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Design and Implementation of an Arduino-Based Ultrasonic Device for Humane Dog Repellent

Kai Liang Lew*, Iksan Bukhori, Athiswaran Krishnan and Cheng Zheng

***Abstract* – Dogs can pose a nuisance and danger to people in residential areas through barking and territorial behaviour, causing discomfort and safety concerns. Dogs and humans both possess hearing capabilities, but dogs can detect ultrasonic frequencies that humans cannot perceive. This enhanced auditory sensitivity makes dogs responsive to high-frequency acoustic stimuli. In this paper, preliminary field observations of an Arduino-based ultrasonic dog deterrent device are presented to explore frequency response patterns in free-roaming dog populations. A frequency-based approach represents a potentially more environmentally safe alternative compared to traditional chemical repellents. This research presents observational data from field testing of a portable prototype that incorporates an Arduino Uno microcontroller, an ultrasonic transducer, and an amplifier to generate adjustable high-frequency sound waves. The microcontroller enables frequency control across the 38 to 42 kHz range to emit an ultrasonic sound that dogs respond to without physical harm. The device is portable, offers frequency adjustability, and is capable of field deployment. Based on the observations from forty encounters with stray dogs, the response rates increased across the frequency range. Across the frequency range, 42 kHz showed the highest observed response. These findings suggest that ultrasonic deterrent applications show promise. Further research is needed to confirm the effectiveness and optimal deployment parameters.**

Keywords— Arduino, Ultrasonic, Dog Repellence, Environmentally Friendly Device, Frequency-based Device, Sound Frequency.

I. INTRODUCTION

Humans and animals share a specific mechanism for hearing. Initially, sound waves are collected by the ear flap and enter through the external auditory canal. These waves then reach the eardrum, which converts them into vibrations. These vibrations are transmitted through the ossicles, comprising the hammer, anvil, and stirrup to the cochlea. The cochlea's movement causes the auditory and vestibular channels to vibrate, generating signals that the auditory nerve carries to the brain, which are interpreted as sound.

Sounds are produced at a range of frequencies. Humans can hear frequencies between 20 Hz and 20 kHz. These frequencies are referred to as audible frequencies. Frequencies below 20 Hz are classified as infrasound frequencies. Natural phenomena such as landslides, volcanoes, and earthquakes often produce low-frequency vibrations. Some animals can detect these infrasound frequencies, enabling them to sense impending natural disasters. On the other end of the spectrum, frequencies above 20 kHz are known

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as ultrasound frequencies. While humans cannot hear ultrasound, many animals, especially dogs, can. Ultrasound frequencies are of great scientific interest and have numerous applications, particularly in medicine for diagnostic and therapeutic purposes. They are also used in industry and other fields. Despite their higher frequencies, ultrasound waves share fundamental properties with other sound waves. The increased frequency does not equate to higher volume but instead changes in the texture or quality of the sound. The difference in hearing abilities between humans and dogs has practical applications for managing animals. Stray dogs pose a significant problem in many urban and suburban areas, causing potential harm, spreading disease, and disturbing the local population.

Dogs find ultrasonic frequencies irritating, a fact that has been historically exploited through special whistles that humans cannot hear but which repel dogs. This principle can be applied to modern urban management, using ultrasonic devices to deter stray dogs and other animals from residential areas. Conventional dog control methods, such as chemical repellents, pose risks to environmental health, non-target animals, and humans. This method is environmentally friendly compared to traditional methods, such as chemical repellent methods, which have proven ineffective at controlling stray animal populations in urban settings.

The enhanced hearing ability of dogs, attributed to the 18 muscles that enable their ears to move toward sound sources, allows them to pinpoint the origin of sounds more accurately than other animals. This capability highlights the potential effectiveness of using ultrasound to manage stray animals in cities, thereby reducing health and environmental hazards while minimising harm to the animals. Although ultrasonic technology is recognised for animal control, existing ultrasonic devices often lack adjustability, portability, and systematic testing, which limits their practical application.

