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Performance Evaluation of a Designed Stand-alone Solar Powered Ultrasound Weaver Bird Pest Control Device

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ABSTRACT

Ultrasound pest control devices have hitherto remained an experimental piece in laboratories with its application limited to households and store houses. By this work, Ultrasound weaver bird pests control device have ventures into the field/farms to confront pest in their natural habitat and to appraise the success thereof. The device was first evaluated in the laboratory, section by section for a technical appraisal before being deployed to the field. The field evaluation was carried out in outdoor weaver bird homes and in weaver birds infested farms. The performance comment both for the laboratory and field evaluations are that, the devices' circuitry meets requirement to generate and transmit high intensity ultrasound in line with design objectives and that the device effectively provide weaver bird pest cover to crops in area measuring three thousand eight hundred and fifty square meters respectively.

Keywords: Performance evaluation, ultrasound, pest, ultrasound pest control device, weaver birds,

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1. INTRODUCTION

Chemical pesticides have become more popular on the list of conventional pest control methods in spite its potential risk to humans and other life forms and unwanted side effects to the environment [1] and [2]. Non-chemical alternatives have been advocated [3], for which electronic pest control is one. It involves various means of repelling pests using electrically powered devices. Ultrasonic devices are a part of this means whereby electronic circuits are designed and constructed to emit high frequency sounds (above 20 kHz) which when targeted at pests; they make them uncomfortable within the area of coverage thereby repelling them away from the area without affecting the environment and non-target organisms [4]. Since the human ear lacks the capacity to hear such sound, it is also harmless to man. This means of physical alteration of the environment to make it inimical or inaccessible to pests has the advantage of being cheap, eco-system and environmentally friendly with no known risk to humans [5]. Previous designs were engrossed in controversies bordering on their effectiveness [6,7,8]. In order to improve the effectiveness of such devices, pest and environmentally specific devices was suggested [4].

In line with this, weaver bird pests were selected as a specific pest and a field survey was carried out in an endemic study area in order to identify threshold sound bearing capacity, stage(s) of attack, and the response of the pest to ultrasound and their respective times for habituation in that environment [9]. These information were used to generate design parameters which was technically incorporated into designing a standalone solar powered weaver bird pests ultrasound device [10]. The said design was implemented using electronic construction technology [11]. There is need, in this area of study to evaluate the success or otherwise of such design implementations. It was however observed that such studies take place in laboratories, households, store houses and artificial environments [12, 13]. In this work, the performance of the designed and constructed device was evaluated not only in the laboratory, but in the natural habitat and feeding spots on the field/farm. Performance comment made under such condition is more reliable in determining whether or not the device meets design intent.

2. METHODOLOGY

The solar powered ultrasonic weaver bird pests device so designed, constructed and currently under evaluation test is shown in Figure 1.

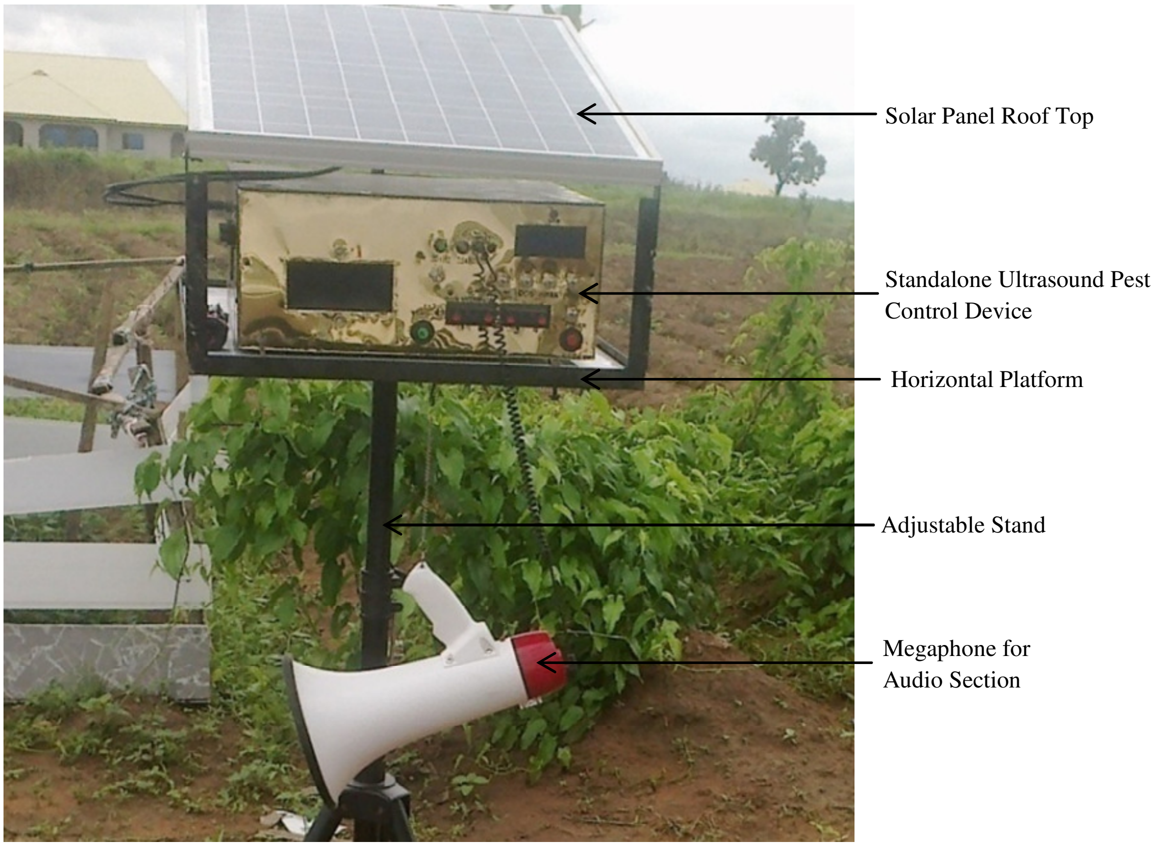

Plate 1: Designed and Constructed Ultrasound Pest Control Device Under Evaluation (11)

