2nd International Engineering Conference (IEC2017)
Federal University of Technology, Minna, Nigeria

Booster Mode Analysis for a Designed Ultrasound Pest Control Booster System

Ibrahim A.G
Department of Physics
Federal University of Technology, Minna

ABSTRACT

In a previous work, an ultrasound pest control booster system to enhance the area of coverage of a stand-alone ultrasound weaver bird pest control device was designed and implemented. The concern of this study is to work out how this system of devices can be adapted in large farm types in terms of the booster units that may be required and in some cases, the rounds of boost that may be required. Mathematically based arguments were used in this analysis with result showing that the expression relating the area of ultrasound coverage on a farm to the number of booster units required when the booster system is in isolated placement and contact placement method is given by $A_{BI} = (n+1)A_S$ and $A_{BC} = (2n+1)^2A_S$ respectively.

Keywords: *Ultrasound, ultrasound booster system, stand-alone unit, ultrasound booster unit, pest, weaver birds.*

1 INTRODUCTION

In a previous work, the concept of ultrasound pest control signal boosting was brought to the fore as a way of enhancing the effective coverage area of a stand-alone ultrasound pest control device (Ibrahim *et al.*, 2013a, Ibrahim *et al.*, 2014). An ultrasound pest control booster is a device that is used to improve the signal strength of an electronically generated ultrasound for the purpose of pest control **(**Ibrahim, 2015**)**. The booster system as designed and implemented consists of a stand-alone unit working in synergy with the booster unit. The stand-alone unit is made up of the stand-alone device, adjustable stand and the solar panel while the booster unit consists of the booster box, adjustable stand and the booster cord as depicted by Figure 1.

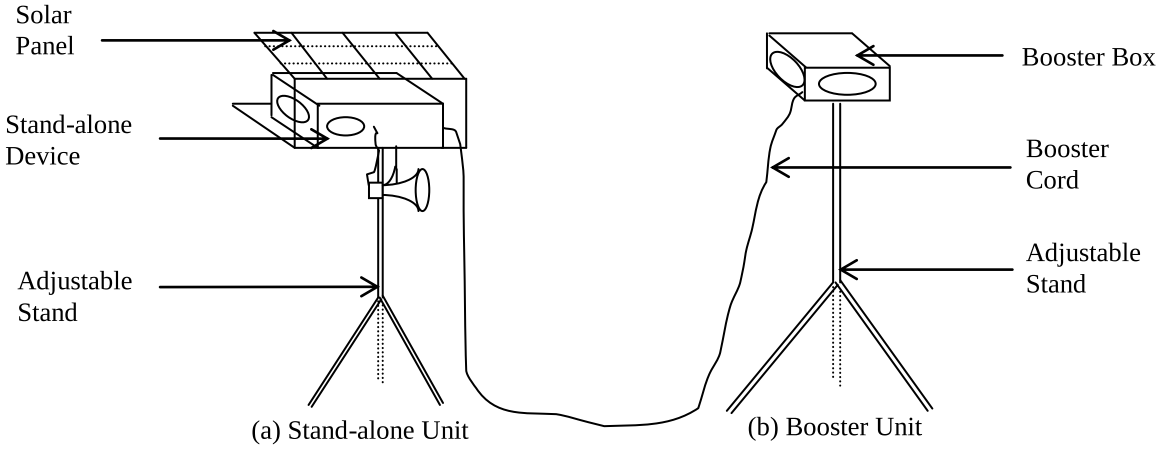

Figure 1: Schematics of the Ultrasound Booster System

The stand-alone device generated the power as well as ultrasound signal requirements and also transmits ultrasound signal in five directions (Ibrahim *et al.*, 2013b). While the booster unit receives electrical power and a portion of the raw ultrasound signal generated by the stands-alone device, processes it using sets of designed amplifiers and transmit same in five directions using ultrasonic transducers (Ibrahim *et al.*, 2016). Making the stand-alone unit the power house as well as the ultrasound signal generator of the booster system while the booster unit is the ultrasound signal booster of the system. The design concept was such that a maximum of four booster units were employed and they shall all take delivery of raw ultrasound from the stand-alone device through the booster cords to their respective booster locations where they are processed and transmitted in five directions. A study to evaluate the performance of the system shows that ultrasound from the units was sensed up to a distance of 35 meters, became faint on further probing and faded away beyond forty meters (Seriki, 2015). Therefore, 35 m was considered as the effective distance around each unit.

