

Design and Construction of an Ultrasonic Cattle Deterrent Device to Curb Farmer-Herder Conflict in Nigeria

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ABSTRACT

Cattle encroachment into farmlands has emerged as a critical issue in regions where agriculture is vital for livelihoods and food security, with Nigeria being no exception. This research aims to design and develop a cattle deterrent device tailored to the unique challenges of farmer-herder conflicts. The device incorporates an Arduino UNO board with an ATmega 2560 microcontroller which serves as the brain of the device, facilitating the integration and control of various sensors and components. Passive Infrared (PIR) sensors detect thermal radiation changes caused by animal movement. They trigger the device when cattle approach the protected area. Ultrasonic sensors detect the presence of cattle by emitting high-frequency sound waves and measuring the time it takes for the waves to bounce back. This information is used to calculate the distance to the cattle from the farmland. An LCD display unit provides real-time feedback and information about device status, helping farmers monitor its operation and effectiveness remotely by receiving feedback through a GSM module that is incorporated on the system. Tests on cattle reaction were carried out at a location in 'Yan Shanu' cow market, Jos, Plateau state, Nigeria. The auditory range of a cow is from 23Hz to 37,000Hz, an irritating sound frequency capable of causing cows to balk, stop, move away was achieved. It was observed that cattle got irritated by the sound at 30KHz (30000Hz) and 142 dB sound pressure level at 1 meter (3.3 feet) away from the device which is the source of the ultrasonic wave.

Keywords:

Arduino Uno,
Cattle deterrence,
Farmer-Herder conflict,
Ultrasonic transducer,
PIR sensor.

INTRODUCTION

Agriculture is the backbone of many economies, including Nigeria, where it plays a pivotal role in providing food security, employment, and economic growth. However, the agricultural sector in Nigeria faces persistent challenges, one of which is cattle encroachment into farmlands. This issue arises from the competition for limited resources, particularly land and water, between sedentary farmers and nomadic herders. As a consequence, conflicts between these two groups have escalated, leading to economic losses, social tensions, and even loss of lives (Omeje, 2008). Technology has the potential to transform the way conflicts between farmers and herders are managed in Nigeria. One of such technologies is the cattle deterrent device. The device is based on the idea that ultrasonic sounds are unpleasant or irritating to the animals, causing them to avoid the area where the sounds are emitted.

Contrary to humans, who have an auditory range of 20Hz to 20KHz, cattle have auditory range of 23Hz to 37KHz (Heffner, 1998), making them much more sensitive to high frequency sounds. Cows dislike high-pitched noise like whistling, horns, yelling and clanging of metals. Intermittent noises can be very distressing especially if they are abrupt and audible. Mammals, including cows, respond to sudden noise with higher intensity, with responses including reaction of surprise, freezing, and running away from the sound source (Dimov et. al., 2023)

Attempts have been made in different parts of the world to use technology to address various kinds of problems and challenges due to animals. In India, an intelligent electronics system was designed to reduce the numerous domestic and wild animal mishaps, including those involving buffalo, cows, and nilgais which were reported. Signal generators and power amplifiers were employed

to drive Twitter Horns at a particular volume. It produced a sound signal that is both unpleasant to animals and inaudible to humans to help prevent these accidents. Certain species of animals including dogs, cats, bullocks/cows, and horses were chosen for the study since they had different hearing frequencies than other animals. Animal-specific frequency spectrum signals are produced which alarmed the particular animal and causes it to flee (Sonone et al., 2014).

Bhagya (2021) used an Arduino UNO board, an LCD display, an ultrasonic sensor, and a dual-tone multi-frequency (DTMF) decoder that recognizes animal frequencies to develop a system that benefits both homes and farms. Ultrasonic frequencies that ward off flies and spiders were transmitted in mode 2 while dog and cat frequencies that repel them were transmitted in mode 1 (between 22 and 25 KHz).

A system that could repel agricultural pests, especially rats and birds was designed by Nurikhsani and Mupita (2022). The tool has a passive infrared-receiving sensor that detects the presence of agricultural pests, and a servo motor that activates and pulls a bell, making sounds that scare away birds and rats. This mechanism is controlled by a microcontroller called the Arduino ATmega 2560.

In order to repel rodent and bird pests in rice farms, Ningsih (2019) developed a prototype device that utilizes two sensors (an ultrasonic sensor and a PIR sensor) to detect the pests. It is an automated pest control tool specifically targeted at bird and rodent pests. It produced noise that can startle the pests and cause them to flee.