An Arduino-based ultrasonic device offers adjustability, cost-effectiveness, ease of use, and humane treatment of animals, addressing many shortcomings of existing solutions. Moreover, the application of ultrasound extends beyond repelling animals. In the medical field, non-invasive diagnostic tools like ultrasound imaging are crucial for visualising internal body structures. Ultrasound therapy also treats certain medical conditions by promoting tissue healing and reducing inflammation. In industrial applications, ultrasound is employed for cleaning, welding, and even non-destructive testing to identify structural flaws in materials.

Although numerous ultrasonic dog-repellent gadgets are marketed, most emit a single fixed tone near 22 kHz, are wall-powered, and have rarely been tested under controlled conditions. Therefore, there is limited adjustability and uncertain field performance. The prototype presented here addresses these shortcomings by providing battery-powered portability, frequency adjustability from 38 to 42 kHz via a single potentiometer, and systematic field observations with forty encounters with stray dogs in natural environmental conditions. These features directly address the practical gaps identified in prior work and constitute the main contribution of this exploratory investigation.

This study focuses on conducting preliminary field observations of stray dog behavioural responses to various ultrasonic frequencies using an Arduino-based system, emphasising practical deployment considerations and real-world effectiveness patterns. The research aims to establish initial observational data regarding frequency response trends in free-roaming dog populations while demonstrating the engineering feasibility of portable, adjustable-frequency deterrent devices for field applications.

II. Literature Review

A. Overview of Ultrasonic Technology

Sound is a form of energy produced by the mechanical vibration of objects travelling through the air as waves. The characteristics of sound, such as its frequency and intensity, are measured in Hertz and Decibels, respectively. The audible range of sound waves, which humans can perceive, falls between 20 Hz and 20 kHz. Frequencies below 20 Hz are classified as infrasonic, while those above 20 kHz are considered ultrasonic [1]. Human ears are only sensitive to sound vibrations within the audible range, as the tympanic membrane responds to vibrations within this frequency range, as shown in Figure 2.1 [1].

Dogs are highly sensitive to ultrasonic sound frequencies. When exposed to ultrasonic sound emitted by a repellent device, dogs can become startled and disoriented. The ultrasonic waves disrupt their nervous system and interfere with their natural frequencies, causing discomfort and confusion [2-4]. This disruption often prompts dogs to quickly move away from the ultrasound source, effectively repelling them from the area [5][6].

The impact of ultrasonic sound on canine behaviour has been the subject of various studies and investigations. Researchers have found that the acoustic structure of a dog's whines, which are often associated with separation anxiety, can be altered by exposure to ultrasonic sound [5]. This disruption in the dog's natural frequencies can lead to changes in their behavioural patterns, such as increased quietness and reduced anxious movements [15].

Furthermore, technology-enhanced training systems, such as wearable devices that emit ultrasonic sound, have been explored as a potential solution for reducing separation anxiety in dogs [15]. These devices are designed to guide owners in implementing practical separation training while also providing a means of mitigating the dog's anxious behaviours. While ultrasonic technology has shown a promising approach, it is necessary to compare it with existing methods for effectiveness and safety.

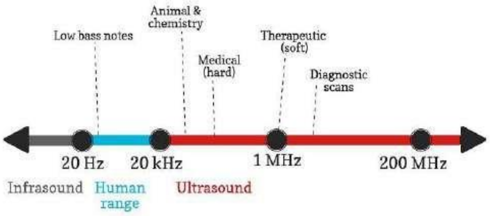

FIGURE 1. The operating frequencies for typical applications of ultrasonic waves [35].

B. Chemical-based Repellents vs. Ultrasonic Devices

The utilisation of chemical deterrents for pest control poses risks to public health, even when applied at lower doses. Concerns have arisen regarding the ongoing use of these chemicals and their potential adverse effects on the environment and human health [8]. Table 1 compares chemical deterrents and repellent devices, highlighting the significant advantage of pest control devices in being environmentally safe and posing no threat to human health.