For the system to be operated, two placement methods can be employed: The isolated placement and the contact placement methods. In each of these placement methods, the need may arise in large farms for large scale booster systems. Accordingly, it is necessary to determine the number of booster units to be deployed and the capacity of the stand-alone device in relation to the size of the farm land.

2 METHODOLOGY

A hypothetical weaver bird infested farm was assumed and the ultrasound booster system deployed. Mathematical arguments were raised using each placement method as a yard stick for theory formulations.

2.1 PLACEMENT IN ISOLATION METHOD

In this placement method, each of the four booster units were positioned well away from the effective distances of each other. Only favorite feeding spots of the weaver birds were covered. Consider the case illustrated in Figure 2 in which an ultrasound pest control booster system was deployed to a weaver bird pest infested hypothetical farm and the placement in isolation method of boosting operated to deter weaver birds.

The ultrasonic pest control booster system is made up of the stand-alone units S, and booster units B1, B2, B3 and B4 deployed in location 1, 2, 3 and 4 respectively. The effective area is given by the area enclosed by a circle (Stewart, 2003)

$$A = \pi d_e^{\ 2} \qquad (1)$$

where A is the effective area of coverage of ultrasound signal, π is $22/7$ and d_e is the effective distance of 35 m. This methodology was used to carry out further analysis under this placement method

2.2 CONTACT PLACEMENT METHOD

In this placement method, the four booster units were kept close such that their effective distance of coverage overlaps with themselves and with that of the stand-alone unit. A definite orientation of 90° were each maintained by the booster units around the central stand-alone unit resulting to a 360° spread. Consider a case illustrated in Figure 3 in which an ultrasound pest control booster system is deployed to a farm and the placement by contact method was operated to deter weaver birds.