Enormous damage to crops caused by avian pests is a problem to farmers in Nigeria. In order to mitigate this

problem while maintaining a healthy ecological environment, Ezeonu et al. (2012) used an environmentally acceptable bird preservation method like ultrasonic. The objective of the study was to create an ultrasonic system that will keep birds out of specified places without harming them. A frequency generator, output transducer, power drive, and frequency scanner were the apparatus used. The ultrasound's frequency fluctuated continually between 15 and 25 kHz. Birds' responses to the emitted waves were observed. It was observed that birds that are lounging and resting are more easily dispersed than birds that are feeding because it is always difficult to break the habit of feeding. To prevent the birds from becoming accustomed to the device signal, a pause in the signals broadcast was made when they had responded to the stimulus to their fullest.

Although many of these systems have been used in pest control and as repellants, not much research has been carried out to use technology to reduce the persistent farmer-herder conflict in Nigeria. The aim of this study is to develop a system that will help to mitigate the effects of this conflict without risk to the farmers, herders, cattle, and the crops.

MATERIALS AND METHODS

The block diagram for the cattle deterrent device is shown in figure 1. As can be seen from the block diagram, the unit consists of ATMEGA 2560 microcontroller, ultrasonic transducer, PIR sensor, ultrasonic sensor, temperature sensor, humidity sensor, vibration sensor, flame sensor, LCD display, buzzer, LEDs, GSM module, and solar power supply unit.

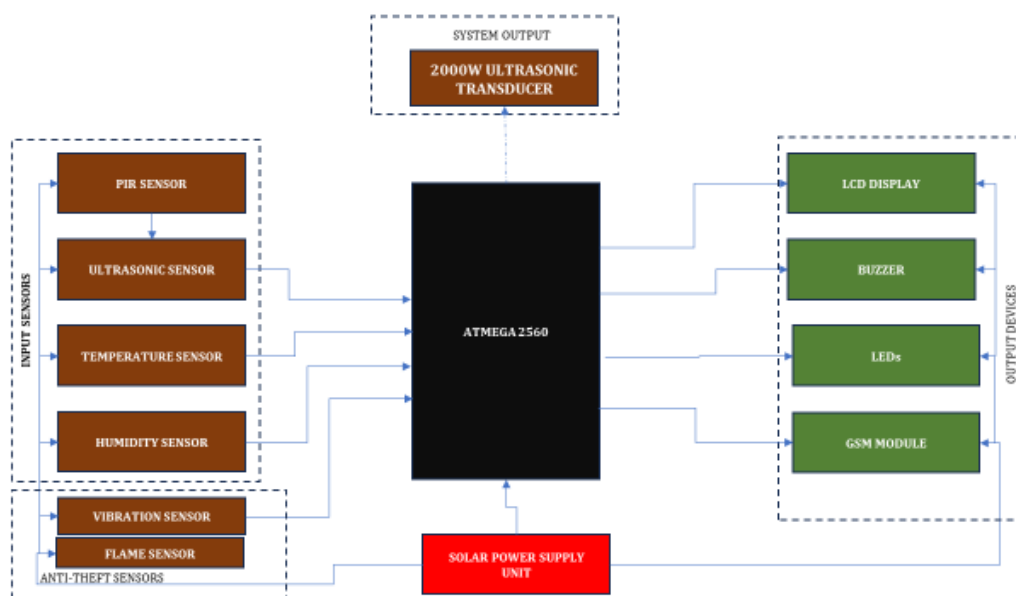


Figure 1: Block diagram of the cattle deterrent device

The system takes its power source from the solar power supply unit, it powers the central processing unit of the

circuit or device which is the ATmega 2560 microcontroller. Design code is written for the system

and uploaded on the microcontroller which controls all the input components that determine the outputs, starting from the PIR sensor, which senses the presence of the cattle, if it senses nothing, the system doesn't come on. The Ultrasonic sensor measures the distance of the cattle from the farmland which determines the intensity of the emitted ultrasound wave, temperature and humidity sensor measures temperature and humidity in the environment, since propagation of sound intensity is

attenuated by these weather conditions. Vibration, flame or smoke sensor are activated when vibration and smoke respectively are felt by the device at a certain threshold, the custodian of the device receives SMS on their phone through the GSM module, ultrasonic piezo electric transducer outputs the disturbing or irritating frequency. All the components above were assembled together to construct the cattle deterrent device and the prototype is shown in figure 2.



Figure 2: Constructed ultrasonic cattle deterrent device

RESULTS AND DISCUSSION

The design and development of cattle deterrent circuit was powered and tested on PROTEUS software, transferred to printed circuit board (PCB) for hardware implementation.

