# Rice Plant Protection System Against Planthopper Pests By Utilizing Ultrasonic Waves Using Direct Digital Synthesizer

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Abstract-the largest pest Attacks against rice plant is pest. The most extermination of peasants is to use pesticides, but improper use of pesticides can thus cause a lot of losses. To overcome these physical methods used by utilizing ultrasonic wave with wave generator uses Direct Digital synthesizers. On the research of the testing was performed against the pest the pest by using frequency range audiosonik i.e. 1100 Hz – 5000 Hz and ultrasonic range i.e. 20 KHz to 60 KHz.

Index Terms- Direct Digital Synthesizer, DDS AD9850, Arduino, Ultrasonic

## 1. Introduction

One of the staple food of Indonesian people is rice. Rice is the result of processing from rice plants. To produce rice the farmers have various obstacles, one of the obstacles in the form of pest attack of wereng, because it can attack rice plants very quickly and in large quantities, so it can thwart the harvest. Planthopper consists of several types of green leafhopper (Nephotettix virescens), white back (Sogatella furcifera), loreng (zigzag), and chocolate (Nilaparvata lugens). Brown planthopper is the most difficult type to overcome because it is easy to adapt to the new environment. A female planthopper can produce eggs between 207 - 902 grains consisting of 76 to 142 groups [1].

The method often used by farmers to eradicate planthopper pests is a chemical method with the use of pesticides, but the use of excessive pesticides and inappropriate rules can lead to immunity to pests. In addition, the use of pesticides can also contaminate water and soil, damage the wetland ecosystem, and affect the content of substances in rice. Because it has a very adverse impact and less precise handling of aphis plant pests, it is necessary to create a system using environmentally friendly technology that is able to protect rice plants from pest attack of aphis. For that done the research by utilizing ultrasonic waves to repel pests planthopper with wave generator using Direct Digital Synthesizer.

There are 2 (two) studies that have been done related to the wave transmissions against pest aphis. In the first study was transmitted with a wave frequency of 0.3 KHz to 42 KHz to planthoppers, and resulted in the conclusion that the pests of aphids away from far enough wave propagation at a frequency of 1.2 KHz to 3 KHz [2]. In the second study, wave transmitting with frequency of 20 KHz to 62 KHz, and the conclusion that the frequency affecting the behavior of aphis pest is ≥40 KHz, and transmitting at the frequency of 40 KHz for 180 minutes causes the planthopper to die [3].

## 2. Fundamental Theory

### *2.1. Brown Planthopper*

Brown planthopper Nilaparvata lugens (Stal) including the Delphacidae family, the order Homoptera, has been discovered by Stal since 1854. Brown planthopper breeds sexually. 3-4 days pre-spell for brakiptera (winged dwarfs) and 3-8 days for makroptera (long-winged). Eggs are placed on the leaf midrib. But if the population is high, the eggs are placed on the tip of the leaf midrib and leaf bone. Eggs are placed in groups, one group of eggs consists of 3-21 eggs. A female can lay 100-500 eggs [4].

### *2.2. Ultrasonic Waves*

The ultrasonic wave is a wave with frequencies above 20 KHz [5]. Ultrasonic waves are included in mechanical waves that have the direction of vibration parallel to the direction of propagation (longitudinal), so ultrasonic waves need a medium when propagating. Ultrasonic waves can propagate through solid, liquid, and gaseous media, this is because ultrasonic waves represent energy propagation [6]. Ultrasonic waves have a certain intensity and degree of intensity when transmitted.