The appraisal of the solar powered ultrasonic weaver bird pests device was done with the intention of putting a performance comments on the device. This is not possible without asking questions as: Do the constituent sections of the device perform to specification? How do they execute task under certain environmental conditions in the study area? How well do they work all together in perfect synergy to satisfy the overall objective of the work? To answer these questions, the device was evaluated in two environments: The laboratory and field/farm.

2.1 Laboratory Evaluation

Under this category, the device was tested in the laboratory using laboratory equipment in order to substantiate their workability. Each section of the device and respective circuits were put to test using relevant testing gadgets. Where test equipment could not be used, alternative means of monitoring their workability in line with the stated objectives were resorted to. The performance comment made under this category was more on the technical operation of the device. The sections and the respective tests carried out to evaluate their performance are enumerated below:

2.1.1 Evaluation of Voltage Regulators

Voltage regulators are used to limit the voltage entering a section of a device to the allowable level that is tolerated by the components in the circuit. In this work, a total of four voltage regulators were used. They include those of the 5 V for the oscillator section, microcontroller, predator cry section and LCD. Also, is the 10 V regulator for the power amplifier section. The performances of these regulators were evaluated using a digital multimeter by connecting the meters probes to the ground and output lines of the regulators to obtain their output voltage. Another evaluation test carried out on the voltage regulators was that of temperature monitoring using a thermometer. The purpose of this was to find out whether or not the voltage regulator were overheating after a prolong use.

2.1.2 Evaluation of Charge Controller

The charge controller monitors the 12 V battery by controlling the 18 V solar panel and the load on the charge controller (i.e the device). To evaluate its performance, three tests were carried out.

a. The solar panel was connected and used to charge an exhausted battery to regulated capacity without switching on the device. This is to check against overcharging and charging duration.

b. After step a, the device was powered while using a voltmeter to note the voltage for which charging will resume. This is to check for the minimum battery pick-up voltage of the charge controller.

c. After charging for a while, the solar panel inlet was unplugged with the device still operational while noting the battery voltage. This is to check for load disconnection (battery trip-OFF) voltage.

2.1.3 Evaluation of Tripping Section

The objective of the tripping section is to guarantee judicious use of the device by shutting down power delivery to the device when the weaver birds are not feeding on the farm (at about 6.30 pm) and to trip-on when weaver birds are expected to be on the farm (from about 6.00 am). To evaluate this section, the device was operated outdoors and close to these time limits while observing the tripping-ON time and the tripping-OFF time. The device was daily taken outdoor and powered at about 4.30 am for the trip-ON time and 5.30 pm for the trip-OFF time respectively.

2.1.4 Evaluation of the Oscillators

Two oscillators were designed for the device: The 25 kHz and the 35 kHz oscillators. To test their performance, a digital frequency meter was employed. For the 25 kHz oscillator, the meter's live probe was connected to pin 3 (output pin) of the 555 timer for 25 kHz oscillating circuit while the ground probe was connected to pin 1 (ground). On powering the device, the frequency meter will display the frequency of the signal being generated. Same procedure was repeated to evaluate the 35 kHz oscillator.

2.1.5 Evaluation of Frequency Selection Section

The role of the Frequency Selection Section is to select between the output of the 25 and 35 kHz oscillator at an interval of fifteen seconds. The objective of this section is to introduce a measure of variability into the signal. Such unpredictable changes tend to delay the setting in of habituation by weaver birds. For the evaluation test, the frequency meter was connected to the output of the 6 V relay (RL_2) of the frequency selection circuit where the output of both the 25 and 35 kHz oscillators are expected to be intermittently selected and supplied to the amplification section. Also used is a stop clock to monitor the duration of frequency selection.

2.1.6 Evaluation of Amplification Section

The amplification section is made up of the preamplifiers and the power amplifiers with their corresponding IC's being the UR 741 and LM 386 respectively. Their performances were evaluated using the oscilloscope. To do this, the input of the preamplifier was first assessed by connecting the signal input probe and ground probe on pin 3 and 4 of the preamplifier IC (UR 741) respectively, and noting the shape and size of the waveform. The output waveform was also assessed by connecting the signal and ground probes to the output (pin 6) and ground (pin 4) of the IC respectively. The same evaluation procedure was used for the power amplifier. The signal input and ground probes of the oscilloscope were connected to pin 3 and 2 of the power amplifier IC (LM 386) and the shape and size of the input waveform was noted. The output waveform was also assessed by connecting the signal input probe to pin 5 of the IC. The read out of the oscilloscope was used to obtain the signal voltages needed to evaluate the gains of the respective amplifiers, if in tune with design specification.

