Acoustical characteristics of device system for chasing away birds at Ngurah Rai International Airport Denpasar Bali

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Abstract. Ngurah Rai International Airport Denpasar Bali has two models of the device for chasing away birds these are Mobile Model and Fixed Model. Acoustical characteristics of the device for chasing away birds is determined by two parameters: SPL and Frequency Responses as well as sound propagation in the free field outdoor acoustics, thus to analyze sound properties radiated by the device for chasing away birds must be using a theoretical approach of Inverse Distance Law. Measurement results on Mobile Model that decreasing value of SPL by moving microphone position into the position of double distances from an original distance were somewhat 6 dB, it is nearly agreed with Inverse Distance Law. While measurement results on Fixed Model using the same mechanism of changing the distance the decreasing value of SPL does not comply Inverse Distance Law since the decreasing is about 10 dB. From results of measurement of decreasing SPL, both two models of the device for chasing away birds can be only used effectively to disperse some birds in which their position is very near the speaker that is about 4 - 8 m. Based on a calculation using Inverse Distance Law, the value of SPL at the distance of 1 m from the speaker is below 100 dB. Measurement results on Frequency Spectrum for Mobile Model was dominant at the frequency of 500 Hz to 3150 Hz, while for Fixed Model was dominant at the frequency of 500 Hz to 2500 Hz. At the end, the device for chasing away birds using acoustical method needs a system of sound generator and speaker which can generate the sound wave with very high of sound power level and it has a flat form of frequency responses with a wide range of frequencies. With the high sound power level, the sound will reach very far away this kind of device is called Long Range Acoustic Device (LRAD).

1. Introduction
An airport within its facilities must be able to guarantee about the safety of airline especially when the flight is taking off and landing. One of the standard requirements must be provided by the authority of International Airport is a device system for chasing away some birds. This device will be run to dissipate some birds when those birds are roaming in the grass area that is close to the runway aiming to avoid an occurrence of birds strike particularly if a bird gets into the flight engine.

The device system for chasing away bird using acoustical method is an acoustic device consist of the sound generator and speaker, the sound output from the speaker is directed to crowd of birds in order the birds flying away from the airport runway. This kind of acoustic device has been installed in the Ngurah Rai Airport Bali [1] and this paper reports about measurement results of sound characteristic exposed by the device then analysis was made whether the device is quite effective in driving out some birds that are frequently crowded around in a field near the airport runway.
In the year of 2003, Research Center for Metrology - Indonesian Institute of Sciences, RCM-LIPI (formerly Research Center for Calibration Instrumentation and Metrology) started carrying out a research on applying an acoustical method for driving out the birds in which at that time there were roaming some kinds of birds around Sukarno-Hatta Airport [2]. Since then it was found and anticipated that to drive out the bird effectively it should use sound exposure with a certain frequency, rather than the exposure of alike sound predator, and the frequency value of sound exposure must be arranged to be fitted with the sensitive frequency of the bird hearing [3]. Like a human hearing system in which has a frequency value of hearing sensitivity, this means if someone gets a high-level sound exposure and its sound frequency value is identic with his/her hearing sensitive frequency hence he/she gets a pain inside ears and reacting immediately to close both ears by his/her both hands. This is the human behavior when exposed to noise with the level of a pain threshold, it would also happen to live beings such as birds. When the birds receive a noise exposure with the level of a pain threshold of their hearing system it is expected that they will be flying away in order to avoid a painful noise.

Figure 1. In the solid angle shown, the same sound energy is distributed over spherical surfaces of increasing area as \( d \) is increased. The intensity of sound is inversely proportional to square of the distance from the point source [4].

Figure 2. The inverse square law of sound intensity becomes the inverse distance law for sound pressure. This means that sound-pressure level is reduced 6 dB for each doubling of the distance [4].

2. Theoretical Approach

2.1 Inverse Square Law and Inverse Distance Law

A device for chasing away bird using an acoustical method that is attached in many airports is actually a device generating sound energy and radiating it in the free field as the activity of outdoor acoustics. Therefore, the theoretical approach is used in analyzing the affectivity of sound exposure is the theory of sound propagation in an open space free fields. Characteristic of sound propagation in the free field area is illustrated as shown in figure 1. A point sound source radiates sound energy to all direction with a steady sound power, intensity (power per unit area) of sound propagates spherically and uniformly extending with the radius of \( d, 2d, 3d, 4d \) and further. The intensity of sound is being decreased with increasing the radius. As the area of sphere surface is \( 4\pi r^2 \), the area of a small segment on the surface of the sphere also varies as the square of the radius. Doubling the distance from \( d \) to \( 2d \) reduces the intensity
to 1/4, tripling the distance reduces the intensity to 1/9, and quadrupling the distance reduces the intensity to 1/16 [4]. The intensity of sound is inversely proportional to the square of the distance in a free field following the Inverse Square Law.

