Hardware Implementation of Beam Formed Ultrasonic Bird Deterrent System

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***Abstract*-Bird activities at the transmission line threatens the safety and stability of transmission lines which results in power disruption. Current available ultrasonic bird deterrent system is not effective in eliminating bird activity at transmission lines as the signals travel in omnidirectional. This results in waste of energy as the signal is transmitted to the places where the birds are absent. Hence, it creates a necessity in developing an improved ultrasonic method which utilizes beam forming method. This paper describes the hardware implementation of an ultrasonic bird deterrent system using beamforming method on transmission lines. This method is capable of focusing its wave on the birds and bird nests in a particular direction at the transmission lines where it creates discomfort to the birds and hence forcing the birds to evacuate the lines.**

Keywords- ultrasonic signal; deterrent system; beamforming

I. INTRODUCTION

In the recent years there has been an increase in the number of birds that choose transmission lines as their nests. The two types of bird deterrent currently available are the windmill bird deterrent system and ultrasonic digital bird deterrent system. However, both of these deterrent system has their setbacks. Firstly, windmill bird deterrent system can be easily aged and destroyed by nature, it has short lifespan and it cannot be used if the amount of wind is not enough to drive the windmill. On the other hand, the ultrasonic digital deterrent system, have limited coverage, and takes slow effect [1].

The ultrasonic signals are omnidirectional where the signals travel in all directions [2, 3, 4]. Due to this behavior, it results in energy loss in unwanted areas which is at the areas of absence of birds. Thus, there has been research on using combination of visual and audible method to repel birds. Study conducted by Fuliang Le et.al (2009) [1] used combination of visual and audible bird control methods in order to repel birds at transmission lines. The birds are repelled by electric shock, sound shock or ultrasonic shock. This bird deterrent system was installed at transmission line as Fig.1.

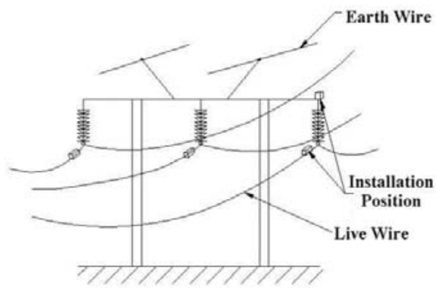

Figure 1. Bird deterrent system at transmission line [1]

This system is known to protect the safety of high tension lines as it prevents birds from nesting at transmission line and deter birds' activities around the critical areas of transmission line. Even though this method only repels after detecting bird's activity at the line, the repelling method i.e. the ultrasonic shock covers a wide area with ultrasonic wave. This scenario may create discomfort for birds at the nearby area and prevent them from inhabiting there. This is not suitable as the main objective of this project, which is to prevent bird activities at transmission lines, and not at the area around it [5] [6] [7] [8].

On the other hand, ultrasonic sensors are widely used in controlling birds at airports and farms [2]. For this, four piezo speakers were place in 90° to each other to provide a 360° area coverage for a crop field. This method was successful to drive birds away from the designated large areas. But, it has the same problem as highlighted by Fuliang Le et. al (2009)

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[1] thus making it unsuitable to repel birds at transmission lines particularly.

In another study to exclude birds from an airfield, a sonic net, which is spatially controlled noise was designed to overlap with the frequency range of birds [9]. 82% of reduction in bird presence was observed at sonic net areas compared to the reference areas without sonic net. This method also covers a large area which is suitable for airfields and crop fields only.

Apart from that, this study also proves that, as the signal leaves speaker, it loses its strength over a distance. This scenario was explained in [10] where the sonic net area experienced a loud sound transmission through a speaker while the mid area experienced a much lower transmission of the similar sound.

An ultrasonic beam-formed deterrent system is developed in this project. This system will not harm the environment and maintaining a balanced ecosystem. The beam formed ultrasonic narrows the focus of the signal, sending it directly to the target, minimizing surrounding signal interference and increase the signal strength that reaches the target [11] [12] [13].

A signal processing technique used in arrays for directional signal broadcast or reception is known as beamforming. The elements of the array are combined in such a way that signal undergoes constructive and destructive interference and achieve directivity. Conventional beamforming techniques includes phase shift beamforming, time-delay beamforming and sub-band phase shift beamforming.

This paper implements phase shift beamforming method whereby the ultrasonic frequency range is within narrowband [14]. Beamforming method is more energy saving compared to the widely available ultrasonic speakers used to repel birds as it is capable of focusing the ultrasonic waves to a specific point.

II. METHODOLOGY

Ultrasound are signal that operates at a frequency more than 20 kHz [3]. It is not audible to human ears but it can create a disturbing environment for birds and pests. Ultrasonic repellents are widely used in market to chase birds and also pests. However, those systems have drawback in the system radiates signal in omnidirectional. This sends the signals to all direction thus resulting energy loss in unnecessary area. Therefore, phased array beamforming is applied in ultrasonic bird deterrent system to direct the sound at only desired area. This method helps to increase the efficiency and directivity of the signal.