The term "electronic" refers to various methods of pest repulsion utilising electrically powered devices, constituting a subset of physical pest control methods that have gained popularity due to their eco-friendly nature compared to traditional deterrents. Electronic devices for pest control primarily consist of two types: ultrasonic devices and electromagnetic devices.

Ultrasonic devices emit high-frequency sound waves exceeding 20,000 Hz, beyond the range of human auditory perception. These devices are designed to emit such frequencies when targeting pests, inducing discomfort within their coverage area and driving them away without adverse effects on the environment or non-target organisms, including humans. This method is favoured over others due to its environmental friendliness, compatibility with ecosystems, cost-effectiveness, and absence of known risks to human health [9-11].

TABLE 1. Comparison between chemical deterrents and repellent devices

Area of Difference	Deterrents Products	Repellent Devices
Hazard level	High	Very low
Response time	Quick	Medium
Effectiveness	Very effective	Low
Cost	Cheap (economical)	Cheap

C. Electromagnetic (EM) Dog-Repellent Systems

In addition to acoustic methods, several commercial solutions employ low-frequency pulsed electromagnetic fields to create an invisible perimeter that triggers an aversive stimulus when a collar-mounted receiver is approached, such as the PetSafe® In-Ground Fence, 915 kHz carrier or to deliver a brief EM pulse that is reported to disturb canine vestibular function [36, 37]. EM systems provide direction-independent coverage and are unaffected by ambient noise. However, they require every target animal to wear proprietary hardware, which may interfere with pacemakers and entail higher installation and maintenance costs than ultrasonic approaches. Comparative field studies show that approximately 55–60% of boundary-respect rates are achieved in trained dogs [38], whereas ultrasound devices achieve similar deterrence without collars but only within a narrow beam and a limited range. Consequently, an ultrasonic, collar-free prototype addresses situations where fitting animals with receivers is impractical while avoiding the regulatory concerns associated with high-power EM transmitters. Recent field reports indicate additional constraints on EM containment. Collar receivers must be worn consistently and can malfunction if batteries fail. Long-term training is needed before dogs reliably avoid the boundary, and interference with underground utilities or nearby radio equipment has been documented in dense urban settings. Controlled trials have also shown a residual escape rate of 30–45 % when dogs are highly motivated by stimuli beyond the perimeter [40]. These practical, welfare and regulatory hurdles further justify the exploration of collar-free ultrasonic approaches for rapid, low-maintenance deployment.

D. Gaps in Existing Ultrasonic Repellents

Commercial dog whistles and plug-in ultrasonic boxes typically emit a fixed tone near 22–25 kHz, yet their deterrent performance is poorly documented. A classic review of 33 sonic-deterrent tests reported that fewer than half produced any measurable reduction in animal incursions [33]. Controlled trials with two garden-repeller units showed marginal behavioural changes in 29 guide dogs once the animals were more than 3 m from the source [34]. Audiometric work demonstrates that canine hearing remains sensitive up to 45 kHz [35], implying that a higher frequency band may be required for reliable aversion. Consistent with this, an IOP-published study found that tones between 38 and 42 kHz repelled 80–90 % of stray dogs, although the prototype used a bench-top signal generator and lacked portability. Collectively, these findings underscore the need for a battery-powered, frequency-tunable dog repellent capable of emitting frequencies above 38 kHz and validated under field conditions, a gap addressed by the present work.

TABLE 2. Pros and Cons of Various Sensor Types

Area of Difference	Ultrasonic transducer	Passive Infrared	Laser
Implementation	Sends ultrasound waves and measures the return time	Detects heat difference between the body and surroundings	Uses a concentrated beam for extended range
Range	2cm to 400cm	5cm to 80cm	Few meters to tens of meters (model dependent)
Directivity	cone of approx. 30°	cone of approx. 5°	From 0.5 to 1° when highly focused
Accuracy	Good, but affected by distance, angle, and temperature	Good, decreases with distance	Accurate within centimetres

Cost	Inexpensive	Inexpensive	Relatively expensive

E. *Evaluation of Various Sensor Types*

All sensors offer information about the surroundings, including odometry, contact, and sensitivity to light, heat, and sound [12]. Ultrasound sensors are commonly employed for detecting motion and measuring distance due to their affordability and ease of use [13]. Besides ultrasound, infrared and laser are utilised for such measurements. The table below outlines the primary pros and cons of these various alternatives concerning solutions for this project [14].