2.1.7 Evaluation of Predator Cry (Audio), Microcontroller and LCD Sections

The microcontroller exercises electronic control over the predator cry (audio section), LCD and frequency selection sections and so were evaluated together. To do this, the device was powered, the megaphone was plugged to the audio outlet and each of the predator switches were selected, one after the other, and the corresponding time taken for each of the sounds were noted. Also, the LCD was closely watched to see if its display is a true reflection of the selected switches.

2.1.8 Evaluation of the Booster Outlet

The standalone device as designed has provision for future development of booster devices. As such provision was made for a booster outlet where electrical power and ultrasound signal can be conveyed from the standalone device into the booster devices via cables. The power section of the outlet was connected from the battery while the ultrasound section was connected from the output of the frequency selection section. The booster signal outlets from where the booster boxes will be fed were examined using digital meter and frequency meter to test for the presence of electrical power and ultrasonic frequency signal respectively.

2.1.9 Evaluation of Ultrasonic Transducer and Area of Coverage

In order to ascertain that the signal being transmitted from the transducers is actually ultrasound, a means of detection is needed. Therefore, an ultrasonic detector [14] was used to help identify ultrasound and also to assess the effective distance of travel. The detector was switched ON from a distance and brought close to the devices broadcasting outlet's field of view, ultrasound being unidirectional. Again, the distance of the detector from the device was varied linearly by gradually stepping backward while maintaining the field of view and extending a measuring tape along in order to obtain the effective distance of travel. The spread from the central position was also investigated extending the detector sideways to the left and right in order to obtain the spread from the central point.

2.2 Field/Farm Evaluation

Under this category, the device was tested under natural outdoor conditions. Also, the device was confronted face to face with the pest it is intended to control: The dreaded weaver bird. The performance comment made here reflects the actual value and quality of the device.

2.2.1 Choice of Locations for Field Evaluation

The design considerations and practices to improve the effectiveness of Electronic Pest Control Devices were proffered [11]. Among them is the idea of specificity, that is, they should be site/location specific and pest specific for optimum performance. This was the reason for selecting weaver bird as specific pest and Doko community and its environs as specific location (study area) for this work. Therefore, this same study area where the field survey that gave rise to the design parameters comes to mind as the best location when considering a choice of areas for field evaluation for this work. The communities and farms visited during the field survey which gave birth to the design considerations and development of critical parameters for this work were revisited a second time, but this time, not with independently assembled equipment, but with the stand-alone ultrasound pest control electronic gadget which shall be used to confront the dreaded weaver birds in the area in order to assess the effectiveness of this device in terms of how well they deter these birds from farms. Four communities, namely: Doko, Boku, Membe and Nupeko were the locations where the field evaluation was carried out. The first three are upland while the fourth was visited because of its nearness to the popular river Niger. The birds often retreat there in search of food and water at a time when water has receded from other communities.

2.2.2 Period and Duration of Field Evaluation

The weaver birds of Doko community, Niger State, Nigeria are migrant in nature. They visit the communities in search of food at a period of the year when dry season is approaching and the regular farmers of other communities have harvested regular crops like maize. At such periods agrarian and riverian communities like Doko and its environs will still be neck deep into cultivating crops like rice, millet and guinea corn. The birds therefore come in search of food and water. This field evaluation was carried out in the months of September, October and November being the peak periods of the pest activity. The duration for the field evaluation was seven weeks. This is because a previous result reveal that ultrasound becomes partially effective in repelling weaver birds after three weeks of transmission and completely ineffective after five weeks of continuous broadcast [9]. This is to test how well the device is fortified against habituation. The period and duration chosen makes room for large number of hungry and desperate weaver birds to be confronted over a longer period and as such any assessment made will be very reliable.

2.2.3 Evaluation Procedure on the Field

On arrival to the communities, the elated farmers who were thrilled at the innovation to solve their pest problems effectively and electronically were always on ground to accompany the team to their farms. Most of the farms were away from motorable roads, but that notwithstanding, the excited farmers assisted by conveying the equipment to farms with severe weaver birds attack. Plates II show a section of the jubilant farmers who volunteered to convey the ultrasound device and accessories to the farms.

Plate Plate II: Team members being lead to Weaver Birds infested Farm by Farmers and Children

Two procedures were adopted for the field evaluation in line with the field survey earlier conducted. These are: Evaluation at bird homes and evaluation on the farm.

2.2.3.1 Evaluation at Bird Homes

The study area is populated by tree clusters which serves as home to the birds and from where they lunch attack on farms. This evaluation was considered in order to assess the likelihood of repelling the birds from a vicinity where their nests, eggs and chicks are. Such vicinities can best be considered as a traditional home for the birds, and as such indicates a strong repulsive effect if able to keep the birds away from such territories. The followings are the procedures adopted for the evaluation at bird home

i. The stand, horizontal platform, standalone device and solar panel were mounted and positioned at the centre of a cluster of trees housing the birds and located around the farm.
ii. The height of each stand was adjusted upward by four meters to allow for better interaction between the signal and the tree housing weaver birds.
iii. The power switch was activated to begin ultrasound transmission.
iv. Commencement of observation. This involves taking note of the bird-flight and the bird-ruturn behavior.

2.2.3.2 Evaluation in Farms

Farms serve as the feeding spot for the birds. Therefore, the device was evaluated to assess how well it can deter the birds from feeding from their popular feeding spots. The followings were the procedures adopted for the field evaluation in farms.