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

For I = Intensity (W/m2 )

P = Power transmit (W)
r = radius (m)

$$TI = 10log\frac{1}{10} \quad (2)$$

For TI = Level of intensity (dB)
I = Intensity (W/m2 )
Io = referency intensity (10-12 W/m2)

### *2.3. Direct Digital Synthesizer*

Direct Digital Synthesizer is a technique for generating analog signals using digital data processing to convert reference signals into precise fixed frequency signals via digital-to-analog conversion (DAC). Some examples of the application of DDS technology is on radar, jammer, and also the wave generator for commercial radio. The main components of DDS are phase accumulator, phase-to-amplitude converter and digital-to-analog converter (DAC) [7]

$$f_{out} = \frac{M\,x\,fc}{2^n} \quad (3)$$

For $f_{out}$ = output frequency DDS (MHz)
M = tunning word
fc = reference clock (MHz)
n = phase accumulator (bit)

## 3. System Planning

### *3.1. System Planning*

This system is divided into 3 (three) parts, namely mainboard and signal generator, amplifier and transmitter, and the power supply. The whole system circuit scheme can be seen in Figure 1.

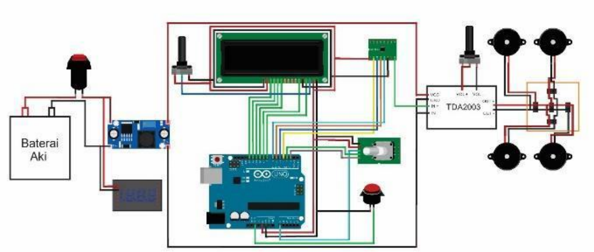



**Figure 1. Overall System Circuit Scheme**

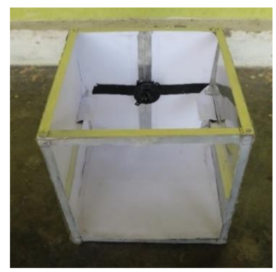
All finished parts are then combined into one. The combined system is inserted into a cube-shaped box of 25 cm x 25 cm x 25 cm in size. The final display of the system can be seen in Figure 2.

**Figure 2. System Final**

### *3.2. Test Box Planning*

The test box used for testing on pests of aphis is made with the shape of a cube measuring 26 cm x 26 cm x 26 cm with a frame made of aluminum.

On all sides of the test box is coated with a clear colored mica, and the top of the box is open. The purpose of transparent and open top mica is to allow sunlight and air to enter the test box to create the same conditions as the test environment in the fields. On some sides are also coated with white paper in order to facilitate the observation. Then on one side is paired a transducer transmitter connected to the system that has been made, as seen in Figure 3.



**Gambar 3. Kotak Uji**

### *3.3. System Flowchart*

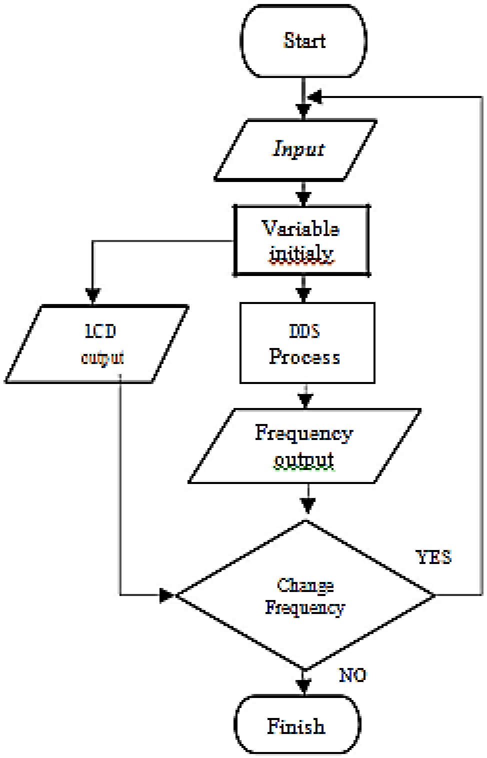


Figure 4. System Flowchart

## 4. Testing Method

*4.1. Software Testing*

This test is divided into 2 types namely, testing the program performed using the software Arduino IDE, and testing the display on the LCD 16x2.

*4.2. Hardware Testing*

The test consists of 4 types of DDS AD9850 output frequency accuracy, Vpp DDS AD9850 and amplifier, amplifier frequency accuracy, and system power consumption measurement.

*4.3. Planthopper Testing*

This test is divided into 2 types, namely, testing in the range of audiosonic and ultrasonic frequencies. Each frequency range has 2 testing stages: the frequency test that is responded by aphid pest and the transmission test 10 (ten) times for each frequency.