According to the comparative study in Table 2, the ultrasonic transducer emerges as the optimal choice for a dog-repelling system. It offers accurate, contactless distance measurements within 2 cm to 4 m, surpassing others with its broader measurement range. With an operating angle of approximately 30 degrees, it provides greater accuracy within this cone, albeit less precision towards the sides than acoustic sensors and lasers. Unlike its counterparts, the ultrasonic transducer does not require a direct line of sight and can detect moving objects that are obstructed by obstacles. Moreover, it is more cost-effective, which aligns with the user's preference for an affordable and efficient device for dog control.

F. *Microcontroller Selection (Arduino vs. Raspberry Pi*

Open-source microcontroller boards are being utilised to reduce design and implementation expenses. The distinctions between the two widely used boards, the Raspberry Pi Model B and the Arduino Uno, will be delineated. Each possesses unique strengths and weaknesses, making specific platforms more suitable for particular projects than others [15]. According to Table 3, each of these hardware types serves specific purposes. Arduino Uno is well-suited for this project due to its beginner-friendly design, open-source nature, ease of setup, low power consumption, and affordability [16]. With the Arduino IDE, users can easily write programs to interface with various hardware components, including sensors, switches, internet modules, and other microcontrollers.

TABLE 3. Comparison between Arduino and Raspberry Pi

Platform	Arduino Uno	Raspberry Pi Model B
Operating system	None	Linux distributions
Integrated development environment	Arduino IDE, Eclipse	Open Embedded, QEMU, Scratch box, Eclipse
Programming language	Writing-based C++	Python, C, BASIC
Architecture	8Bit	32Bit
Processor	ATMEGA328	BCM2835 (ARM)
Clock Speed	16 MHz	700 MHz
RAM	2 Kbyte (0.002MB)	512 MB
ROM	32 Kbyte	SD Card (2 to 16 GB)
I/O (several protocols)	14	8
USB	One input only	Two input
On Board Network	None	10/100 wired Ethernet RJ45
Cost	Cheap	Expensive

On the other hand, Raspberry Pi is designed for more advanced projects, offering capabilities such as Ethernet connectivity, audio and video processing, and ample memory [15]. Essentially a miniature computer running Linux from an SD card, the Raspberry Pi excels in handling complex tasks. However, it lacks extensive options for interfacing with external sensors, making it less ideal for projects requiring diverse electronic interactions, such as the one at hand [15].

III. METHODOLOGY

Figure 2 shows the basic methodology and overall processes for this project. This includes the initial problem identification, literature review, component selection and device design, hardware assembly and Arduino programming, field testing of device performance with dogs, and analysis of observational data to establish preliminary effectiveness indicators for the ultrasonic dog-repellent device.

FIGURE 2. Methodology and overall processes for this project.

A. *Device Design and Hardware Components*

The development of a dog-repellent device has been carefully designed to ensure durability and proper functionality. The design phase establishes the foundational work for the project. The design ensures that dogs are not harmed when being deterred. Autodesk Inventor was used to design the device shield, allowing users to operate it comfortably and efficiently. Figure 3 shows the final product of the device.

FIGURE 3. Front View of the Device

FIGURE 4. Arduino UNO

Arduino is a microcontroller that can precisely control the components [17] and requires a rechargeable battery to power it. To allow the Arduino to control these components, it is necessary to input the code into the chip so that it can control the components as desired. It controls the ultrasonic transducer to emit high-frequency sound waves that may deter dogs from the area [18]. A single button is designed to activate the emission with a single press. This ensures that users can activate it easily and that the button is accessible when users require immediate activation in emergencies [18]. Moreover, Arduino is very popular among numerous innovative systems [19-27]. Figure 4 shows the microcontroller.