The intensity of sound as power per unit area is a difficult parameter to measure. Sound pressure is easily measured. As intensity is proportional to the square of sound pressure, the Inverse Square Law (for intensity) becomes the Inverse Distance Law (for sound pressure). This means sound pressure varies inversely as the first power of the distance. Figure 2 shows the illustration of the Inverse Distance Law for pressure applies in a free field, the sound-pressure level in decibels is plotted against distance and the sound pressure level is decreasing 6 dB per doubling of the distance. This calculation can be shown in equation (1) below, taking example the sound-pressure level \( L_1 \) at distance \( d_1 \) from a point source is known, the sound-pressure level \( L_2 \) at another distance \( d_2 \) can be calculated from:

\[
L_2 = L_1 - 20\log \frac{d_2}{d_1} \text{ dB}
\] (1)

Thus, the difference in sound-pressure level between two measuring points that are \( d_1 \) and \( d_2 \) distance from the source is:

\[
L_2 - L_1 = 20\log \frac{d_2}{d_1} \text{ dB}
\] (2)

2.2 Frequency Sensitivity of Bird Hearing

The theoretical approach of acoustics in analyzing the sensitivity of bird hearing system is through the understanding of an acoustical characteristic of a human hearing system since an audible range of bird hearing is almost comparable with the audible range of human hearing system [2], [3], [5]. The most hearing sensitive frequency of birds is a frequency value on the lowest sound level of bird threshold hearing. This means that a sound received by a bird at its hearing sensitive frequency is the most easily heard and it makes a quick reaction from birds although the sound level at its hearing sensitive frequency is categorically very low. On the other side, a sound-pressure level of threshold pain at its hearing sensitive frequency is the lowest value compared with the sound-pressure levels at its other frequencies of threshold pain. When the hearing sensitive frequency of birds is known, it is, therefore, to drive away birds using acoustical technique can be more efficient e.g. to generate sound at a hearing sensitive frequency with the sound power level is somewhat not too high.

A mechanism to get a hearing sensitive frequency of a certain kind of bird so far is to do some measurement and make a recording of sound (whistle) incurred by a certain kind of bird [6], [7]. A certain kind of bird will whistle sound at certain range frequencies and those values of range frequencies are considerably identic with the sound frequencies received by a hearing organ of that certain kind of bird. In other words, an occurred sound frequency spectrum is exactly hearing frequency spectrum of a certain kind bird. From the sound recording, it can be identified a peak of sound spectrum frequency which is later assumed that the peak of the spectrum is an indicator of the highest hearing sensitive of that certain kind of bird. Figure 3 shows an example of the measurement result graphs of the sound whistled by a kind of birds at Lagoon Nusa Dua in the year of 2009. Those birds are similar with the kind of birds that frequently roaming in the area close to the runway at Ngurah Rai Airport. The graphs show that the peak of sound frequency spectrum occurred at low frequencies of 40 Hz and 80 Hz and also occurred at mid frequencies of 1250 Hz and 6300 Hz. Those values of frequencies can be as a reference or assumed that a-hearing-sensitive frequencies of the kind of birds that frequently roaming in the area close to the runway at Ngurah Rai Airport are 40 Hz, 80 Hz, 1250 Hz and 6300 Hz.

The bird audible characteristic is comparable with the human audible characteristic therefore, a bird normal hearing is like a human normal hearing that is human can receive sound normally with SPL under 70 dB. It is, therefore, like a human, a bird will get annoyance when hit by noise exposure of 85
dB [8]. As already mentioned before that if someone gets annoyed by high noise exposure he/she will instantly react avoiding interference, so will do the bird by flying away from a noise.

![Figure 3. A sound frequency spectrum of a certain kind of birds similar with the kind of birds that frequently roaming in the area closed to the runway at Ngurah Rai Airport: the results of measurement taken in 2009 [7].](image)

3. Measurement Results and Discussion
Ngurah Rai International Airport has had two models of bird chasing devices that are mobile and fixed models as shown in figure 4. In the mobile model, speakers as a point sound source is installed in the pickup car with the high position of 2 m from the ground, in a fixed-model-speakers installed in a permanent position with the high is only 1 m from the ground and placed in a field area where birds are frequently roaming around this area. As according to a theoretical approach, acoustical characteristic of these devices is determined by two parameters that are the value of SPL and frequency spectrum. Measuring SPL can examine at once the ability of sound source generator and speakers to generate a maximal sound power, and this is the main indicator for sound propagation ability in the free field open space: the higher sound power the further distance of the receiver can receive a sound with significantly high level.

