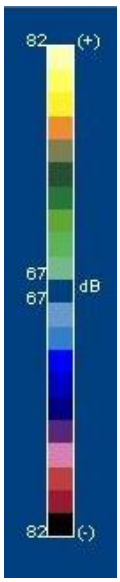


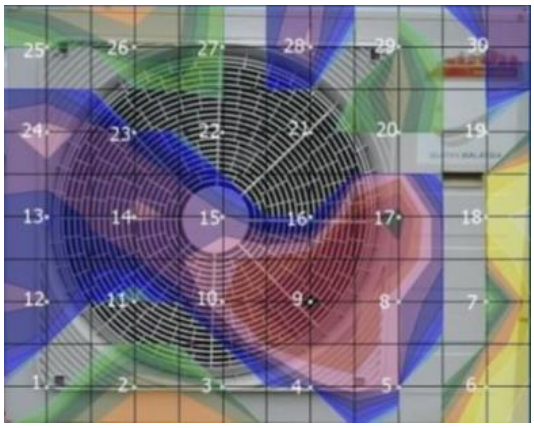
Figure 3 Sound intensity mapping colour indicator

3. Results and Discussion

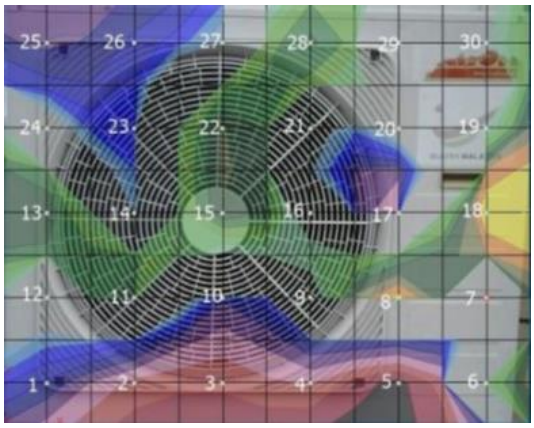
3.1 Sound Intensity Mapping

3.1.1 At the temperature of 16°C

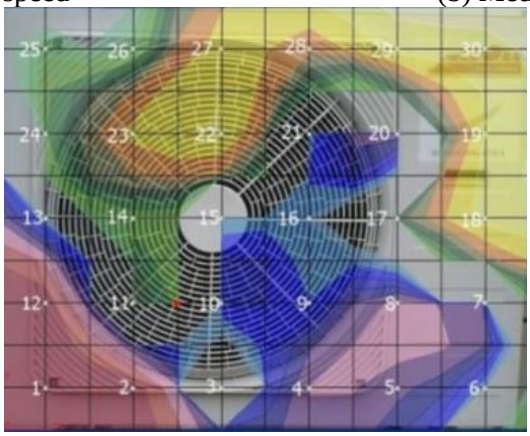
Figure 4 (a) to (c) present the intensity mapping of the outdoor unit when the fan speed varied from low to medium, and high level at temperature 16˚C. With the low fan speed, it can be noticed that the noise intensified at the right side where the compressor located. Disregarding the direction of the sound, the highest noise was obtained in the mentioned area with 94.06 dB. As the fan speed being increased to medium speed, such trivial difference can be seen in the mapping where the highest noise level still concentrated at the right side with 94.80 dB. On top of that, point 5 with the black colour code provides that the vibration generation by the compressor operation could also contributes to the noise produced. Further increase of fan speed has bring the SPL to the higher value located at point 30 with 99.08 dB where this rating obviously not in the normal range of air-conditioner operating sound. On the other hand, the result points out that the fan section also could be one of the noise sources in the system as 98.11 dB of SPL could be obtained. This finding lead to the agreement to the previous study that highlighting the noise generated by condenser fan is undeniable [10]. To sum up, the results show that there is a linear relationship between the fan speed and noise emitted as the increment of fan speed has driven the noise to the higher extent. Apart from that, the noise is found to be concentrated at the compressor and fan where the similar finding can be found in a work by Sani et al [12].