1. The stand, horizontal platform, device and solar panel were mounted and positioned at the middle of a weaver bird infested farm.
2. The height of the stand was adjusted upward or downward to about same height with the crops in order to achieve levelling.
3. The power switch was activated to begin ultrasound transmission.
4. Commencement of observation.

3 RESULTS AND DISCUSSION

The outcome of the evaluation procedures carried out both in the laboratory and on the farm are presented in that order.

3.1 Laboratory Evaluation Result

3.1.1 Evaluation result of voltage regulators

The test results reveal that all the regulators performed to specification as no case of over- voltage, a damaging factor was discovered. However, slight under-voltages which were within tolerant limit was noticed for the 10 V regulator. This observation is not unconnected with the limited solar energy availability at the time of measurement. The temperature of the said regulator was also 18 ^{o}C above the room temperature and therefore prone to burn out in a long run due to overheating. This observation was due to the fact that the regulator alone controls five preamplifiers (UR741) and five power amplifiers (LM 386). To fortify it for this task, an appropriate heat sink was installed. Plate III shows the digital meter reading for the 10 V regulator.

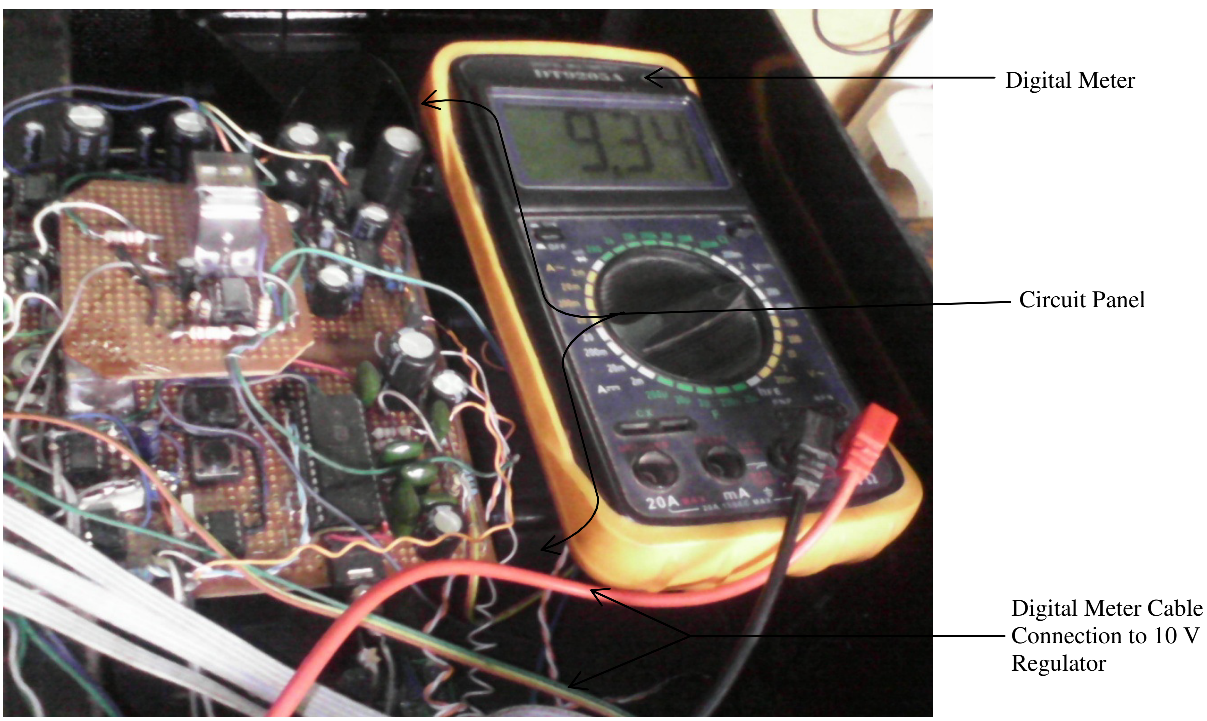

Plate III: Digital Meter Reading of the 10 V Voltage Regulator

3.1.2 Evaluation Result of Charge Controller

Result of test (a) reveals that the solar panel was able to recharge the exhausted 12 V battery from a voltage of 7 V to 12 V in twenty five minutes. At this point the voltmeter reading remained constant while the charging indicator on the charge controller stopped blinking. This indicates that charge controller protects the battery from overcharging. It has shut down the solar panel terminal in order not to overcharge the battery. Again, the charging duration of twenty five minutes for a battery as low as 7 V is good enough as the charge controller as designed will not allow the battery to drain to this value before charging resumes. This implies that a duration shorter than twenty five minutes will be obtainable to get a full charge.

Result of test (b) shows that after powering the device, the battery discharged to 10.9 V before the charging indicator began blinking to resume charging as evidenced by the gradual increase in the voltmeter reading. This indicates that the minimum voltage the battery will drop to before charging resumes is 10.9 V. This can be tolerated as the highest voltage rated component is 10 V

Result of test (c) shows that at the instant the solar panel was unplugged, the voltmeter reading immediately started declining gradually to 10.5 V before the device shut down. The load indicator on the charge controller also went OFF. This indicates that at 10.5 V, the load (device) is disconnected from the battery so as not to over drain the battery flat, leading to a permanent damage. This also prevents malfunctioning of voltage sensitive components. The evaluation result here is that, the charge controller is over-charging and under-charging protected with a minimum battery pick-up voltage, trip-off voltage and charging duration of 10.9 V, 10.5 V and less than twenty five minutes respectively.