*4.4. Coverage Area Testing*

This test is done using a roll meter, protractor, and smartphone

## 5. Result And Discussion

5.1. Software Testing

Software testing is divided into 2 types namely, testing programs performed using Arduino IDE, and testing the display on 16x2 LCD. The created program has been successful and there is no error when compiling on Arduino IDE software. In Figure 5 there is the word "Done compiling", which indicates that the program created no errors.


**Figure 5. Compiling Program Result**

Testing the display on 16x2 LCD is done by turning on board Arduino Uno R3 which has been connected with LCD 16x2. In the program that has been created the first line shows the frequency being transmitted, while in the second line shows the jump value for each change made. Figure 6 shows "Freq: 20,000 Hz" on the first line and "Step: 10 Hz" on the second line. This shows that the display on LCD 16x2 is in accordance with the program that has been made.


**Figure 6. 16x2 LCD display**

*5.2. Hardware Testing*

Hardware testing is divided into 4 types: DDS AD9850 output frequency accuracy testing, DST AD9850 Vpp and amplifier value, amplifier output frequency accuracy test, and system power consumption measurement.

*5.3. Accuracy Frequency Output DDS Testing*

The test is done using frequency counter device. The test is divided into 2 (two) types that is in the audiosonic and ultrasonic frequency range. The first test was performed on an audiosonic range with frequencies ranging from 1100 Hz to 5000 Hz. Testing is done by changing the frequency of every 100 Hz increment. The results of the test are made in graphical form which can be seen in Figure 7. In the figure there are results of 3(three) times the frequency test. In the first test the average accuracy of 98.83%, the second test 98.65%, and the third test 98.78%. This graph also shows that although the frequency increases the accuracy remains stable. This can happen because the DDS AD9850 has a 5 bit digital control phase that can adjust the output phase increase every 11.25o, so that the phase is sent to the phase-toamplitude converter more and more. The more samples of the phase shipped, the more accurate the formation of the sine signal. In the DAC section also has a resolution of 10 bits, which can change the value of the digital amplitude into a voltage value of 210 or equivalent to 1024 samples of voltage values are processed along with 125 MHz sample frequency, so the conversion into analog sine signals more accurate, especially at low frequencies.

The second test is performed on an ultrasonic range with frequencies ranging from 20 KHz to 60 KHz with an increase of 2 KHz. The result of the test is also made into graph form which can be seen in Figure 8. In this frequency range the average accuracy yield on the first test is 83.62%, second test 83,81%, and third test 83,71%. The graph in Figure 8 shows that, the higher the frequency the decreasing the accuracy. The first to third test has a difference of accuracy value that is not much different, so based on the data from the three tests it can be seen that the graph shown in Figure 8 is the characteristic output frequency of DDS AD9850 at a frequency of 20 KHz to 60 KHz. Based on the data that has been obtained on the test frequency output DDS AD9850 from 1100 Hz to 5000 Hz and 20 KHz to 60 KHz can know the frequency output characteristics of DDS AD9850.