(a) Low fan speed



(b) Medium fan speed

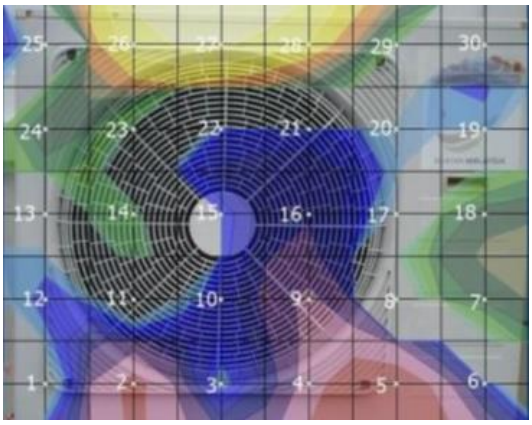


(c) High fan speed

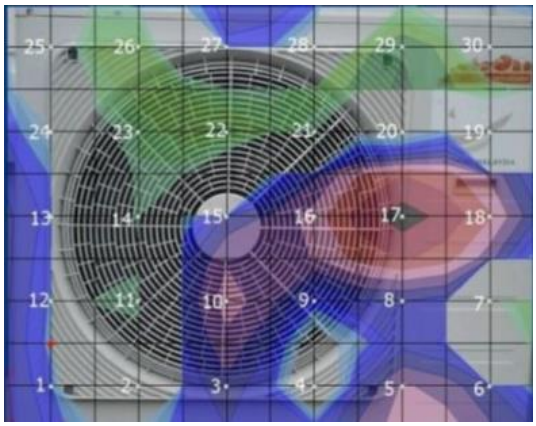
Figure 4 Temperature of 16˚C

3.1.2 At the temperature of 20°C

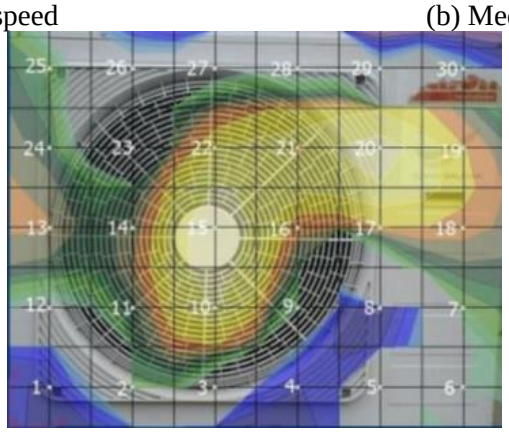
The intensity mapping for low, medium, and high fan speed at temperature of 20°C are shown in Figure 5 (a) to (c). The intensity mapping indicated by the low fan speed revealed that as the temperature being brought up, the sound was radiated in circular motion as the top and bottom of source represented by the higher level. The highest SPL could be obtained at the top with 90.39 dB. With the medium speed of fan, the dominating noise source emerged suggesting that the compressor operation led to the higher noise level with 92.30 dB. Whereas the mapping for maximum fan speed at current temperature was identical to the previous temperature where the highest noise generated through the fan and the compressor where the highest could be noticed in the centre of the fan with 98.72 dB. These events have strengthened the fact that both components strongly influenced the overall noise level to be higher by the frequent activities. Added by Burgess and Thompson [8], the fan in the air-conditioning system could generate the noise in various way namely the casing, blades, motor, and shaft seal. Hence, proper actions to reduce the noise such as improving the casing material thickness, redesign the fan blades, an efficient motor and proper shaft sealing is needed.



(a) Low fan speed



(b) Medium fan speed



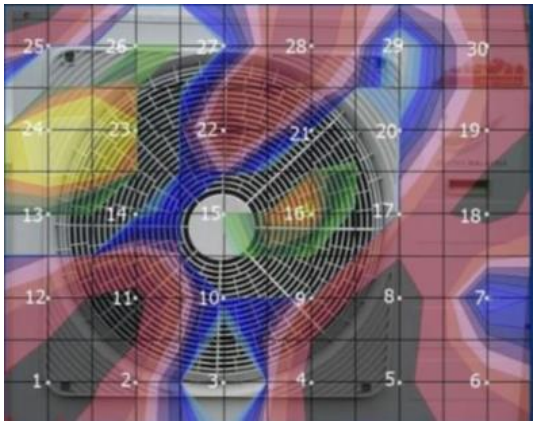
(c) High fan speed

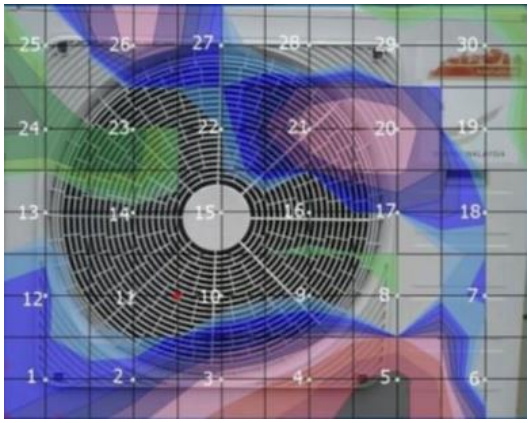
Figure 5. Temperature of 20˚C

3.1.3 At the temperature of 24°C

By raising the temperature to 24°C, the results obtained are depicted in Figure 6 (a) to (c) when fan speed is increased from low, medium, to high-level. As can be seen in (a), it is noticeable that the noise generated spread around the casing of the outdoor unit which mostly concentrated in the right side where the highest SPL also comes out at point 18 with 89.12 dB. Unsurprisingly, increasing the fan speed tend to provide clearer pattern of noise emitted as the differences between noise components much more