An ultrasonic signal was generated, code for the frequency generation was written for the ATmega 2560, the generated signal was converted to sonic and ultrasound, emitted by the ultrasonic piezo transducer. Ultrasonic level detector (instrument) and digital storage oscilloscope was used for detecting the signals propagated from the device. Detection test for signals produced showed that the arrangement of the 4 piezo ceramic transducers placed at 90° to each other produced 360° sound dispersion coverage. The frequency of the emitted ultrasound varied continuously between 100Hz and 65kHz automatically because the code for the system

was generated to automatically alter from 100HZ, 600HZ, 10KHz, 20KHZ, 30KHZ, 40KHz, 50KHZ, 60KHZ, 70KHz within a period of 10 seconds and the cycle begins again.

Observations of cattle reactions to the broadcasted waves were made. Tests on cattle reaction and behavior was carried out at a location at "Yan Shanu" cow market Jos Plateau state capital, Nigeria. The cattle response in portions of the market where the broadcasted waves got to, showed that cows got irritated at 30,000Hz, 142dB, since this was noticed, the ultrasonic sensor which is responsible in calculating the distance of the cow to the farmland or the position of the device is programmed to emit this irritating sound at 1 meter (3.3 feet) away from the position of the device. The response of the cattle is consistent with work done by (Sonal et al., 2022).

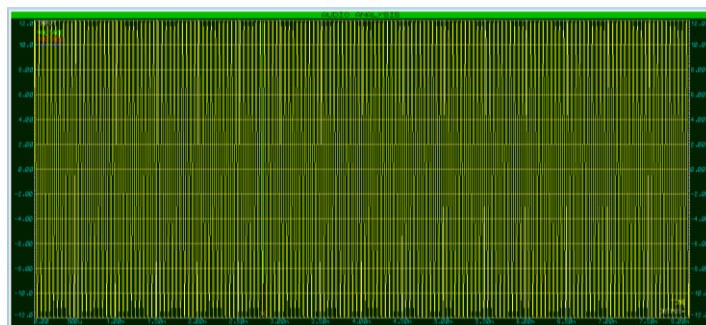


Figure 3: 20KHZ



Figure 4: 30KHZ

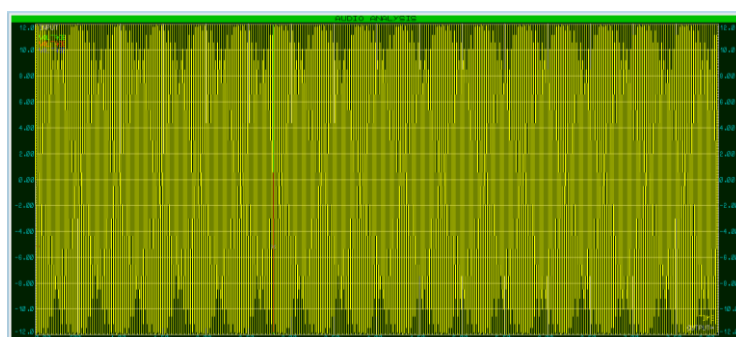


Figure 5: 40KHZ

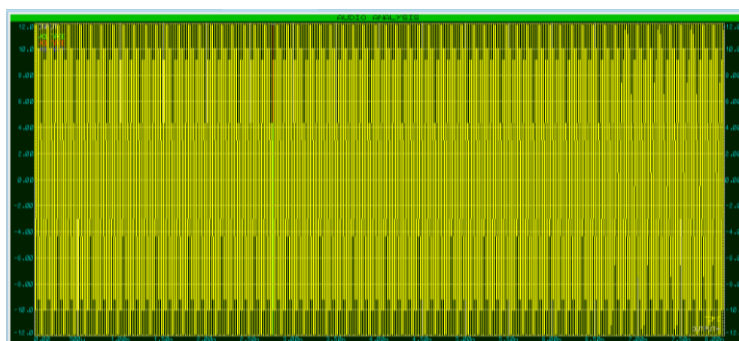


Figure 6: 50KHZ

Figures 3 to 6 represent the frequency signal wave generated and outputted by the ultrasonic device with equal sampling rate of 500 microseconds as seen above with increased amplitude on each figure. The difference

in amplitude, shows increases in the sound wave which is associated with sound's loudness as it changes from 1KHz to 70KHz for effective cow deterrence.

Sound Pressure, Distance and Wave Propagation

The output power of the piezoelectric transducer used in the work for the ultrasonic cattle deterrent device has a maximum power of 2000W. The intensity (I) of the sound emitted by the device at a distance of 1m and 2m was calculated to be 39.78W/m², 9.946 W/m², respectively, using the inverse square law.

$$I = \frac{P}{4\pi r^2} \quad (1)$$

Where,

I is the intensity at distance r, P is the Power of the transducer, and r is distance.