The Arduino Uno has been selected as the control unit. The next essential component is the output device that generates the ultrasonic frequency. Ultrasonic transducers are a crucial component used in this project. It can emit high-frequency sound waves that deter dogs. Arduino controls it. The emitted sound wave can irritate the dogs, so when the dog feels uncomfortable, it will try to move to another place [28]. The sound wave does not harm dogs and humans, but it still depends on the sensitivity of the dog's hearing. The transducer is shown in Figure 5.

FIGURE 5. Ultrasonic Transducer

The ultrasonic transducer employed in this study is 40kHz. This transducer has a beam angle of approximately 30 degrees. The off-axis response is around 6dB at 30° from the centre. If the dog is outside this 30-degree range, the impact of the ultrasonic sound is reduced, which affects field testing results. It operates from 5 to 12 V direct current power supplied by Arduino. The current consumption is from 30 to 50 mA during activation. While sound pressure level was not measured during field testing, the transducer produces a sound that humans cannot hear, but it is very loud and uncomfortable for dogs.

With the device being portable, it needs a power source. The battery powers the device's components. A battery that can be recharged is more cost-efficient than a battery that cannot be recharged. The battery makes the device portable because it does not need constant access to a power outlet. Thus, this device can transport the user to any desired location. Arduino has the feature to manage power consumption, allowing the battery to last longer before it runs out or needs to be recharged [29].

A potentiometer is used to tune the frequency of the sound wave produced by the ultrasonic transducer [30]. This is because hardcoding the frequency inside the Arduino is inefficient, requiring the use of a computer to change the code. The potentiometer has highlighted its importance in tuning the frequency without requiring a computer connection. By adjusting the potentiometer, the power supplied to the ultrasonic transducer changed. If the device has other sensors, such as a motion sensor and other detection components, fine-tuning the potentiometer can be crucial, as these components may be affected if the power supply is insufficient.

B. Study Area

Based on the project, it required an understanding of the usage of each component. Such knowledge includes how the ultrasonic transducer emits the sound wave, fine-tuning the sound wave in the code, and the limit of sound waves that the components can produce. These aspects need to be understood so that the developed device can be reliable and does not cause harm to animals or nearby humans.

Component integration requires knowledge of all the components and the maximum current and voltage that can be applied without damaging the component. Moreover, understanding each component functionally can help design the circuit more efficiently. It can also ensure compatibility with no issues. Figure 6 shows the circuit diagram of the device. In Figure 6, Arduino digital pin D9 generates a 40 kHz PWM square wave that drives the piezo-ultrasonic transducer through NPN transistor Q1, providing the required current. The potentiometer connected to analogue pin A0 sets the PWM timer value, thereby tuning the output frequency, while the 18650 battery powers the Arduino via VIN and the output stage through a 5V boost converter.

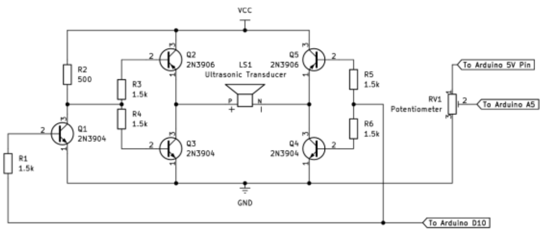

FIGURE 6. Circuit Diagram

While the circuit design establishes its functional framework, an efficient power management system is important to ensure extended operation. Power management refers to the efficiency of power consumption. This also relates to the rechargeable battery, as it can operate for a longer period. This study includes optimising power consumption techniques, such as allowing the device to enter sleep mode if it remains inactive for a specific period. This can minimise the time it takes for the battery to recharge.

The user interface is also an important component that requires careful design. This is because the design of a user interface can determine if the device is user-friendly or not. It typically includes an on-and-off switch with an LED to indicate whether the device is on or off. Moreover, the LED can also serve as part of the battery level indicator, allowing the user to know when to recharge their battery.