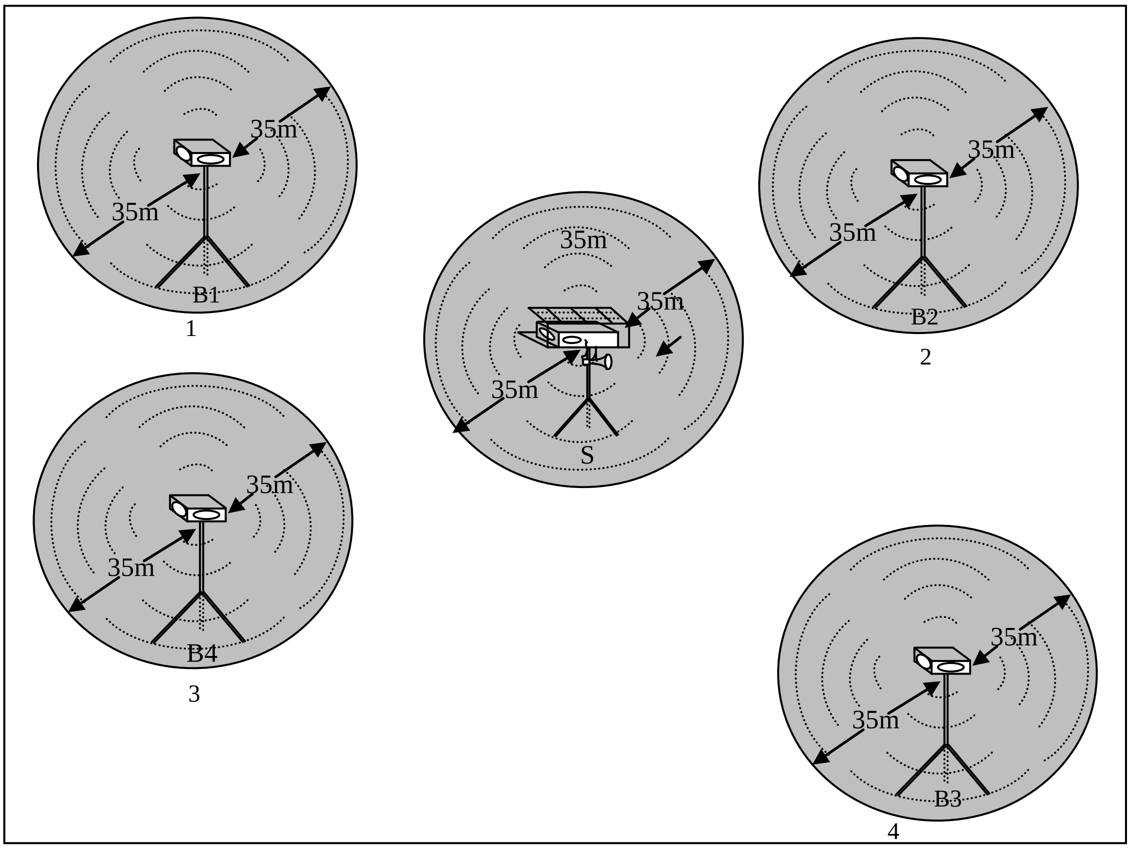

Figure 2: Isolated Placement Method of Ultrasound Boosting in a Hypothetical Farm