3.1.3 Evaluation Result of Tripping Circuit

The outcome of the outdoor testing of the devices' tripping section shows that, as the device was taken outdoor and powered at about 4.30 am, the device was neither generating nor transmitting ultrasound despite the fact that the battery and load indicator remained ON. This was because the Light Dependent Resistor (L.D.R) had not received light enough to trigger the section's timer to toggle the section's relay in order to energize successive sections of the device. But as daylight approaches, the clicking sound of the relay was heard, indicating that the power line has been energized as witnesses by the LCD coming up and scrolling to indicate the frequency of transmission. This trip-ON time was repeatedly observed at about 6.05 am to about 6.20 am on different days. Also, at about 5.00 pm, same procedure was repeated to assess the trip-OFF time. But this time, transmission commenced immediately after the device was powered due to sufficient solar light. But at about 6.50 pm to about 7.10 pm, the device automatically shuts down. These tripping ON and OFF times are not constant as repeating the evaluation on other days revealed a slight variation. This is because daylight may be shorter or longer depending on weather and season of the year and daily clear sky situation. This action of the device indicates that the tripping section of the device has passed the evaluation test, as it is kept in operation during the time weaver birds were expected to be active on the farm.

3.1.4 Evaluation Result of Oscillators

The results of the evaluation test on the 25 kHz and 35 kHz oscillators was a display of their corresponding values on the digital frequency meter. This indicate that the oscillator circuits were effectively generating ultrasound of desired frequencies. Plate IV shows the set up for the evaluation test and the corresponding output display for the 25 kHz oscillator under test.

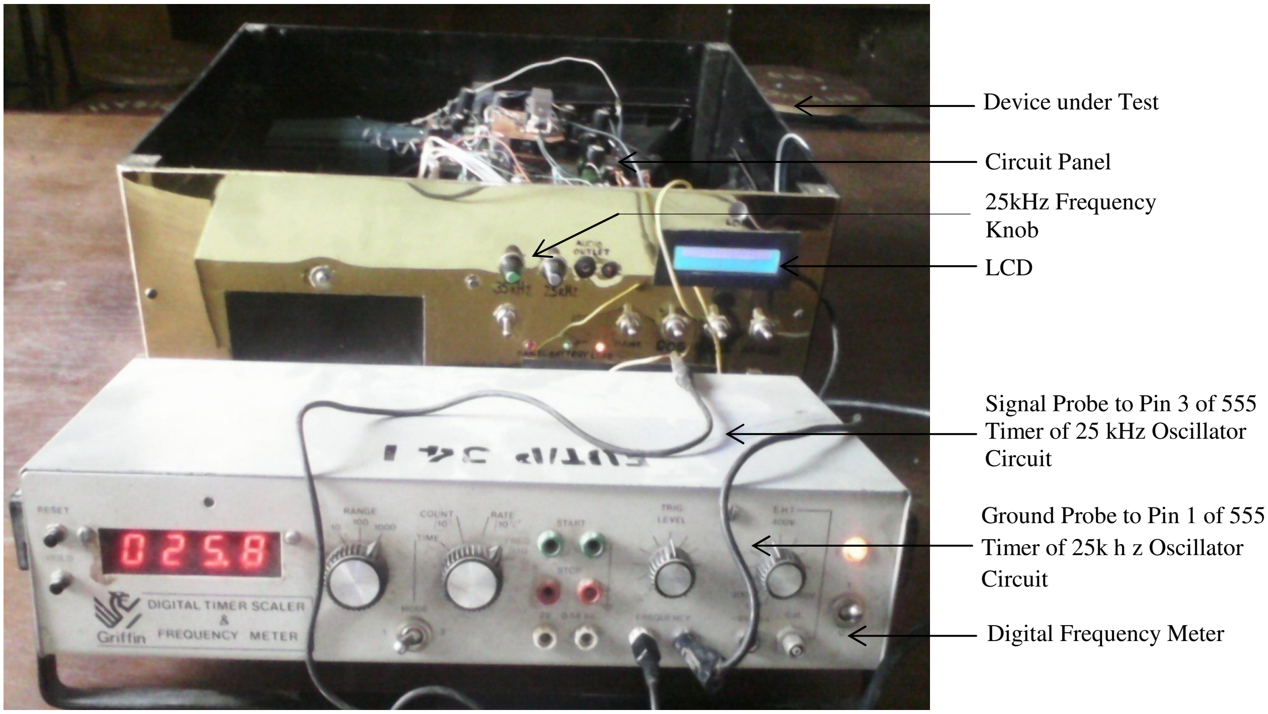

Plate IV: Frequency Meter Readout of the 25 kHz Oscillator

The output of the digital frequency meter reads 25.8 kHz. By slightly adjusting the 25 kHz frequency knob, a variable resistor in the oscillator circuit fine tunes the output to exactly 25 kHz which is also displayed on the LCD screen. A similar result was also obtained for the 35 kHz oscillator, with the meter displaying 35 k Hz. These results confirm that ultrasound signal of magnitude 25 and 35 kHz are actually being generated by the respective oscillators for onward processing.

3.1.5 Evaluation Result of Frequency Selection Section

With the device powered and digital frequency meter probes rightly positioned at the output of the frequency selection circuit, the frequency meter reads 25 kHz for fifteen seconds after which it changes to 35 kHz for another fifteen seconds. The process of frequency selection continues uninterrupted until the device is switched off. Thus, indicating that the objective of the frequency selection circuit was effectively achieved. The set up for the frequency selection circuit evaluation test is similar to that of Plate IV, except for the positioning of the probes and the presence of a stop clock to monitor the selection duration.