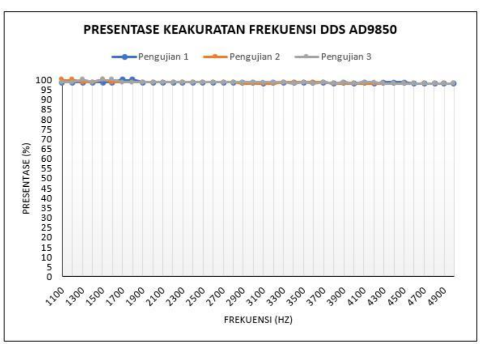



**Figure 7. DDS Frequency Accuracy of 1100 Hz-5000 Hz**

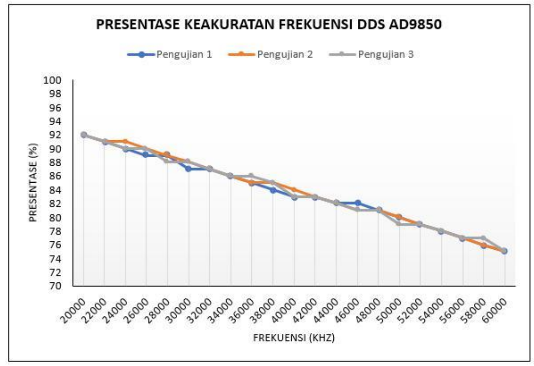



**Figure 8. DDS Frequency Accuracy of 20 KHz-60 KHz**

*5.4. Comparison of Vpp DDS and Amplifier Values*

Comparison of Vpp DDS AD9850 and amplifier aims to know the amplitude given by the amplifier, and to know the value of Vpp given by the amplifier at each frequency. Testing is done by changing the frequency generated by amplifier and DDS AD9850 starting from 1100 Hz up to 60 KHz with 1 KHz increment. At each frequency change is recorded how much Vpp value is read then made into the table. The result of the test can be seen in Figure 9. The average Vpp value generated by DDS AD9850 is 1.72 V and amplified by the amplifier so that the average Vpp value becomes 9.84 V, with the given gain being 15, 14 dB. In Figure 9 it is also seen that from the frequency of 1100 Hz to 60 KHz the value of Vpp in the amplifier tends to be stable, so that the gain is a fixed gain used in the frequency transmission test against the planthopper pests.

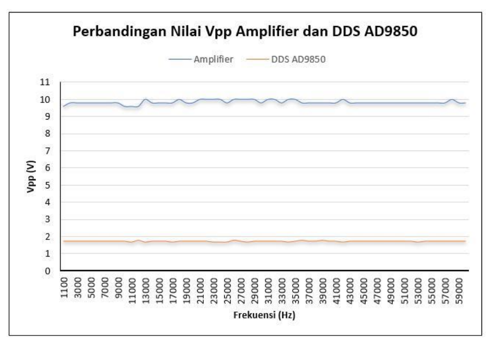



**Figure 9. Comparison of Vpp DDS and Amplifier Values**

The Vpp value can be stable because the sinus signal generated by the amplifier is cut off as shown in Figure 10. The signal may be truncated due to the amplitude distortion in the amplifier that occurs because the gain exceeds the capacity (over drive), causing the signal to clip at both peaks. In Figure

4.6 the maximum Vpp is 10 V which occurs only at some frequencies and the lowest Vpp is 9.6 V. The signal is mostly truncated at 9.8 V, which is caused because the source voltage applied to the amplifier is only 10 V, will not exceed that voltage. Voltage and current measurements are also done using a multimeter to determine the amplification power of the amplifier. The measured voltage and current output of the amplifier using a multimeter is 3.4 V and 2.45 A. Based on the calculation of the voltage and current measured using a multimeter can be known power amplification of the amplifier is equal to 8.33 W. On transducer transmitter used has an efficiency that can be calculated using the following formula:

$$
\begin{aligned}
\text{Efficiency} &= \left(10^{(\text{transducer sensitivity}-112/10)}\right) \times 100\% \\
&= \left(10^{(100-112)/10}\right) \times 100\% \\
&= 0{,}063 \times 100\% \\
&= 6{,}3\%
\end{aligned}
$$

for transducer sensitivity in dB, and 112 is a constant in dB. Based on the above calculation, the transducer efficiency used is 6.3%. The amplifier gain power of the amplifier is 8.33 W, so the output power of the transducer can be calculated:

$$
\begin{aligned}
P_{\text{transducer}} &= 6{,}3\% \times 8{,}33 \\
&= 0{,}52479 \text{ W}
\end{aligned}
$$

Based on the above calculation can be seen that the transducer transmit power used is 0.52479 W.