Sound pressure level is given as

$$SPL = 20\log_{10} \left(\frac{I}{I_0} \right) \quad (2)$$

Where,

$I_0 = 10^{-12} \text{W/m}^2$ reference intensity in air. Equations (1) and (2) are used to calculate the intensity and sound pressure level (SPL) at distances of 1 to 7 m and the results tabulated as seen in table 1.

Values of the temperature, humidity, and voltage were obtained from the LCD display and tabulated in table 2.

Table 1: Sound Pressure Level

S/N	Distance (m)	Sound Intensity (W/m ²)	Sound Pressure Level (dB)
1	1.00	159.155	142.14
2	2.00	39.789	136.12
3	3.00	17.684	132.06
4	4.00	9.947	130.01
5	5.00	6.366	128.16
6	6.00	4.421	126.58
7	7.00	3.248	125.24

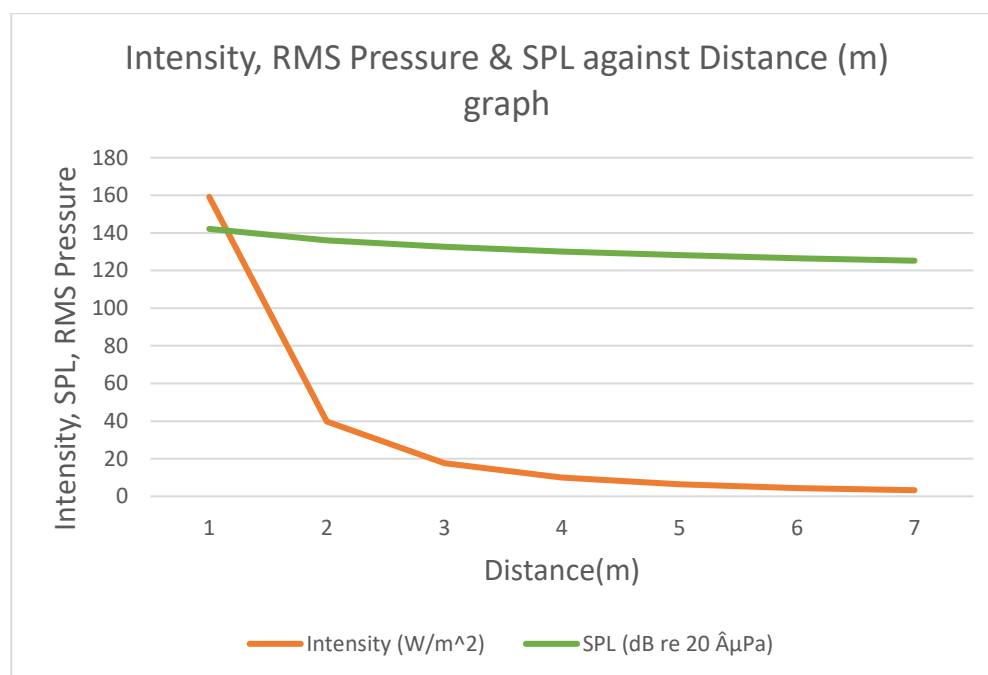


Figure 7: Graph of Sound Intensity and Sound Pressure Level Against Distance

Figure 7 is the graph of sound intensity and sound pressure level SPL against distance plotted from values gotten from table 1, it is seen that SPL decreases with increased distance from the source of sound due to spreading of sound waves but the SPL increases with

reduced distance, therefore the closer the cattle gets to the farmland which is the place of the source of the sound from the device, the higher the sound pressure level, the more the cattle gets irritated, thereby causing them to avoid the area.

Table 2: Temperature, Humidity and Voltage

S/N	Temperature °C	Dew point	Relative humidity %	Voltage V
1	33	2.9	15	5
2	25	6.2	30	7
3	20	7.7	45	10
4	15	6.0	55	12