User and animal safety represent the most important aspect requiring consideration before finalising device design. While the ultrasonic transducer does not harm users or animals, consideration of other factors remains important, such as exposure levels to ultrasonic sound waves and electrical hazards. Additionally, the device incorporates protective components, such as shielding, grounding, and compliance with safety standards.

C. Parameters

The standard soundwave frequency for deterring dogs is between 20 and 25 kHz. Sound waves in this frequency range are usually inaudible to humans but fall within a dog's hearing range. Aside from temporary annoyance, this range effectively deters the dog without causing harm.

The battery life is the lifespan of the battery. Each time a battery is recharged, its lifespan is reduced. Therefore, it is important to consider the battery life for cost efficiency. The battery duration that needs to be recharged is usually calculated based on the ultrasonic emitter's power consumption and the device's switch-on duration per usage.

Coding is a crucial component in making the device operate efficiently. This allows the Arduino UNO to control the ultrasonic transducer and other components. If the code is written messily, the device may consume more power to emit the frequency during usage. Thus, an efficient code can give a real-time response and less power consumption.

Circuit design typically requires a significant amount of knowledge and careful consideration. The circuit's design must optimise power consumption, minimise noise, and ensure reliable operation. The overall performance of the devices can be determined by the design.

The device's power consumption was estimated based on the component specifications. The Arduino Uno draws approximately 50 mA during operation, and the ultrasonic transducer consumes from 30 to 50 mA when activated. The LED indicator uses around 20 mA. The total system power consumption is around 120 mA during active operation. The device operates continuously for approximately 21 hours when equipped with a standard 2600mAh 18650 rechargeable battery.

The device's weight and size required a balance between them. This is because a device designed to be portable should be of lesser weight and smaller size. This aspect needs to be considered first, as it can impact the circuit design and the components used in the device.

D. Experimental Procedure

Forty free-roaming stray dogs encountered during routine animal-control operations in Melaka were observed individually under field conditions that precluded controlled experimental parameters. Testing was conducted over several weeks across different areas within Melaka. Testing locations included areas near local markets, industrial zones, and residential streets in Melaka where stray dogs are frequently reported. While specific locations were not documented during field observations, the use of different routes reduces the chances of repeated encounters with the same animals. For each dog, the ultrasonic device was initially maintained in an inactive state for 30 seconds to record baseline behaviour, then activated while its output was adjusted stepwise from 20 kHz to 42 kHz using the built-in potentiometer. The lowest frequency that prompted a clear avoidance response, such as dogs retreating or turning away, was recorded. Each animal was exposed for no longer than 30 seconds in total. There is no handling, restraint or physical contact. The observations involved no handling, restraint, or physical contact. The observations were non-invasive and approved by the local animal control authority. No dog was harmed or restrained.

These observations were conducted in open field environments where dogs approached spontaneously, preventing standardisation of distance and aiming angle parameters between the device and individual animals. This methodological constraint reflects the practical realities of field testing with free-roaming animals rather than controlled laboratory conditions. The operator typically activated the device when dogs approached within a few meters, holding the device at chest height and directing it generally toward the animal. The absence of instrumentation for these parameters represents a recognised limitation that prevents systematic analysis of distance and directional effects on deterrent response.

The acoustic output intensity of the ultrasonic transducer was not calibrated during field testing. Sound-level measurement equipment was unavailable at the test site, preventing verification of emitted sound-pressure levels under actual operating conditions. According to manufacturer datasheets [39], the piezoelectric transducer used is specified to produce 110 dB SPL at 30 cm on-axis, but this value was not independently confirmed during field testing. Future work will include on-site SPL measurements to quantify amplitude and assess its effect on dog behaviour.

IV. Results and Discussion

A. Result

Forty encounters with stray dogs were involved in the experiment. Each dog's behaviour was observed when the device was turned off and turned on. This analyses their response before and after exposure to ultrasonic frequencies across various ranges. The observational data indicated that ultrasonic frequencies ranging from 38 kHz to 42 kHz produced observable behavioural responses in dogs, with animals typically creating distance from the device. These observations suggest that dogs experience some level of discomfort with these ultrasonic frequencies. The dogs' reactions following activation of the device indicate potential deterrent effects from ultrasonic waves in this frequency range. Figure 7 shows the line chart of dog responses to ultrasonic sound.