method was obtained from (1). Substituting into (1) yields,

$$A = \pi \text{ x } (35)^2 \qquad (2)$$

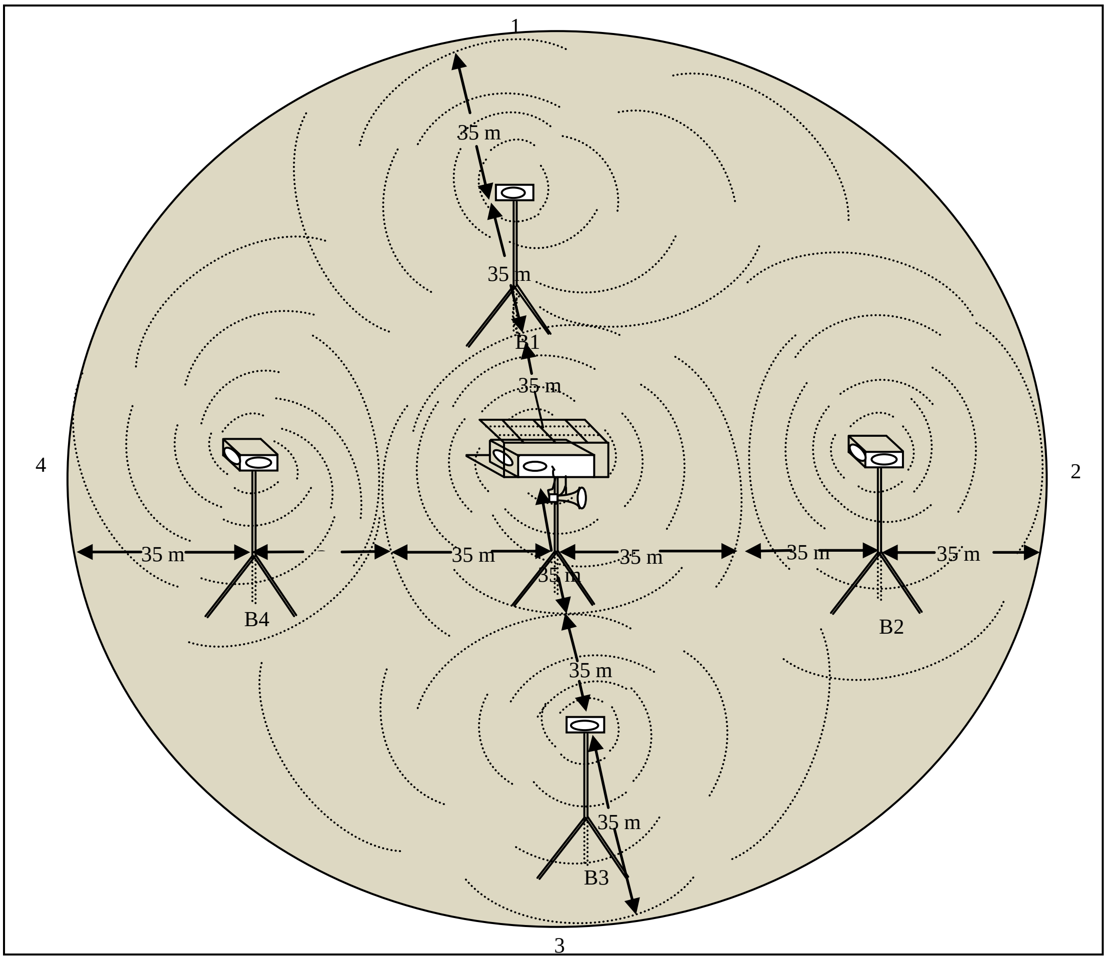

Figure 3: Contact Placement Method of Ultrasound Boosting in a Hypothetical Farm

Figure 3 shows the weaver birds infested hypothetical farm to which an ultrasonic pest control device made up of the stand-alone system S, and booster system B1, B2, B3 and B4 deployed in locations 1,2,3 and 4 respectively. Earlier observation and measurements of effective distance of 35 m will still apply around all the units. The effective area of coverage for each unit is again obtained from (1). This serve as the methodology upon which further analysis was carried out under this placement type.

3 RESULTS AND DISCUSSION

3.1 ANALYSIS FROM PLACEMENT IN ISOLATION

To achieve intended objectives under this placement type, the effective area of coverage under this placement

$$A = 3{,}850 \text{ m}^2 \qquad (3)$$

Therefore, an effective area of three thousand eight hundred and fifty square meters of effective weaver bird cover is guaranteed around each unit.

Let A_S, A_{B1}, A_{B2}, A_{B3} and A_{B4} be the effective area of coverage for the stand-alone unit, booster unit B1, booster unit B2, booster unit B3 and booster unit B4 respectively. It can easily be shown that,

$$A_S = A_{B1} = A_{B2} = A_{B3} = A_{B4} = 3850 \text{ m}^2 \qquad (4)$$

Therefore, the total effective area of coverage is the sum of individual effective areas of coverage. Summing sequentially from (3) and (4), we have,

$$A_S = 3850 \text{ m}^2 \quad (5)$$

$$A_S + A_{B1} = 7700 \text{ m}^2 \quad (6)$$

$$A_S + A_{B1} + A_{B2} = 11550 \text{ m}^2 \quad (7)$$

$$A_S + A_{B1} + A_{B2} + A_{B3} = 15400 \text{ m}^2 \quad (8)$$

$$A_S + A_{B1} + A_{B2} + A_{B3} + A_{B4} = 19250 \text{ m}^2 \quad (9)$$

Equation (5) to (9) provide the total effective area of coverage when only the stand-alone is in use, when one booster unit (B1) is attached, when two booster units (B1 and B2) were attached, when three booster units (B1, B2 and B3) were attached and when four boosters units (B1, B2, B3 and B4) were attached respectively. Equation (9) means that using this placement method of four booster units, a total effective area of coverage of nineteen thousand two hundred and fifty square meters of adequate weaver bird pest cover is expected.

Let the effective area of coverage of the ultrasound booster system operating in isolated placement method of booster mode be A_{BI} and the number of booster unit(s) attached to the stand-alone unit be represented by n. It follows that,

when $n = 0$ (No booster unit was attached to the stand-alone unit) and from (5),