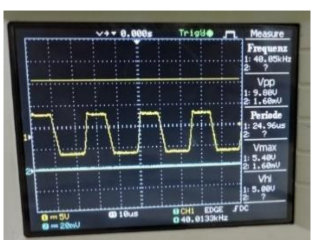



**Figure 10. Sine Waves Distortion**

*5.5. Amplifier Frequency Testing*

Testing the output frequency accuracy of the amplifier is done by connecting the output amplifier pin on the frequency counter device. This test aims to ensure the accuracy of the frequency generated by the amplifier. The test is performed by changing the frequency in the audiosonic range with the frequency of 1100 Hz to 5000 Hz with an increase of every 100 Hz and in the ultrasonic range with a frequency of 20 KHz to 60 KHz with an increase of every 2 KHz. At each audiosonic and ultrasonic range the test is 3 (three) times. The results of this test are made in graphical form which can be seen in Figures 11 and 12.

At the 1100 Hz to 5000 Hz frequency test the average value of the first test accuracy was 93.8%, the second test 93.78%, and the third test 77.63%. In the third test the average value of accuracy is lower than the other tests because the accuracy of the frequency of 1100 Hz and 1200 Hz is only 19% and 32%, and the accuracy of the frequency 1300 Hz to 1900 Hz is 0% as shown in Figure 11 The indication that causes a decrease in accuracy at 1100 Hz and 1200 Hz is that there is an increase in temperature that occurs in the TDA2003 IC amplifier due to overcapacity, this statement can be corroborated with a frequency decreasing accuracy in the third test not occurring in the first and second tests. Frequencies 1800 Hz and 1900 Hz on all three tests do not produce the same frequency as the source or have an accuracy of 0%. The biggest indication that can be taken is the presence of components that do not work well, so it can not produce a signal at that frequency. At other frequencies have an accuracy of between 98% and 100%, this indicates that at the frequency of 1100 Hz to 5000 Hz amplifier has a good performance.

Tests at frequencies from 20 KHz to 60 KHz resulted in average values in the first test of 83.62%, second test 83.71%, and third test 83.67%. In Figure 12 shows the characteristics of this amplifier, the more the frequency increases, the more accurate it goes down to the source. The decrease in accuracy follows the source frequency of the DDS AD9850 as shown in Figure 8. The highest accuracy is at 92% and the lowest accuracy is at 75%, indicating that at a frequency of 20 KHz to 60 KHz the amplifier also has a good performance.

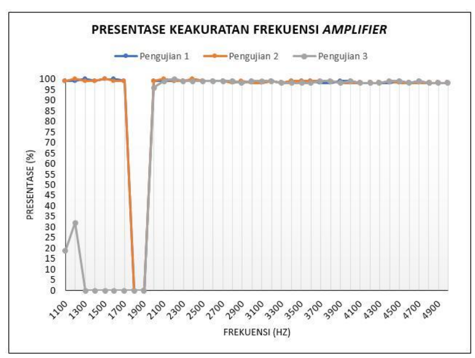



**Figure 11. Amplifier Frequency Accuracy of 1100 Hz- 5000 Hz**

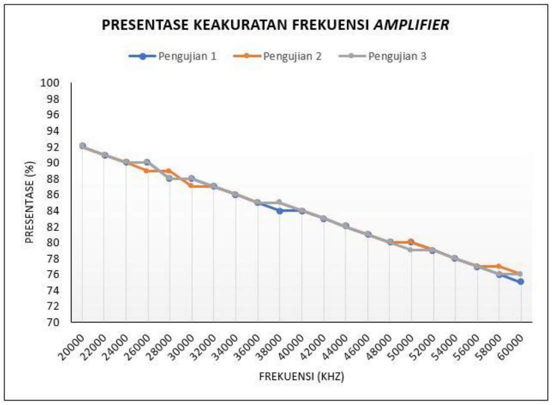



**Figure 12. Amplifier Frequency Accuracy of 20 KHz60 KHz**

*5.6. Planthopper Testing*

Testing of transmissions to pest aphis is done in the area of rice fields located in District Gatak, Sukoharjo regency, Central Java in June 2017. Tests conducted in the range of audiosonic frequency 1100 Hz to 5000 Hz, and ultrasonic 20 KHz to 60 KHz. In each frequency range, 2 (two) types of tests are performed. The first test is the frequency test that is responded by pest aphis and the second is test 10 (ten) times of transmission to frequency of first test result.