3.1.6 Evaluation Result of Amplification Section

The input signal voltage V_{in}, of the preamplifier was calculated from the oscilloscope as 2×10^{-3} V. For the output, the signal voltage V_{out}, was calculated as $1\ V$.

Gain of an amplifier is given by equation (1) as,

$$A = \frac{V_{out}}{V_{in}} \quad (1)$$

Where A is the gain of the preamplifier. Equation (1) was evaluated as

$$\frac{V_{out}}{V_{in}} = \frac{1\ V}{2 \times 10^{-3}\ V}$$

$$= 500$$

It is clear that the output surpasses the input by five hundred times, signifying that the input has been amplified five hundred times in line with design specification. For the power amplifier, the input waveform was noted to be the same as the output of preamplifier. This was expected because the output of preamplifier serves as input to the power amplifier. From the size and shape of the output waveform, the output signal voltage was calculated as 180 V Gain of the power amplifier is given by equation (1) and evaluated as,

$$A = \frac{V_{out}}{V_{in}} = \frac{180\ V}{1\ V} = 180$$

It is clear that the output of the power amplifier surpasses the input by one hundred and eighty times. This deviated slightly from a design calculation which was intended for a gain of 200. Again, this slight difference might be due to a drop in supply voltage, being solar driven. With these results, it can be said that the amplification section performs optimally according to design specification.

3.1.7 Evaluation Result of Predator Cry, Microcontroller and L.C.D Sections

Test result shows that the audio sound from the megaphone and readout on the LCD were in harmony with the selected hawk, dog, human and distressed weaver bird sounds respectively. Timing results also reveal that each sound plays for fifteen seconds in accordance with the design. The area of coverage of the audio sound depends on the degree of adjustment of the megaphone's volume control. This can travel to a maximum of about six hundred meters on proportionate adjustment. Plate V shows a selected predator switch (Hawk) and the corresponding display on the LCD respectively.

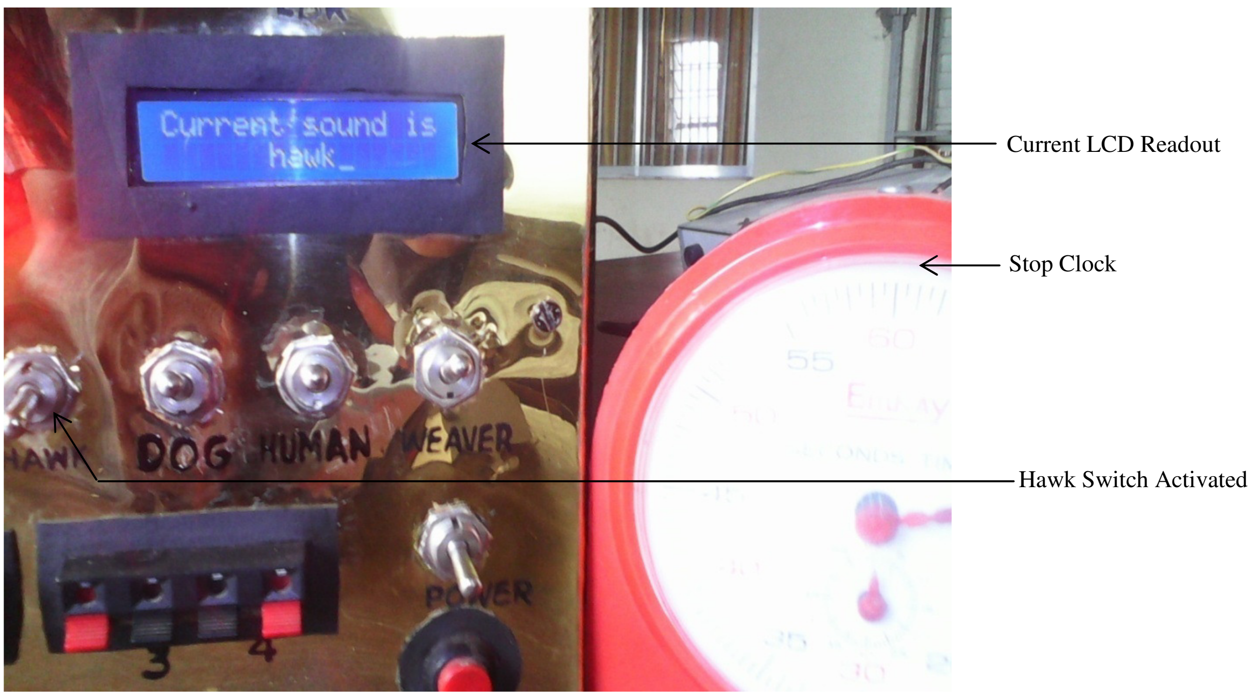

Plate V: Timing of Hawk Switch and corresponding LCD Readout

3.1.8 Evaluation Result of Booster Outlet

The voltage available at the power section of the outlet as measured by the meter is 12 V. while the digital frequency meter connected to the ultrasound section of the outlet alternately reads 25 and 35 kHz every fifteen seconds. These readings were recorded simultaneously for the outlet and for the device. These results confirm good communication between the stand-alone device and the booster outlet terminal. Thus, can be tapped by booster devices for onward transmission to their respective booster locations.