$$A_{BI} = A_S = 3850 \text{ m}^2 \quad (10)$$

$$\Rightarrow A_S = 3850\,(0 + 1) = 3850 \text{ m}^2 \quad (11)$$

When $n = 1$ (when only one booster unit was attached) and from (6),

$$A_{BI} = A_S + A_{B1} = 7700 \text{ m}^2 \quad (12)$$

$$\Rightarrow A_{BI} = 3850\,(1 + 1) = 7700 \text{ m}^2 \quad (13)$$

When $n = 2$ (when two booster units were attached) and from (7),

$$A_{BI} = A_S + A_{B1} + A_{B2} = 11550 \text{ m}^2 \quad (14)$$

$$\Rightarrow A_{BI} = 3850\,(2 + 1) = 11550 \text{ m}^2 \quad (15)$$

When $n = 3$ (when three booster units were attached) and from (8),

$$A_{BI} = A_S + A_{B1} + A_{B2} + A_{B3} = 15400 \text{ m}^2 \quad (16)$$

$$\Rightarrow A_{BI} = 3850\,(3 + 1) = 15400 \text{ m}^2 \quad (17)$$

When $n = 4$ (when four booster units were attached) and from (9)

$$A_S + A_{B1} + A_{B2} + A_{B3} + A_{B4} = 19250 \text{ m}^2 \quad (18)$$

$$\Rightarrow A_{BI} = 3850\,(4 + 1) = 19250 \text{ m}^2 \quad (19)$$

Looking at the similarities between (11), (13), (15), (17) and (19), it can be generalized that, for an ultrasonic pest control device with a stand-alone area of coverage A_S ($A_S = 3850 \text{ m}^2$) and to which n number of booster units were attached, the total effective area of coverage for a booster system in isolated placement A_{BI} is given by,

$$A_{BI} = (n + 1)A_S \quad (20)$$

With (20), it is clear that the effective area of coverage for a booster system in isolated placement (A_{BI}) is a multiple $(n + 1)$ of the effective area of coverage for the stand-alone unit (A_S).

3.2 ANALYSIS OF CONTACT PLACEMENT METHOD

For this method, the arrangement in Figure 3 shows only a round of boost achieved by four booster units oriented 90° each around the stand-alone unit. The total effective area of coverage for this placement type is obtained using the common circle formed by the joint action of the four booster units and not the individual boxes as is the case with isolated placement. From Figure 3, it is clear that for this first round of boost, the effective distance (radius) from the central stand-alone unit is 105 m and the total area of coverage is obtained using (1) as follows,

$$A = \pi \text{ x } (105)^2 = 34{,}650 \text{ m}^2 \quad (21)$$

From (21), it is evident that this placement method has increased the area of coverage beyond twice of what is obtainable in isolated placement. Also of interest in contact placement method is the fact that, additional boost can be achieved by increasing the booster units in quadruples, forming another circle upon the existing one in concentric manner. If another set of four booster boxes are added to the one shown in Figure 3 in order to achieve another round of boost, the new effective distance (radius) becomes 175 m (70 m is added around the circle). And the new total effective area of coverage is obtained as follows,

$$A = \pi \text{ x } (175)^2 = 96{,}250 \text{ m}^2 \quad (22)$$

For larger farm requiring greater ultrasound coverage, a third round of boost is required. Thus, making the effective distance (radius) from the centre equal to 245 m and the new total effective area of coverage is the obtained as follows,

$$A = \pi \text{ x } (245)^2 = 188{,}650 \text{ m}^2 \quad (23)$$

For a fourth round of boost, an effective distance (radius) of 315 m is created and the total effective area of coverage is calculated as,

$$A = \pi \text{ x } (315)^2 = 311850 \text{ m}^2 \quad (24)$$

Equation (21) to (24) provide the effective area of coverage when only one round of boost (four booster units) was employed (from (21)), when two rounds of boost (eight booster units) was employed (from (22)), when three rounds of boost (twelve booster units) was employed (from (23)) and when four rounds of boost (sixteen booster units) was employed (from (24)).

Let the total area of coverage for a booster system in contact placement be represented by A_{BC} and the number of rounds of boost (number of a set of four boxes) employed be represented by n. It follows that,
when $n = 1$ (one round of boost), (21) has same result as,

$$A_{BC} = 3850(3)^2 = 34650 \text{ m}^2 \qquad (25)$$

When $n = 2$ (when two rounds of boost was employed) (22) has same solution as,

$$A_{BC} = 3850(5)^2 = 96250 \text{ m}^2 \qquad (26)$$

When $n = 3$ (when three rounds of boost was employed) (23) can also be expressed as,