Phased array in the context of an array of ultrasonic speakers is steered to point in different directions without moving the speakers. Phased array is widely used in radar systems where the antenna sends out signals to scan the sky to detect any objects [11]. This method is applied to the speaker array to transmit the ultrasonic signal to the desired direction. Fig. 2 shows the flowchart of phased-array ultrasonic bird deterrent system.

1) Ultrasonic Signal Generation

Referring to Fig.2, ultrasonic signal is generated by using DSP TMS320F28335. This board acts as an ultrasonic signal generator using sine PWM modulation that serves as an input to the phase shifting section. The TMS320F28335 DSP contains six enhanced pulse-width-modulation (ePWM) modules, whereby each of it has two channels and thus can generate up to 12 PWM output signals. This project requires only 8 channels and it is sufficient to beam-form the output signals. A typical PWM signal consists of a series of pulses, depending on the type of PWM signal, whether it is located at the beginning, center, or the end of a PWM signal period. In each period, the PWM module outputs one analog value as average voltage over the period by switching between the "high" and the "low" state at the appropriate time. The output signal can be smoothened using a low-pass filter, which eliminates the high-frequency signal content, including the PWM base frequency.

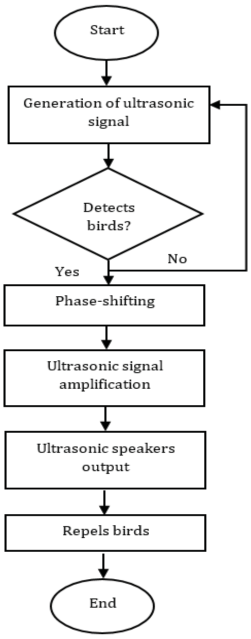

Figure 2. Flowchart of Phased-Array Ultrasonic Bird Deterrent System

2) Phase Shifting

The ultrasonic signal generated by DSP TMS320F28335 is then phase shifted according to the desired angle. Each transducer transmits phase shifted signal which will causes the angle to be steered to the place with presence of bird. The phase is calculated using (1) through MATLAB simulation.

$$\emptyset = \sum_{m=1}^{M} w(m) e^{i(2m-M-1)*arg} \quad (1)$$

Where;

arg = πd[sin(θ-π/2-γ)]

θ = Scanning angle, q =-90:1:90

γ = phase shift angle

w(m) = [1,1,….,M], uniform weight on each element

d = distance between transducers

M = 8 transducers and m is the index on M

3) Signal Amplification

Phase array results in phase-shifted signal. These phase-shifted signals are then amplified to increase the signal voltage. An amplifier circuit is constructed to amplify the output signal generated by DSP TMS320F28335, which will be the input to the circuit. The amplifier circuit is consisting of resistor-capacitor filters and bipolar junction transistors (2N2222A and BD139-10).

The resistor-capacitor filter is connected at the base of the bipolar transistor (Q1) in a common emitter configuration. The function of the filter is to change the input signal waveform from square wave to sine wave. Output of the circuit is measured at the transducers. The schematic diagram of the amplifier circuit is shown Fig. 3. The input is given by DSP TMS320F28335 as square wave with frequency range lies in between 20 kHz to 40 kHz. This input signal is phase-shifted before entering into RC filter according which is done using MATLAB simulation.

The transistor Q1 (2N2222A) will give negative feedback with the 1 kohm resistor. The output of the Q1 transistor is measured at the collector which is the input of the Q2(BD139-10) transistor. The capacitor removes DC voltages caused by the biasing of Q1 transistor. The Q2 transistor is a fixed bias through the 2.2k ohms resistor. The output of the Q2 transistor is measured at the transducer with 8H inductance. Electrolyte capacitors are used in this circuit which are associated with the biasing of Q2 transistor to block the DC voltages.

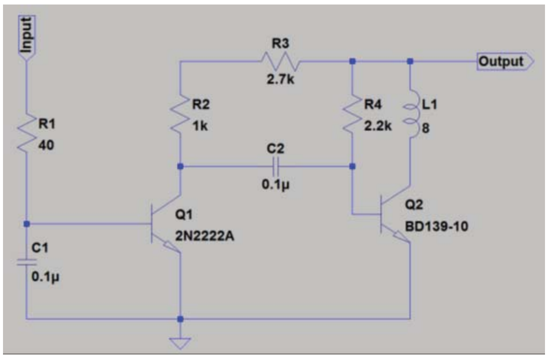

Figure 3. Design of an amplifier circuit

4) Ultrasound speaker output

Fig.4 shows the arrangement of the outcome of the phased array module using ultrasonic transducer array. Referring to Fig. 4, an array of speakers is arranged linearly, with distance between the speakers, given as d. When the motion sensor detects the presence of bird on the transmission line, the angle detected is sent to the repellent system. Based on the angle detected, the phase shift angle is calculated based on (1). Each speaker is phase shifted to ensure that the signal from each speaker will be in the same phase when arriving at the transmission line. The beam formed ultrasound signal is then transmitted to the transmission line where the birds present.