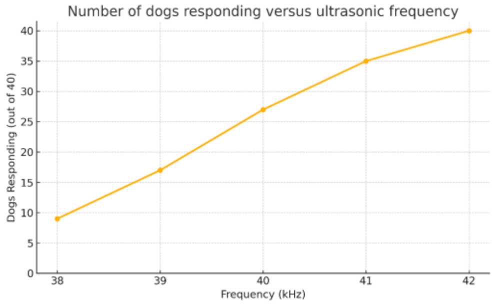

FIGURE 7. Number of dogs showing avoidance versus ultrasonic frequency

The response pattern observed across the 38 kHz to 42 kHz frequency range showed increasing response rates at higher frequencies. The field testing environment, while lacking controlled experimental conditions, provided valuable preliminary data on device performance under real-world deployment scenarios. These initial findings suggest that the 38 kHz to 42 kHz range warrants further controlled investigation for the development of effective dog deterrent applications. Table 4 shows the number of dogs recorded.

TABLE 4. Dogs exhibiting avoidance behaviour at each ultrasonic frequency

Frequency (kHz)	Dogs Responding (n = 40)
38	9
39	17
40	27
41	35
42	40

Field observations revealed that all 40 dogs showed avoidance behaviour at 42 kHz during this preliminary study. This frequency demonstrated the highest observed response rate among the tested range. Figures 8(a) and 8(b) provide photographic evidence of typical dog responses, demonstrating dogs moving away from the activated ultrasonic device.

(a)

(b)

FIGURE 8. (a) Dog moving away from the device. (b) The dog repels from the device

The field observations conducted in outdoor settings indicated potential deterrence effects across varying distances under the specific conditions encountered during testing. Initial observations suggested that dogs avoided approaching the device when operational, though systematic distance measurements were not recorded due to the uncontrolled nature of field conditions.

B. Discussion

The observational data suggest that ultrasonic frequencies between 38 and 42 kHz may have an effective influence on dog behaviour in field settings. The highest frequency tested, 42 kHz, elicited responses from all 40 dogs in this preliminary study, indicating this frequency as potentially optimal within the tested range. The observed differences in response rates at frequencies below 38 kHz suggest that dogs may demonstrate greater sensitivity to higher ultrasonic frequencies, which aligns with an established understanding of canine hearing capabilities. Table 5 summarises critical aspects of the device's performance, durability, usability, and effectiveness observed during testing.

TABLE 5. Key Functional Aspects and Observations from Device Testing

Aspect	Details and Observations
Frequency Range	The device produces ultrasonic waves from 38 kHz to 42 kHz. It is effective for repelling dogs without being audible to humans.
Power Consumption	An 18650 rechargeable battery powers it. Low power consumption ensures longer battery life for extended outdoor use.
Observed Response Range	Preliminary observations indicated potential effects across varying distances in open environments. Systematic range testing under controlled conditions is necessary to establish definitive parameters.
Adjustable Settings	Potentiometer for frequency and intensity control. Allows customisation for different environments or needs, enhancing overall effectiveness.
Durability	Tested for a few hours of continuous operation. Reliable for short-term use, may require periodic checks for longer use.
Environmental Testing	It works well in normal conditions but is not waterproof, so it should be protected from rain to avoid potential damage.
Behavioural Observations	Initial field observations suggest potential for deterrent applications, though controlled studies are needed to establish definitive effectiveness parameters.
Noise Interference	No interference was observed with common electronic devices. Safe to use in residential and commercial areas without disrupting nearby electronics.