$$A_{BC} = 3850(7)^2 = 188650 \text{ m}^2 \qquad (27)$$

When $n = 4$ (when four rounds of boost was employed) (24), can be rewritten as,

$$A_{BC} = 3850(9)^2 = 311850 \text{ m}^2 \qquad (28)$$

From equations (25) to (28), it can be generalized that, for an ultrasound pest control device with a stand-alone area of coverage A_S and employing n number of boost, the total area of coverage for a booster system in contact placement A_{BC} is given as,

$$A_{BC} = (2n + 1)^2 A_S \qquad (29)$$

With (29), it can be said that the effective area of coverage for a booster system in contact placement (A_{BC}) is also a multiple, that is $(2n + 1)^2$ of the effective area of coverage for the stand-alone unit (A_S).
The practical implication of (20) and (29) is that it provides information as to the exact number of booster units required for a given size of farm land, and by extension, the cost implication can easily be ascertained. These findings are true if certain conditions are kept constant. Such conditions include the use of same capacity amplifiers, same specification of ultrasonic transducers and sufficient power requirement in terms of solar panel capability and battery power. In this work, the first round of boost requires that the battery is doubled while one solar panel was maintained. However, a detailed power analysis is required to arrive at this conclusion.

4 CONCLUSION

From this analytical study, an expression has been obtained relating the effective area of coverage (farm size), stand-alone unit and the booster unit for the ultrasound pest control booster system under isolated placement method. Same was also obtained for the contact placement but this time, with reference to rounds of boost. Contact placement method of ultrasound booster system enhances wider reach compared to contact placement method. This is because of the geometrical effect that a round of boosting introduces compared to the individual arithmetic effect in the case of contact placement. However, isolated placement method is encouraged in special cases such as, mixed cropping (where the pest selects preferred crops), different planting times (early and late planting) leading to certain crops approaching the critical stage of vulnerability to pest attack at different times and selective harvesting. Use of contact placement in these cases will amount to waste as unnecessary areas will be saturated with ultrasound. By this study, progress has been made in the field of ultrasound pest control as more crops will be secured from pests activities when brought under the enhanced coverage offered by the ultrasound pest control booster system.

ACKNOWLEDGEMENTS

The contributions of Prof. O.D Oyedum and Prof. O.B Awojoyogbe of the Department of Physics, Federal University of Technology, Minna to this work is highly appreciated.

REFERENCES

Ibrahim, A.G., Oyedum, O.D., Awojoyogbe, O.B., Okeke, S.S.N. (2013). Electronic Pest Control Devices: Their Necessity, Controversies and Design Considerations. *The Int. J. Engr & Sci.*, 2(9) 26-30.

Ibrahim, A.G, Oyedun, O.D, Awojoyogbe, O.B, Okeke, S.N.N. (2013) Design, Construction and Characterisation of an Ultrasonic Device for the Control of Birds in Farms. A paper presented at the National Institute of Physics Conference held in March 2013 in Abuja, Nigeria.

Ibrahim, A.G., Oyedum, O.D., Awojoyogbe, O.B., Okeke, S.S.N. (2014) Developmental Features and Implementation Challenges of Electronic Pest Control Devices in Developing Countries. *Int. J. Sci. & Engr. Res*. 5(2) 411- 416.

Ibrahim, A.G. (2015). Development and Performance Evaluation of a Solar Powered Ultrasonic Device for the Control of Weaver Birds in Farms. A Ph.D Thesis, Department of Physics, Federal University of Technology, Minna, Nigeria.

Ibrahim, A.G., Oyedum, O.D., Awojoyogbe, O.B., Ezenwora, J.A and Aje, J.D. (2016). Pest and Environmental Specific Application of Ultrasound in Pest Control. *Advances in Multidisciplinary and Scientific Research*, 2(4) 189 – 200.

Seriki, D. (2015). Design and construction of an Ultrasound Detector. An undergraduate project in the Department of Physics, Federal University of Technology, Minna.

Stewart, J. (2003). Single variable calculus early transcendentals. (5th. ed.). Toronto ON: Brook/Cole. *ISBN 0-534-39330-6*. p. 3.