*5.7. Response Frequency Testing of Planthopper*

The frequency test that is responded by pest of wereng aims to find the frequencies that are responded and can make the planthopper feel uncomfortable. Testing is done by placing samples of pest of wereng that have been attached to the pieces of rice stalk into the test box with horizontal position and is in front of the wave transducer transducer. The pests of aphis wereng are left to stand still, then the wave is transmitted. The response from aphis plant pests is divided into 3 (three) categories. The first category that is silent, is when the wave transmissions done the planthoppers do not move and not affected. The second category that is moving, is when the wereng wave emissions do the movement even if only move the wings or twist the body but do not move. The third category is to move places, is when the transmitted aphis responds by moving from the original place even if only shifted. The test is performed in the range of audiosonic and ultrasonic frequencies by transmitting waves for 20 seconds for each frequency. The emitted frequency is changed according to the increase of each frequency range. In the audiosonic range starting from 1100 Hz to 5000 Hz and the frequency is changed with increments every 100 Hz, while in the ultrasonic range starting from 20 KHz to 60 KHz and the frequency is changed with an increase every 2 KHz. The test is performed 5 (five) times with the result of this test made in table form which can be seen in Appendix 13 and Appendix 14. In this test selected frequency responded by aphis plant at 3 (three) test or more than 5 (five) test done and marked with gray in the table. The selected response frequency is the "moving" and "moving" categories. Based on the data from the five tests, the selected frequency of selected aphid pest response is as shown in Table 1. The selected frequency contained in the table is re-tested with 10 (ten) times of transmission to locate and determine the frequency most responded by planthopper pests.

**Table 1 Testing Results of Frequency Response of Planthopper**

| No. | Respon Frequency | |
|---|---|---|
| | Audiosonic | Ultrasonic |
| 1. | 1100 Hz | 20 KHz |
| 2. | 1400 Hz | 22 KHz |
| 3. | 1600 Hz | 36 KHz |
| 4. | 1700 Hz | 50 KHz |
| 5 | 2200 Hz | - |
| 6. | 2500 Hz | - |
| 7. | 2600 Hz | - |
| 8. | 2700 Hz | - |
| 9. | 2900 Hz | - |
| 10. | 3000 Hz | - |
| 11. | 3100 Hz | - |
| 12. | 3500 Hz | - |
| 13. | 3800 Hz | - |
| 14. | 3900 Hz | - |
| 15. | 4000 Hz | - |
| 16. | 4100 Hz | - |

*5.8. 10 Times Transmit*

The test of 10 (ten) times of transmit aims to find and determine the frequency most responded by aphid apes. This test is performed by turning on and off the system as much as 10 (ten) times on the frequency of the results of the frequency response test. The results of this test can be seen in Figure 13 and Figure 14.