3.1.9 Evaluation Result of Transducer Section

When the detector was brought closer to any of the five broadcasting outlet's field of view, the sound of the buzzer was heard and loudly. This loud sound of the buzzer indicates the presence of ultrasound signal of high intensity and illustrated in Figure 1 by a dark green coloration. Moving away linearly from the stand to between 40 m and 60 m witnessed a gradual reduction in sound, illustrated by the light green coloration. On further extension, the buzzers sound became very faint beyond 60 m as shown by the lightest green coloration. The buzzer sound got completely attenuated at 63 m. This indicates that the signal is transmitted to a distance of about 60 m. However, the intensity reduces beyond 40 m. For the horizontal spread, ultrasound signal was detected up to 1 m from the central point. This spread reduces as one moves closer to the device. These results confirm the unidirectional and slightly spread out nature of the signal from a source. Whether or not the ultrasound signal detected can scare weaver birds away from its area of coverage will only be known after the field evaluation in the bird's natural environment. Figure 1 illustrates the nature and extent of coverage of the ultrasonic transducer.

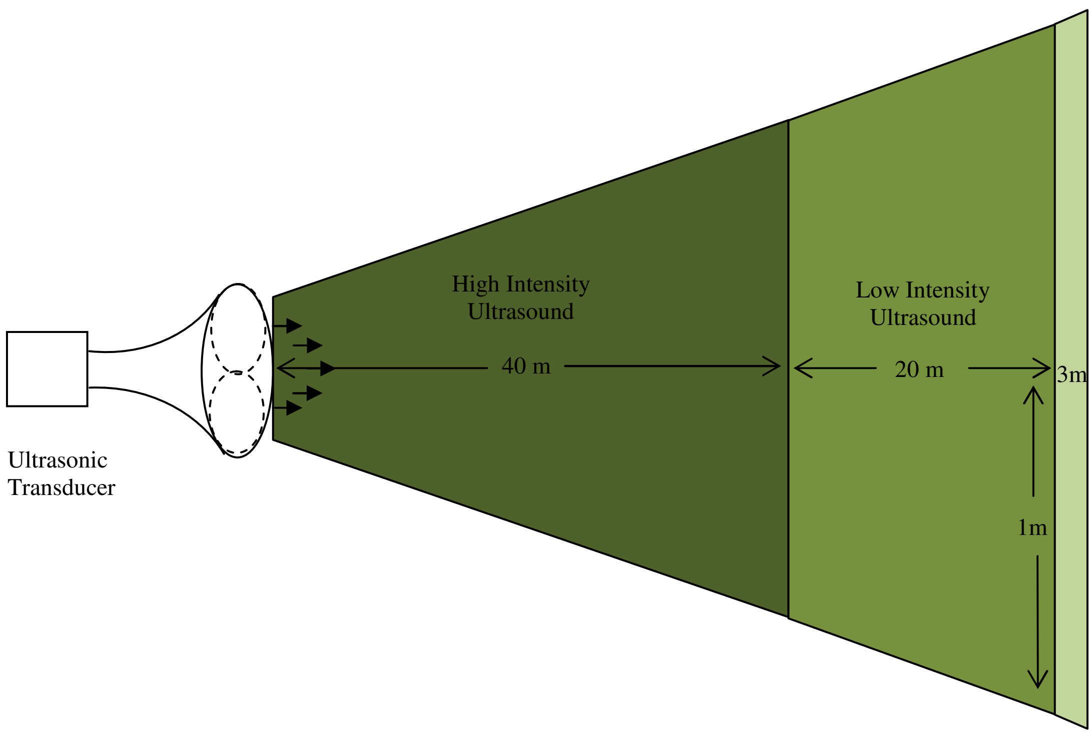

Figure 1: Illustration of Ultrasonic Transducer's area of coverage

3.2 Field/Farm Evaluation Results

After setting up the stand and commencement of broadcast, the team members (made up of the researcher, technologists and farmers) usually split up around the vicinity to inspect and record interesting occurrences in connection with the weaver bird-flight and bird-return behavior. The evaluation results obtained at bird homes and in the farms are presented below:

3.2.1 Result of Field Evaluation at Bird Homes

For about two minutes of transmission, a lot of disorderly movements of the birds were noticed. They can neither perch comfortably on a branch nor in their nest due to increased restlessness. After about five minutes of endurance, the instability climaxed into colonies of intermittent flights. The flights were always initiated by one or two bird and others jointly follow. The hitherto noisy vicinity is now gradually becoming less noisy as few birds were able to endure the disturbing effect of the ultrasound signal for about ten minutes. After this period, absolute silence was noticed around the vicinity as the remaining birds which initially moved to the peak of the trees in an attempt distance themselves from the disturbance later flew in swamps to distant trees about 100 meters away.

When the device was switched OFF, the birds embarked on a gradual return after about an hour. On further switching ON the device, a repeat of earlier observation of disorderliness, instability and mass-flights was noticed. The effectiveness of ultrasound in keeping the birds away from the vicinity of broadcast was maintained daily for about a month of continuous broadcast before the birds gradually became accustomed to ultrasound. This necessitated the activation of the predator cry section to relay programmed audio sounds of weaver bird's predators one after another, starting with hawk, dog, human screams and distressed sound of weaver birds under predator attack. This action fortified the device against habituation over the remaining period of three weeks.