The frequency range selection for this study, from 38 kHz to 42 kHz, was driven by the lack of response from dogs when the ultrasonic device operated within the 20 kHz to 30 kHz range. Initial trials with these lower frequencies yielded no observable reactions, suggesting that dogs do not perceive or are less sensitive to ultrasonic sounds in this range. This led to the hypothesis that higher frequencies might align better with the auditory sensitivity of dogs, which prompted the exploration of the 38 kHz to 42 kHz range.

The observed response pattern at 42 kHz is consistent with the 80-90% avoidance rates reported by Atheeb et al. [31] for 38-42 kHz laboratory tones; however, a direct comparison requires consideration of the different testing environments and methodological approaches. While previous studies with fixed-tone devices operating near 22 kHz reported effective ranges of approximately 3 meters [33,34], the current field observations suggest a potential for extended-range applications, although systematic range verification under controlled conditions remains necessary.

Determining optimal frequency parameters presented significant challenges requiring iterative calibration of the ultrasonic device. The apparent relationship between frequency and response rate observed in this study highlights the complexity of designing ultrasonic devices that effectively engage with animal auditory systems. Small variations in frequency appear to correlate with differences in response rates, underlining the importance of precision in frequency selection for future research applications. The preliminary findings suggest that the 38 kHz to 42 kHz range represents a promising area for controlled investigation, providing a valuable benchmark for future studies involving ultrasonic animal deterrent systems.

A limitation of this preliminary study involves the absence of biometric information capture, including age, body mass, and breed characteristics. Additionally, the study did not record precise device-to-dog distances or orientations, preventing an analysis of the effects of separation distance and beam direction on deterrent response. Frequencies above 42 kHz were not tested due to hardware constraints and the typical upper limit of canine hearing. Specifically, the MA40S4S transducer's acoustic output drops by more than 15 dB beyond 43 kHz, making reliable testing above 42 kHz impractical with current hardware [39]. However, dogs can detect sounds up to 45 kHz, suggesting future controlled studies may benefit from exploring this extended range. Individual dog identification was not verified during field observations, and some animals may have been encountered multiple times.

V. Conclusion

The device successfully emits frequencies between 38 and 42 kHz, with 42 kHz showing the highest observed response rate in all tested stray dogs during this preliminary field study. Its compact design, battery operation, and use of a potentiometer for real-time frequency tuning distinguish it from prior solutions, which often lacked adjustability or portability. Field observations indicated potential deterrence effects across varying distances without harming the animals, demonstrating the device's feasibility for real-world deployment scenarios. This work contributes preliminary data toward the development of cost-effective, deployable systems for non-invasive animal control.

The ultrasonic dog-repellent device has room for improvement. The device can be equipped with weather resistance, ensuring it does not affect performance in outdoor environments. It can be waterproof, so the components in the device are protected from being short-circuited. Moreover, this project can utilise a deep learning method to automatically tune the ultrasonic waves based on the dog's location [32]. Future research should investigate ultrasonic frequencies above 42 kHz to determine whether they can further enhance deterrence effectiveness.

The device can also be integrated with a Bluetooth or Wi-Fi module to function as a remote control device. This allows the device to be placed in a different location, and the user can activate it from a remote location, eliminating the need for physical interaction. Additionally, future iterations could incorporate AI-driven response monitoring to automatically log and adapt to dog reactions, enabling personalised deterrent profiles. Exploring miniaturisation and solar-powered operation may also enhance long-term deployment in outdoor public spaces.

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Author contributions

Kai Liang Lew: Writing – Review & Editing;

Iksan Bukhori: Writing – Review & Editing;

Athiswaran Krishnan: Conceptualisation, Data Curation, Methodology, Validation, Writing – Original Draft Preparation;

Cheng Zheng: Writing – Review & Editing.

Conflict of interests

No conflicts of interest were disclosed.

Ethics statements

Ethical approval was not required for this study as it involved only non-invasive behavioral observations of stray dogs without physical contact, restraint, or harm. The ultrasonic repellent device used in the experiment emits sound frequencies within safe and humane limits, ensuring no discomfort or distress beyond temporary annoyance. All procedures were conducted per standard ethical practices to ensure the animals' welfare.

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