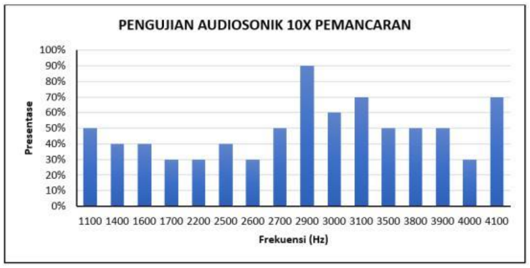



**Figure 13. Audiosonic Testing Result**

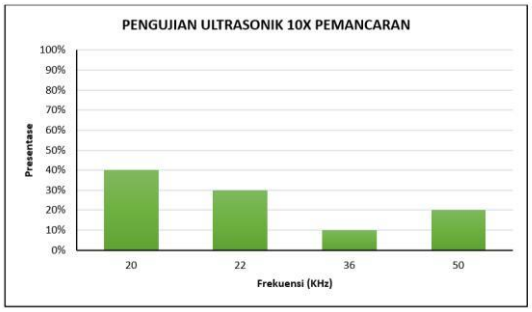



**Figure 14. Ultrasonic Testing Result**

In the audiosonic frequency range as shown in Figure 13, the most frequencies responded by aphid apes are at 2900 Hz with a percentage of 90%. This indicates that out of 10 (ten) times of transmission only 1 (one) times the pests are not responding. Based on the research that has been done by Tutik Nurhidayati along with Harris Pirngadi in 2009 resulted in the conclusion that the pest of aphis plant away from wave propagation far enough at the frequency of 1.2 KHz to 3 KHz. The frequency which has the highest percentage of the 10 (ten) times transmitted test results is 2900 Hz, so the result of this test has a match with the results of research that has been done by Tutik Nurhidayati along with Harris Pirngadi. Wereng pests can be affected by the wave emission caused by the wereng is exposed to the vibration generated by the wave emission so that it feels uncomfortable. The effect on the aphis is determined by the intensity of the emitted waves. The higher the intensity level of the wave the greater the vibration generated, so the influence on the wereng is also getting bigger. In this test the planthopper is placed with a distance of 2 cm from the transmitter transducer, so the wave intensity level generated is 140.19 dB or equal to the intensity of 104.45 W / m2.

In the ultrasonic frequency range as seen in Figure 14, the frequency most responded by aphis planthopper is at 20 KHz with a percentage of 40%. The percentage value indicates that from 10 (ten) tests, only 4 (four) tests were responded by aphid apes. In research conducted by Rian Agusdian, et al in 2012 resulted in the conclusion that the frequency that affects pest aphis is ≥40 KHz. Based on the conclusion of the study, the frequency of 10 (ten) times of transmission test results in the ultrasonic range is less suitable with the results of the study. This can happen because there are differences in several factors namely, the test method, the transducer used, the duration of the test, the test site and the test box used. In a study conducted by Rian Agusdian et al using 8 (eight) ultrasonic transducers with a diameter of 13 mm, while the transducer used during the test in this study was 1 (one) transducer fruit with a diameter of 50 mm. The duration of the test for each frequency emitted in the study was 60 minutes, whereas in this test 20 seconds on the responded frequency test. The location used for testing in this final task is to place the test box in the rice field area, thus creating the same conditions between outside the box with inside the test box. The test box used in this final project is coated on several sides with white paper and the other side is coated with clear mica with the top of the open box so there is not much reflection of the wave that occurs in the box, while in research conducted by Rian Agusdian, et al using a glass test box with the top covered by clear plastic so that many reflections of waves that occur in the test box that causes the influence of waves against the planthopper tested is larger.

Based on the data from this test and the references from the two studies above can be concluded on the test of pest aphis that, the most frequencies responded by the aphid apes are in the audiosonic range of 2900 Hz with a percentage of 90% and the intensity level of 140.19 dB whereas at the highest frequency ultrasonic range responded by aphid apes is at 20 KHz with a percentage of only 40%.

### *5.9. Coverage Area Result*

Test coverage area is done by using Xperia M2 smartphone that has installed Advanced Spectrum software. The test is done by turning on the system at 2900 Hz frequency on the open field, then the smartphone is placed in front of one of the transducers of the system. As long as the system is on, the smartphone moves away from the transducer until the received wave has the least intensity level. Testing is done at several angle of emission that is

90o , 45o , 135o , 0o , and 180o . At each angle measurements of maximum jet distances, with the results seen in Table 2.

**Table 2 Measurement of Transmit Results**

| Transducer | Distance of Radiance Every Angle (m) | | | | |
|---|---|---|---|---|---|
| | $90^o$ | $45^o$ | $135^o$ | $0^o$ | $180^o$ |
| Front Side | 30 | 21,4 | 31,8 | 15,5 | 20,7 |
| Right Side | 29 | 34,7 | 33,1 | 24,7 | 22,7 |
| Back Side | 40,5 | 43,2 | 38,4 | 35,3 | 27,6 |
| Left Side | 39,6 | 38,9 | 41,1 | 26,6 | 22,7 |

Based on the measurement data, an illustration of the coverage area of the wave beam generated by the system can be seen in Figure 15.