3.2.2 Result of Field Evaluation in Farms

Prior to the commencement of transmission, the birds were feeding gregariously and few were crowding around the reflecting frontal surface of the device while in idle mode. At the instant the device was operated, the birds engaged in some short-range flights away from the stand. Always perching to assess if they could tolerate the disturbance in their new location. If they could not, they flew a little farther and re-assess the disturbance. They continued until a safe haven was found about forty to forty five meters (or eighty meters in diameter around the stand) away from the stand. Some birds made safety flights to trees located within this circumference, only to eventually fly away, finding no hiding place within the area of coverage. However, some birds were able to venture into the periphery (about 2 – 3 meters) of the safe vicinity to pick up food and fly away.

Though such areas were earlier delineated during the laboratory evaluation as areas where the presence of ultrasound is high. Feeding normally resumes about an hour of suspending transmission. Habituation to ultrasound was noticed in week four but the activation of the predator cry section refortified the device over the entire period. In summary, the laboratory evaluation tests carried out on major components and sections came out positive. And since all sections work in perfect synergy for the overall good of the device, a performance comment was made that, technically speaking, the device meets requirement to generate and transmit ultrasound in line with design objectives. High intensity signal was detected to a distance of forty meters in each of the five directions. Also, following the series of tests, measurements and monitoring that were carried out on several farms in the study area over a period of seven weeks, as observed by the technical team and the farmers.

The summary of the field evaluation result are:

i. The effective distance (radius) of coverage of the stand-alone device where the safety of crops is guaranteed is thirty five meters (35 m). This is five meters less than that for the laboratory evaluation. This generalization was made due to field observation of feeding activities at the fringes of laboratory observable boundaries and to accommodate cloudy and hazy days when solar energy availability is low. This can lead to a reduction in the power available to drive high intensity ultrasound to expected limits.

ii. The effective area of coverage for the stand-alone device was obtained using the formula for the area enclosed by a circle [15].

$$A = \pi d^2 \quad (2)$$

where A is the effective area of coverage of ultrasound signal, π is $^{22}/_{7}$ and d is the effective distance of 35 m. Equation (2) was evaluated as three thousand eight hundred and fifty square meters (3,850 m^2). This result is depicted schematically as shown in Figure 2.

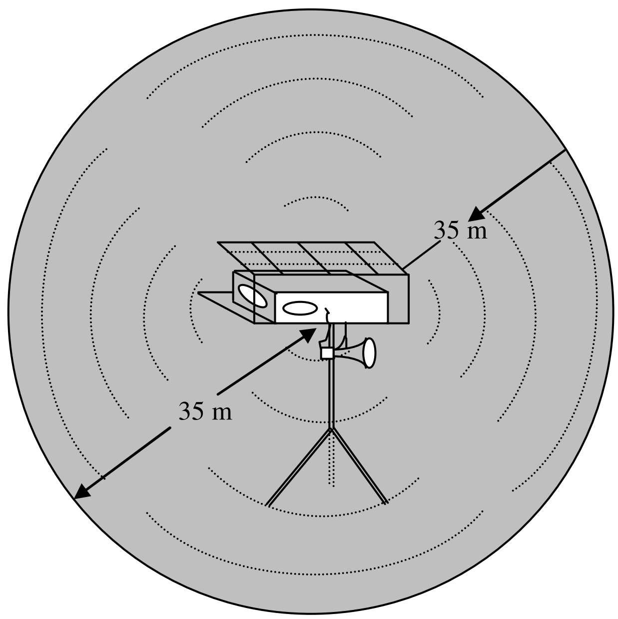

Figure 2: Schematics of the Effective Area of Coverage

It was generally observed that, it took a longer time to dislodge the birds from their homes than from farms. This was probably due to a show of territorial behavior when at home. When on the farm, the birds at the slightest ultrasound disturbance, will prefer moving far away from the stand and in most cases to other farms where feeding continues undisturbed.

4. CONCLUSION

The Solar Powered Ultrasonic Device so designed and constructed was appraised by evaluating its performance based on intended objectives. To do this, the device was evaluated indoors (the laboratory) and outdoors (the farm) for a thorough assessment in terms of the technicalities and performance respectively. The laboratory evaluation tests carried out on major components and sections shows that the device meets requirement to generate and transmit ultrasound in line with design objectives. Also, is the field evaluation in which the device confronted the dreaded weaver bird of Doko community and environs, head-on. The performance comment made here was that the device effectively deterred weaver birds within an effective distance and effective area of thirty-five meters and three thousand eight hundred and fifty square meters respectively.

The effective period of four weeks before the onset of habituation agrees with a previous work [16] which predicted using statistical analysis that a week of effective period can be recovered from the partially effective weeks. This extension of effective period of the device to a month against three weeks obtained during preliminary studies provide a user with a convenient period to utilize the device to cover delicate crop moments when the crops are more vulnerability to weaver birds attack. The incorporation of the audio section and a timely deployment of the device in line with recommended handling practice can lead to a near zero loss to the dreaded weaver bird even up to harvest. This work has presented the outdoor application of ultrasound pest control devices particularly in agriculture. When massively deployed for pest control in farms, the aftermath will include: increase in food productivity, enhanced income of farmers and stimulation of interest in agricultural activities. All of which will lead to the attainment of food sufficiency while guaranteeing safety of the environment and animal species. The positive outcome of this performance evaluation has satisfied the condition necessary for achieving the aim of this area of research, which is to utilize ultrasonic technology to implement an alternative eco-system and environmentally friendly pest control method that can keep targeted weaver birds away from farms.

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