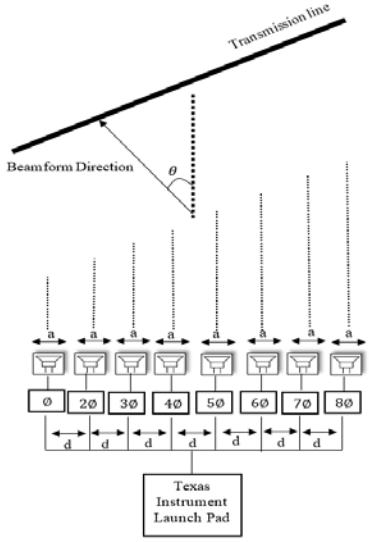

Figure 4. Phase Array transducer arrangement

III. Results & Discussions

The Fig.5 shows the output signal waveform from DSP TMS320F28335. The signal is generated between 20kHz to 40kHz which is within the ultrasonic frequency range. The input voltage is around 4.5V to 5V.

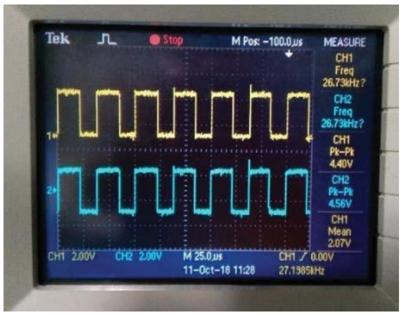

Figure 5. Output signal from DSP TMS320F28335

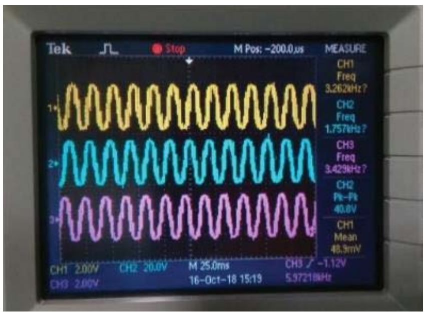

Figure 6. Output signal after low pass filter

The square wave signal generated by DSP TMS320F28335 is smoothened using a low-pass filter to remove the high-frequency signal content. The Fig.6 shows the output signal waveform after the low pass RC filter. The signals are also phase-shifted individually. The phased array signals then sum off in order to produce constructive and destructive interference that directs the signal only to desired γ direction. The value of angle to be shifted is calculated using (1) which is done in MATLAB simulation. The simulation results are not included in this paper as this paper only discuss on hardware outputs.

The Fig. 7 shows the output signal at the transducers after being amplified. The ultrasonic signal is amplified from 5V to 9.6V. Fig. 8 and Fig. 9 shows the ultrasonic signal waveform with and without beamforming at the receiver respectively.

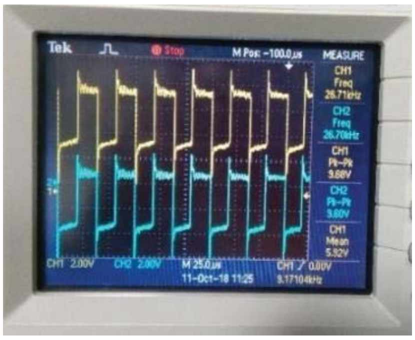

Figure 7. Output signal at transducers after amplified.

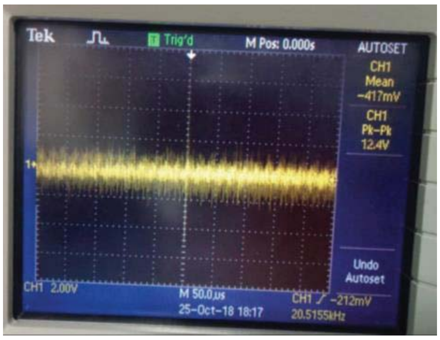

Figure 8. Ultrasonic signal waveform at receiver without beamforming.

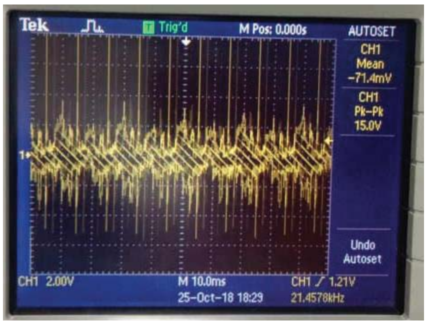

Figure 9. Beam-formed ultrasonic signal detected at receiver.

IV. Conclusion

This paper illustrates a beam-formed ultrasonic bird deterrent system which need to be installed at transmission line area. This bird deterrent system can prevent birds nest at transmission lines and repel their activities. This technique has advantages such as large data storage ability and reduced cost compared to other time-domain beamforming techniques. This hardware implementation of phased-array beamforming ultrasonic bird deterrent system is able to beam-form ultrasonic waves to a particular direction (with the presence of birds). Therefore, this beam-formed system succefully provides a more efficient bird deterrent system with less energy loss.

Acknowledgement

My sincere appreciation and thanks to Universiti Tenaga Nasional for the guidance given and sharing current practices and knowledge under the project grant UNIIG2017.

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