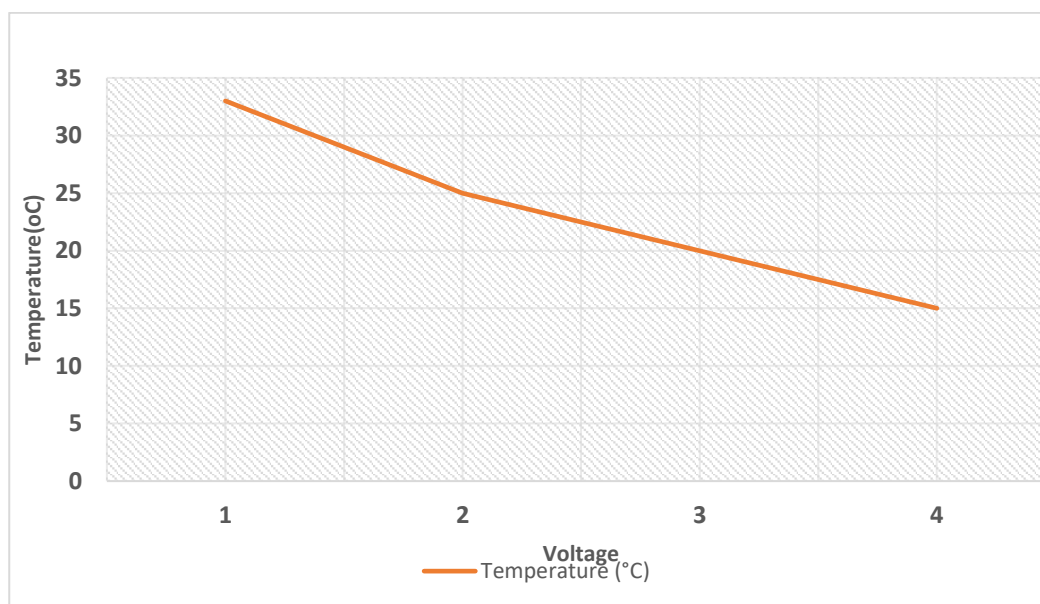
**Figure 8: Temperature-Voltage Graph**

Figure 8 is a Temperature- Voltage graph, plotted from values on table 2. It was noticed that high frequency sound waves produced by the ultrasonic piezo transducers is attenuated in intensity with decrease in temperature and increase in humidity with distance from the sound source. This was true for low temperature and high humidity. The speed of sound in a medium is directly proportional to temperature. As temperature increases, the speed of sound also increases, and as temperature reduces the speed of sound also decreases. This phenomenon was noticed to affect the travel time of ultrasonic waves through air, this is because in colder (low) temperature, the molecules in the air have lower kinetic energy, leading to a decrease in the speed of sound. Conversely high humidity in the air attenuates the propagation of ultrasonic waves. Higher humidity levels can lead to increased absorption of ultrasonic energy, causing a reduction in the intensity of the waves as they propagate, this is due to more water vapor in the air increasing its density. In low humidity the air is less dense because there is less water vapor presence which allows sound waves to travel faster.

Since this was noticed, the code for the system was designed to activate higher DC voltages of 5V, 7V, 10V and 12V accordingly using the input of the humidity and temperature sensor such that as the temperature decreases and humidity increases the amplitude of the sound wave

also increases for effective deterrence amid low, high temperature and humidity level, respectively. In sound processing, voltage variations represent the amplitude of the sound signal. An increase in voltage generally corresponds to higher amplitude (louder sound) while a decrease, results in lower amplitude. As seen in the output frequency signal waveforms in figures 4 to 7.

While other related research work focused on repelling rodents, pests, mosquito and insects etc, this work, design and construction of ultrasonic cattle deterrent device attempts to proffer solution to the farmer-herder conflict by developing a device capable of emitting disturbing yet harmless ultrasonic frequency to restrict cattle encroachment into farmlands that adapts to the weather condition of Jos, Plateau state, Nigeria successfully.

CONCLUSION

Farmer-herder conflict in Nigeria has grown into a very dangerous problem that has assumed a nation-wide dimension which has led to destruction of lives and properties. Although several solutions have been proffered yet the problem still persists. This work is an attempt to use technology in order to address this challenge. An ultrasonic cattle deterrent device was developed using an Arduino UNO board with an ATMEGA 2560 microcontroller, ultrasonic transducer, PIR sensor, ultrasonic sensor, temperature sensor,

humidity sensor, vibration sensor, flame sensor, LCD display, buzzer, LEDs, GSM module, and solar power supply unit. The device utilizes the fact that cows have an auditory range from 23Hz to 40,000Hz. Any high-pitched sound above the auditory range of humans will be inaudible to humans but irritating to cows, causing them to balk, stop, or move away from the sound source. The device was tested at the “Yan Shanu” cattle market in Jos. It was observed that the device emitted an irritating sound of 30,000Hz and 142dB sound pressure level of the ultrasonic frequency at 1 meter (3.3 feet) away from the device, successfully deterring cattle movement into unwanted areas.

This device is recommended for use in farm houses where it can be protected from vandalization. It is not suitable for use in open farm areas where it can easily be destroyed. Improvements can be made to the device so that it can be deployed to cover a wider area instead of using several units which will be make the cost exorbitant.

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