Measurement of SPL at Ngurah Rai Airport was carried out with the shortest distance of receiver (microphone) position from the sound source was 4 m. Then, measurement of decreasing characteristic on SPL by moving receiver position away from a sound source and measurement of the frequency spectrum in order to find a frequency response characteristic of a sound source of each model devices. It was found that a sound exposure of each source from each model device was not a tune sound of single frequency but consisting various frequencies including artificial predator sound i.e. alike hawk voice.
Table 1. Measurement results of SPL for mobile model and for fixed model

| Microphone position from Speakers (m) | Sound Pressure Level, SPL (dB) |
|--------------------------------------|---------------------------------|
|                                      | Mobile Model                  | Fixed Model                  |
| 4                                    | 86,6                           | 84,0                          |
| 32                                   | 75,7                           | 74,8                          |
| 64                                   | 69,6                           | 65,0                          |
| 128                                  | 61,7                           | 54,0                          |

Table 1 shows measurement results of SPL for both two models. For mobile model decreasing SPL further the position of 32 m by moving microphone position at double distances of the last position of microphone that is 32 m to 64 m and then to 128 m decreasing of SPL is approaching the Inverse Distance Law that is somewhat 6dB. While for the fixed model as the same way as did for the mobile model (32 m, 64 m and 128 m) decreasing of SPL value in not meet the Inverse Distance Law that is somewhat 10 dB this is because the placement position of a fixed-model speaker is only 1 m from the ground so that it does not comply a condition of open space free field since the soil and grass on the ground are high sound absorbent.

Measurement results indicated strongly that both two models of the bird chasing devices are much far from minimum requirements needed by a bird chasing device i.e. a sound radiation generated by its device is expected still working effectively to disperse the crowd birds at 100 m position from the device. In order to comply with minimum requirements as well as to meet the Inverse Distance Law, the minimum SPL of the device is ideally 124 dB at the distance of 2 m or about 118 at the distance of 4 m thus it is expected at the distance of 100 m the value of SPL is still higher than 85dB. While for both two models with the condition of an acoustical characteristic as the data shown by the measurement results, the devices will only be effective to disperse the crowd birds when they were very close to the speakers that are 4 - 8 m. Using calculation of the Inverse Distance Law, the value of SPL at the distance of 1 m from speakers for the mobile model and for the fixed model is respectively 98 dB and 96dB.

Measuring a frequency spectrum is also called measuring the frequency characteristic was carried out for both two models. Microphone distances from speakers for each model were 1m for the mobile model and 4 m for the fixed model. The chosen distance is purely based on an environmental condition and the measurement can be carried out conveniently as long as a sound level received by the microphone was far above a background noise level. Figures 5 and 6 are showing the graphs of measurement results of the frequency spectrum for mobile and fixed models. For the mobile model starting from frequency of 500 Hz up to 3150 Hz the form of a spectrum is considerable flat and quiet dominant since the sound level average at this frequency range is the highest. While for the fixed model, frequency dominant start from 500 Hz until 2500 Hz. According to measurement results in 2009 (see figure 3) hearing sensitive of the kind of birds that often roaming in the area close to the runway and assuming that the peak of frequency spectrum is a hearing sensitive frequency of the birds so those two models of bird chasing devices would only be effective for sound radiation at the frequency of 1250 Hz.
At last, the above discussion has given a clue about very a simple solution that is to chase away the crowd birds using the acoustical technique it is needed a sound generator and a speaker system that can generate the sound wave with a very high sound power level and a wide flat frequency response. A high-level sound source is automatically able to have far-reaching sound energy. This kind of an acoustic device is usually required for the military activity this means the device must have a specification of a military standard. The device can be used as a non-lethal weapon [9], this kind of sound source is also known as speaker of Long Range Acoustic Device (LRAD) [10] [11]. In many countries such as in the USA, Germany, as well as several other countries in Europe, LRAD has been used by the police as equipment. In the event of demonstration, the police use the equipment of LRAD to disperse crowd large group of people rally. An example of a speaker product as equipment of Long Range Acoustic Device (LARD) is shown in figure 7.

4. Conclusions
Acoustical characteristics of the bird chasing devices of Ngurah Rai International Airport Denpasar Bali namely mobile model and fixed model both two models have a sound-pressure level (SPL) less than 100 dB at the position of 1 m. With this value, the coverage chasing birds is very short that could only reach...
birds within the position somewhat 8 m. Dominant frequencies generated by both two models are not quite wide enough, the mobile model starts from 500 Hz up to 3500 Hz and the fixed model is even much narrow that starts from 500 up to 2500 Hz. The development of the bird chasing device using acoustical technique is actually the development of acoustic instrumentation technology i.e. developing sound generator with its speaker arranged to have a capability in generating SPL up to 160 dB in 1 m, much higher of sound power level that means much far away distance covered by sound propagation, so high level sound pressure will still be received by a receiver with very far position from the device.

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