distinct. Referring to Figure 6(b), the bottom at the right side of the noise source revealed that the operation of the compressor still be a significant source with the value of 94.52 dB. With the high fan speed operation, the sound intensity mapping in (c) shows that most of high noise level located at the fan and its casing. Nevertheless, it is indubitable that at this point, the vibration of the rig structure that hold the outdoor unit as well as the casing material and thickness could also be the prominent source of noise as the highest SPL presented at point 1 with 92.98 dB. This has been agreed by Diga et al. [3] which stated that such a whistling or humming sound can be radiated by the system through vibrations.


(a) Low fan speed


(b) Medium fan speed

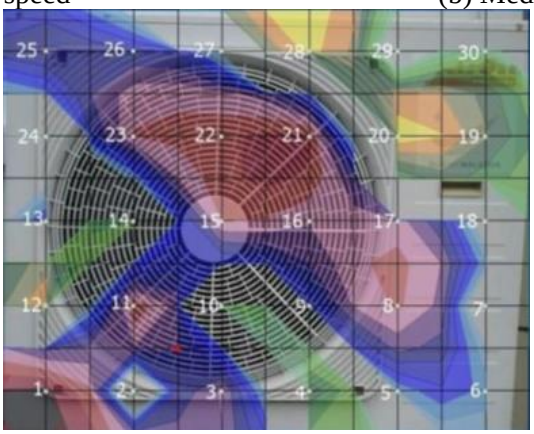

(c) High fan speed

Figure 6. Temperature of 24˚C

3.2 Sound Power Level

In the sound quantification, the SPL is used to determine the noise rating of machines, equipment and any unit that associated with the sound generation [14]. Therefore, to provide a strong justification for the relationship between the temperature and fan speed to the noise level generated by the air-conditioning system, the SPL results for all points of measurement are plotted according to the temperature. Based on the results in Figure 7, trends indicate that there is a linear relationship between the fan speed and noise level as the high fan speed significantly shows a higher level compared to those medium and low fan speed. Whereas trifling differences can be noticed between the low and medium speed where most of the points are represented higher by the medium. Identically, the results of raising the temperature to 20°C still maintained the trends and owed to the drop of SPL generated as plotted in Figure 8. Hence, proving the theory that the lower temperature and higher fan speed instigate to persistent operation of the system which consequently increasing the sound radiated [4,5]. Further increase of the temperature does not show any significant differences in the trend as shown in Figure 9 except for the lower noise level could be expected. The results do provide the consistency in the noise

level regards to the temperature and fan speed with the high fan speed being the highest followed by medium and low fan speed.

