Sound Energy Approach in The Use of LRAD as A Bird Deterrent Device in Sam Ratulangi Manado International Airport, North Sulawesi, Indonesia

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Abstract. To fulfil the airport safety requirements as stated in International Civil Aviation Organization document, ICAO 9137-3 AN part 3 – Airport Services Manual, Wildlife control and reduction, especially the bird stike control programme, the Sam Ratulangi International Airport is decided to apply the auditory method to control the birds in aerodrome area. Study on this need have been carried out using the sound energy approach, more specifically on inverse square law theory in free field. The theory said that by doubling the distance between the speaker and the sound level meter will decrease in sound pressure level of around 6 dB. From the field measurement results, the measured sound pressure level were 85 dB and 79 dB at the distance of 50 m and 100 m from the speaker. Both levels and distance were used in trials of repelling birds at 1600 Hz to 3150 Hz in frequencies. The use of long range acoustic device, LRAD speakers, that generate 156 dB at a distance of 1 m in front of the speaker can effectively reach longer distances.

1. Introduction

Bird strike is the impact of touching two high-speed materials which have very large differences in characteristics, where birds are soft in contact with rigid fuselage, resulting in nonlinear material behavior, high strain rate, and very large deformation [1]. The incidence of bird disturbance is reported to increase every year mainly due to environmental conservation and protection programs that are increasingly stringent so that it supports the growth of populations of species of birds. Bird disturbance can occur at varying heights and 41% of bird disturbance events in America occur during take-off or landing [2].

International Civil Aviation Organization (ICAO) document 9137-AN section 3, Wildlife Control and Reduction requires the prevention of bird disturbance at airports to be met for flight safety [3]. Flight safety is regulated in the Law of the Republic of Indonesia No. 1 of 2009 concerning Aviation, and reporting procedures for bird attacks in airports and surrounding areas are regulated in General Director of Civil Aviation Regulation No. KP.468 in 2011 [4,5].

The techniques for controlling bird disturbances at airports can be categorized as auditory, visual, chemical, exclusion, habitat modification, and annihilation. Auditory is usually done using the acoustic method by recording the sound of predatory animals and emitting predator animal sounds through loudspeakers at airports [6]. Another method that developed by acoustic researchers in Indonesia is to
use the bird communication frequencies which are estimated also be the frequencies of bird sensitive hearing. These frequencies are then emitted through loudspeakers to a group of birds [7].

As the one of International Airports in Indonesia, the Sam Ratulangi International Airport must fulfil the airport safety requirements as stated in regulations above. The Sam Ratulangi International Airport is decided to apply the auditory method to control the birds in aerodrome area by using the hearing sensitive frequencies method. The airport puts some long range acoustic device, LRAD speakers to repel the birds at its aerodrome area.

This paper reports about the study of the effective range of speaker area by using the sound energy approach, more specifically on inverse square law theory in free field and the effectiveness of repelling birds by using LRAD speakers in Sam Ratulangi International Airport.

2. The Inverse Square Law Theory[8]

Radiation of sound energy in all directions with power (power) with a constant sound / fixed, sound spread with intensity (power per unit area) that is spread evenly to all the direction forming the surface of the ball (spherically) is increasingly expanding with a radius of d, 2d, 3d, 4d and so on. With the intensity of the sound continues to decrease the additional distance of the ball radius where the surface area of the ball is 4πr2. Addition of the distance doubled from d to 2d will decrease the intensity to a quarter (1/4 of it), addition of the distance tripled to 3d intensity decreases to 1/9, addition of the distance fourfold ie 4d intensity will decrease by 1/16. The sound intensity of an open free area with the addition of the distance from the point of the sound source will decrease in proportion to the inverse square of the distance, confirm the inverse square law.

![Figure 1](image)

**Figure 1.** A series of illustrative characteristics of sound in an open free area spreading in all directions and forming a ball (spherically). Sound intensity is inversely proportional to the square of the distance from the point of the sound source

Sound intensity, ie power per unit area is a parameter that is not easy to measure, which is much easier to measure is sound pressure. The intensity is proportional to the pressure squared: I ∝ p^2 ∝ 1 / r^2, r is the distance from the sound source, that p ∝ 1 / r, then the inverse square law for sound intensity becomes the inverse distance law for sound pressure, this means that the amount of sound pressure will vary with distance. The amount of sound pressure at a certain distance from a sound source point in open space if measured at different distances then the sound pressure will be inversely proportional to the change in distance from the measuring point. As shown by Figure 2 the sound pressure level (SPL) in the decibels is mapped and varies with distance, there is a decrease in sound pressure level of 6 dB for each doubling the distance of the measuring point to the sound source.
Figure 2. The inverse square law for sound intensity becomes the inverse distance law for sound pressure. The sound pressure level decreases by 6 dB for every double addition of distance.

This calculation can be shown by equation (1) below, for example the sound pressure level at the position closest to the sound source is $L_1$ with distance $d_1$ from the sound source. Then in the next position the sound pressure level is $L_2$ with distance $d_2$ from the sound source then:

$$L_2 = L_1 - 20 \log \frac{d_2}{d_1} \text{ dB}$$

Thus the difference in sound pressure level of the two measuring points with the distance from the sound source $d_1$ and $d_2$ respectively:

$$L_2 - L_1 = 20 \log \frac{d_2}{d_1} \text{ dB}$$

3. Bird Hearing Frequencies [9]

Birds communicate with each other using sounds produced by the birds themselves. Birds have hearing sensitivity 10 x more sensitive than humans. By using the analogy that birds are living things, there are sensitive areas of hearing birds that can be subject to sound at certain sound pressure levels that will touch the threshold of pain so that they feel uncomfortable.