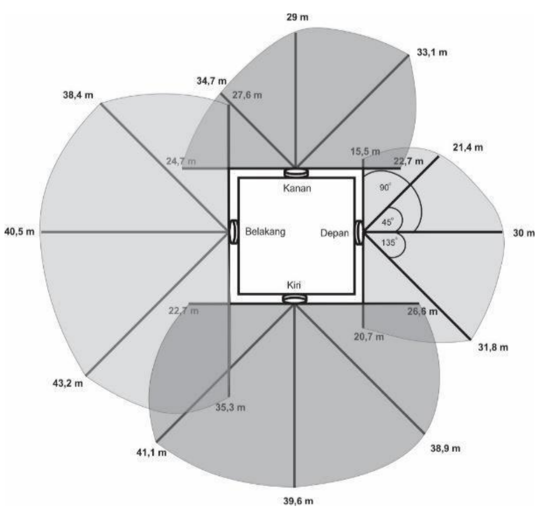



**Figure 15. Coverage Area**

## 6. Conclusion

*6.1. Conclusion*

Based on the results of testing and analysis that has been done can be concluded as follows:

1. A portable wave generator system has been developed using DDS AD9850 and Arduino Uno R3 which can generate sine wave with frequency from 1100 Hz to 60 KHz.
2. The average frequency accuracy produced by DDS AD9850 is 98.75% and the amplifier is 86.03%.
3. The total power consumed by the system is 3.1627 W, so with 12 V 5 AH battery power supply can turn on the system for 18.97 hours.
4. After exposure to ultrasonic waves the behavior of pest aphis is mostly silent, whereas after exposed to the audioconic wave the behavior of aphis planthopper is mostly to move away from the transducer transmitter.
5. Frequency that most influence the behavior of planthopper is 2900 Hz with an intensity of 104.45 W / m2 and an intensity level of 140.19 dB.
6. The output power of the transducer is 0.525 W with an efficiency of 6.3% resulting in a coverage area of 3191.17 m2 .

*6.2. Suggestion*

Based on test results and analysis can be given some suggestions as follows:

1. Testing on aphis plant pests should be continued with changes in distance between planthopper pest with transmitter transducer so it can be known the smallest intensity level and the furthest distance that can affect pest aphis plant, otherwise it needs to be transmitted wave until the pest of dead aphid, so it can be known how long the pest of aphis is dead to the most responded frequency.
2. At the power supply used should be added by using solar panels so it will be more practical when charging the battery

## Reference

[1] Bebet Nurbaeti, I. A. (2010). Hama Wereng Coklat (Nilaparvata lugens Stal) dan Pengendaliannya. Lembang: Balai Pengkajian Teknologi Pertanian Jawa Barat.

[2] Agusdian, R., Frida, A.R., Widayanti. (2012). Sistem Proteksi Tanaman Padi dari Serangan Hama Wereng Menggunakan Gelombang Ultrasonik dan Penunjuk Arah Angin. Yogyakarta: Universitas Islam Negeri Sunan Kalijaga.

[3] Tutik Nurhidayati, H. P. (2009). Rancang Bangun Alat Pengusir Hama Wereng Menggunakan Aplikasi Gelombang Ultrasonik. Diambil kembali dari Resits:http://resits.its.ac.id/index.php/journal/1-42178/Rancang_Bangun_Alat_Pengusir_Hama_Wereng_Menggunakan_Aplikasi_Gelombang_Ultrasonik (23 April 2017).

[4] Baehaki. (1993). Berbagai Hama Serangga Tanaman Padi. Bandung: Angkasa.

[5] Cheeke, J. D. (2002). Fundamentals And Applications Of Ultrasonic Waves. Florida: CRC Press LLC.

[6] Phila Delpin, B. A. (2008). Rancang Bangun Alat Elektronik Pengusir Hama Tikus Pada Rumah Tangga. Makassar: Universitas Hasanuddin.

[7] Devices, A. (1999). A Technical Tutorial on Digital Signal Synthesis. Analog Devices, IncDevices, A. (2009). Fundamentals of Direct Digital Synthesis (DDS). Analog Devices, Inc.