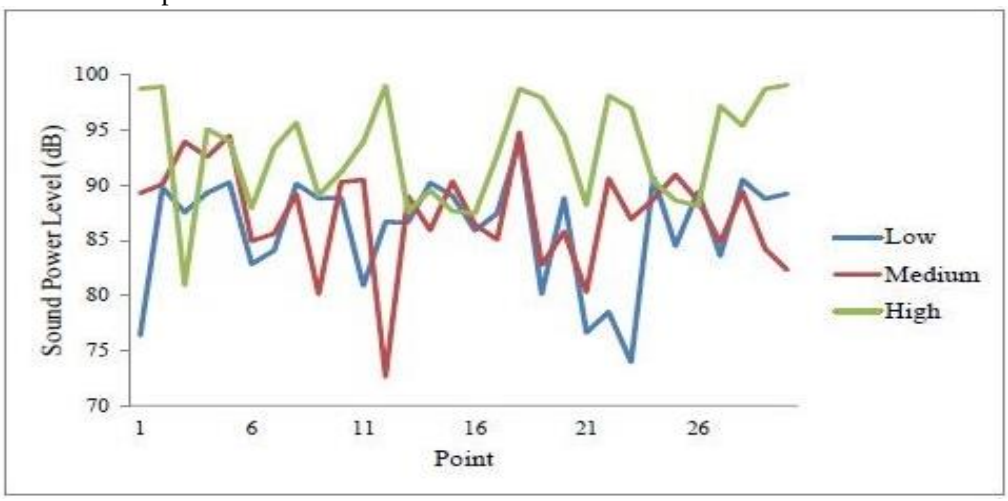


Figure 7. SPL comparison based on different fan speed in temperature of 16°C

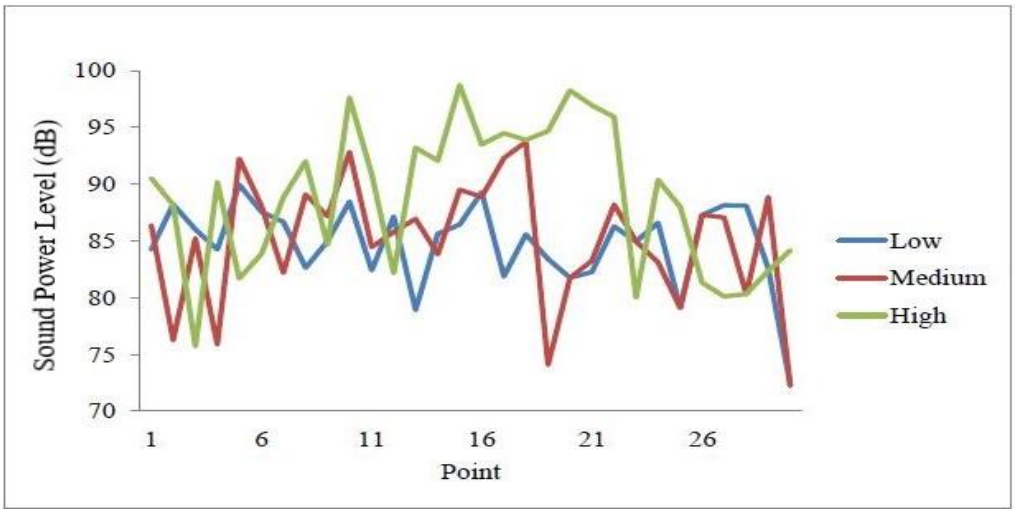


Figure 8 SPL comparison based on different fan speed in temperature of 20°C

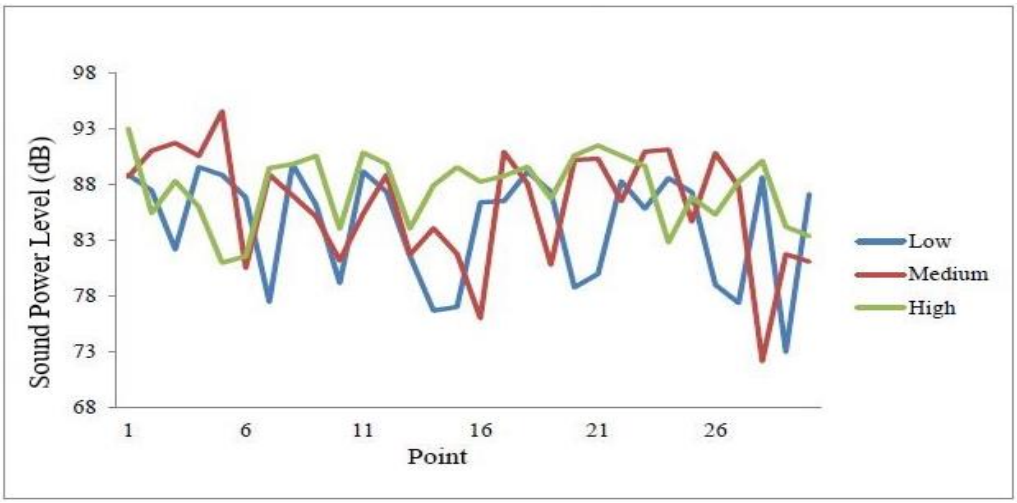


Figure 9. SPL comparison based on different fan speed in temperature of 24°C

4. Conclusion

At the end of this study, finding shows that in the split air-conditioning system particularly the outdoor unit, the noise emitted is parallel to increment of fan speed as well as the reduction of the temperature. Highest noise rating can be found in the lowest temperature and high fan speed as the frequent processes occurred. Meanwhile, the mapping results indicate that the noise are spread to the casing from two major sources namely compressor and condenser fan. Thus, these two components need to be taken into consideration in choosing or even manufacturing an air-conditioner to provide the comfort environment. In short, the sound intensity mapping together with the sound power level application proven to be an efficient method to identify the noise hotspots and its rating.

Acknowledgments

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