Bird ear is divided into three parts, namely the outer ear, the middle part, and the inner part. The outer ear consists of a tube (ear canal) which will deliver sound waves to the eardrum (eardrum). Behind the eardrum there is the middle ear which consists of a single bone called collumella which is responsible for transforming the vibrational signal into electrical pulses and is transmitted to the inner ear called the cochlea. The inner ear is filled with fluid and nerve cells will deliver electrical pulses to the brain for processing. The results of processing electrical pulses by the brain is in the form of sound perceptions such as loud weak, rhythm, high-low, distance, sound position and so forth. With this ability, living things like humans and birds can focus their attention and respond or act on the sounds that are heard in their ears.

4. Measurement Results

The background noise in Sam Ratulangi International Airport aerodrome was measured to find out the minimum level should be emitted from the speakers by using the inverse square law theory. The minimum level at the furthest of speaker perimeter range must be at least 10 dB higher than the highest $L\text{Aeq}$ of background noise. The highest $L\text{Aeq}$ of background noise is 75.8 dB measured. Thus, the minimum level should be 85.8 dB or rounded to 86 dB at the furthest of speaker perimeter range.
Figure 3. Background Noise Measurement Results at Sam Ratulangi International Airport measured on May 29, 2016. Red line is the morning measurement, blue line is the noon measurement, and black line is afternoon measurement.

The aircraft noise and birds communication frequencies were measured and both were compared to see the frequency distribution. The aircraft noise about 40 Hz to 250 Hz. Meanwhile the bird communication frequencies about 1600 Hz to 4000 Hz.

Figure 4. Comparison between aircraft noise (silver bar) and bird communication frequencies (colours) measured at Sam Ratulangi International Airport.

After obtaining the above data, a field trial was carried out to repel birds. The first experiment was carried out by emitting 85 dB of sound at a distance of 50 m, frequencies of 1600 Hz, 2000 Hz, 2500 Hz, 3150 Hz and 4000 Hz. The output frequency is set to automatic swipe per frequency for 2 minutes to see bird behaviours. The second experiment was carried out in the same way to "shoot" a flock of birds within 100 m without changing sound amplification. In this second experiment, the sound level at 100 m is 79 dB measured.
Figure 5. Buffalo egrets (bubulcus ibis) fly away from the speaker when given sound exposure in a bird's sensitive hearing frequency area with a loudness level of 85 dB.

In the first experiment, when the sound signal was at 1600 Hz, the birds had not yet responded. The birds were still carrying out their activities, looking for food in between the grass. When the sound signal moved to frequencies of 2000 Hz and 2500 Hz, most birds simultaneously flew away from the origin of the sound. When the signal moved to 3150 Hz, the remaining birds flew all away from the speaker perimeter area and leave a clean area of the bird.

In the second experiment, when the sound signal at frequencies of 1600 Hz to 2000 Hz the birds at the target location did not respond at all. Then when the frequency shifted at a frequency of 2500 Hz, 3150 Hz and 4000 Hz, there were only some birds that flew but not far away. The flew birds landing back at another location within 10 meters of their original position before. This indicates that the exposure of acoustic waves with a level of 79 dB has no disruptive effect on the bird's ears even though the frequency is in accordance with the communication frequency of the bird.

5. Discussion
The distance of Sam Ratulangi International Airport runway is 2650 m and 45 m width. If the perimeter range of speaker is 100 m, then the airport will need about 13 fixed speakers to be put near the runway to clear the runway area from birds. From the experiments and equation (2), the ideal sound pressure level at the furthest perimeter area is about 85 dB. It means that at 100 m should reach 85 dB, and it means at 1 m in front of speaker should be 119 dB measured.

The amount of 13 fixed speakers could be reduce by expanding the perimeter area to 500 m. It only need 2 fixed speakers to be put near the runway, and the rest unreach area can be cleaned by the mobile speaker system. For the fixed speaker, it should meet the need of emitting sound at 1 m in front of speaker about 139 dB measured in order to reach 85 dB at 500 m.

The officer who in charge to maintain the bird deterrent speakers should be equipped with ear muff to protect his hearing. Based on the Indonesia Ministry of Health regulation No 70/2016, the threshold of noise could accept by human ear is 14.06 seconds for 118 dB sound pressure level and 0.11 second for 139 dB [10].

Based on the measurement results, experiments results, and the calculation of sound pressure level that should be emitted from speaker, Sam Ratulangi International Airport decided to use long range acoustic device (LRAD) as the speaker for the bird deterrent system. It installed on a pickup car as the mobile version of bird deterrent system. The specification of LRAD is a speaker capable of producing loud and clear sound, this device is able to produce up to 156 dB sound in a distance of 1 meter with a flat frequency response graph that indicate that this device relatively could emit the stable sound [11,12].
6. Conclusion

The sound energy approach especially by using inverse square law theory in free field can assist to determine the speaker specification needed as a bird deterrent device in Sam Ratulangi International Airport. In addition, the data needed to determine the system specifications are background noise, aircraft noise frequencies, bird species and communication frequencies in the aerodrome area.

From the field measurement results, the measured sound pressure level were 85 dB and 79 dB at the distance of 50 m and 100 m from the speaker. Both levels and distance were used in trials of repelling birds at 1600 Hz to 3150 Hz in frequencies. The 85 dB more effective to make the bird flew away from the speaker.

If the perimeter area of the speaker is about 500 m, the speaker should meet 139 dB at 1m in front of speaker in order to reach 85 dB at 500 m. This 85 dB meet the 10 dB above of the highest LAeq background noise, that about 75.8 dB.

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The authors of this paper stated that both authors were the main contributors to the writing of this paper.

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