Development of Bio-control Technology for Subterranean Termites *Coptotermes curvignathus* Holmgren Using Electromagnetic Waves

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Abstract

This paper proposes a non-destructive technology to control subterranean termites *Coptotermes curvignathus* Holmgren infestations. In the experiment, the apparatus for termites control used electromagnetic waves at two frequencies: 300 Hz and 300 kHz. Termites were exposure to electromagnetic waves on direct methods with variation of exposure time 15, 30, 45 and 60 min respectively. The use of electromagnetic waves for termites control are very beneficial, they are odorless, noiseless, friendly to environment, and easy to apply. The result showed that electromagnetic waves had an effect to termites. The value of termites mortality was range between 25.45~82.27% and the average value of termites filter paper consumption was between 8.89~39.44%. Meanwhile on control treatment, termites mortality and termites filter paper consumption were respectively 14.05% and 79.88% in average. The highest frequency of electromagnetic waves and the longest irradiation time caused the highest average value of termites mortality. The magnitude field from apparatus was range between 0.069~0.1815 μT, which is safe to utilize around the human body. The best result was achieved on frequency 300 kHz and irradiation time 60 min. These results represent important information about the potential use of electromagnetic waves technology for termites control as an environmentally benign alternative in spite of the insecticides uses.

Key words: bio-control, *Coptotermes curvignathus,* electromagnetic waves, subterranean termites.

Introduction

Termites are known as a group of serious pests in the world. Subterranean termites *C. curvignathus* Holmgren are an important group of urban insects pest in tropical countries (Lee *et al*. 2007). The decrease of termites habitat causes the termites become wood feeder in the settlements. Termites are insects which are successfully to adapt in various condition of settlements and farms. Their ability to survive in settlements area is also influenced by their life style which is colonized in big numbers (Brune 2007). These termites often cause serious damage to wooden buildings and the damage costs reach to 100~300 billion rupiahs every year (Nandika *et. al*. 2003). The damage caused by subterranean termites has an important economic effect. Chemical treatments, including soil treatment, wood impregnation, or fumigation has been widely used over the last few decades. However, an increased public concern about unfavorable effects would not support the massive use of insecticides any more (Tsunoda 2005).

Therefore, a new solution for termites control with less or non-chemical is very urgent and needed, which is an attractive research subject for termite experts. The on-site termite treatment with physical methods is one of the most promising alternatives. One of the technologies which are potential to be developed is the use of bio-control technology using electromagnetic waves. In the present day, the use of electromagnetic waves has also been considered in efforts to eliminate termites. Electromagnetic waves or electromagnetic radiation is a combination of electric field and magnetic fields that oscillate and propagate through space and carry energy from one place to another (Ju *et al.* 2003). U.S. Patent No. 5,473,836 issued to Liu discloses a method for removing insects from hidden place by inducing an electromagnetic field to create physical vibrations. U.S Patent No 5,442,876 issued to Pederson discloses a method for controlling termites by heating the area where termites are located by means of electromagnetic energy. This technology is very beneficial, they are odorless, noiseless, friendly to environment, and easy to apply. Nevertheless, until now there is no detail research has been conducted on the response of about subterranean termites *C. curvignathus* against electromagnetic waves in Indonesia.

Based on this fact, it is necessary to develop the research about the use of electromagnetic waves as subterranean termites *C. curvignathus* controlling apparatus for buildings. The main objective of this study is to obtain fundamental scientific data for the development of a non-destructive termite control management methods using electromagnetic waves that could be applies to control subterranean termites *C. curvignathus* infestation in buildings.

Materials and Methods

The materials used in this research were as follows: subterranean termites *C. curvignathus* Holmgren, Whatman No 2 filter paper, distilled water, petridish, acrylic transparent box, analytic balance, potentiometer, power supply, oscilloscope, voltage regulator, iron core, thermocouple, electromagnetic field tester (EMF), function generator, digital multi-meter, spectrum analyzer, windings, crystal, standard electric isolator, coil, ribbon cable, circuit testing board, pulse generator circuit, and power supply. The methods were as follow*:*

Termites

C. curvignathus was taken from laboratory colonies maintained at the Laboratory in Forestry Faculty Tanjungpura University, Pontianak, Kalimantan Barat, Indonesia. Mature workers and soldier of *C. curvignathus* species was used for the test. The number of workers was 50 and soldiers was 5. These numbers was selected to obtain a nearly equal weight/volume of termites for electromagnetic waves irradiation.

Apparatus

The apparatus was designed on a small scale with electronic compound to generate electromagnetic waves at frequencies 300 Hz and 300 kHz (Figure 1). This design was based on some references from other researchers such as Liu (2007); Mah (2007); Pederson (2007); and Bergerioux (2007). Termites were exposed to electromagnetic waves in the acrylic box at the Control System Laboratory, Faculty of Engineering Tanjungpura University. The room temperature was maintained at 27ºC during the test.

Bioassay to Determine the Effects of Electromagnetic Waves

Termites *C. curvignathus* were put in a transparent acrylic box (100 mm in length, 50 mm in width and 50 mm in height). Electromagnetic waves were irradiated from the upside of the acrylic box. The distance between the bottom of horn antenna and termites was about 10 mm. The test termites were exposed to electromagnetic waves for 15, 30, 45 and 60 min respectively. Temperature in acrylic box before and after irradiation was measured by thermometer for analyzing the thermal difference. After irradiation of electromagnetic waves, termites were removed to petridish to evaluate the mortality and termites consumption. Petridish with diameter 70 mm contained filter paper (Whatmann No 2) which saturated with 0.4 ml distilled water. Termites were kept for 3 weeks in a termite culturing room. Termite mortality after three weeks exposure was calculated as follow:

$$\text{Termites Mortality (\%)} = \frac{N_2}{N_1} \times 100\%$$

where: N_1= Numb. of initial termites

N_2 = Numb. of live termites after 3 weeks exposure

Weight loss of filter paper after three weeks exposure was calculated as follow:

$$\text{Weight loss (\%)} = \frac{W_1 - W_2}{W_1} \times 100\%$$

where: W_1 = Initial weight of filter paper (gram)

W_2 = Weight of filter paper after three weeks (g)

Evaluated the Safeties of Electromagnetic Waves Apparatus

Evaluation was conducted using electromagnetic fields tester brand Hioki 3470-10 on the highest frequency (300 kHz). The measurement in this experiment carried out in three dimensions with axis x, y and z in which the electromagnetic waves propagation data on each axis is performed at various distance of 1 cm. Ten replications were done for each position.

Results and Discussion

Electrical Characteristic of Electromagnetic Waves Apparatus

The electromagnetic waves apparatus was analyzed with measurement and theoretical computation to know the power, wavelength and power density of each apparatus. The measurement considered three main parameters, i.e. frequency, current, and amplitude. From these parameters, the power, wavelength, and power density could be computed theoretically. Figure 2 shows the used electric power of electromagnetic waves apparatus at frequency 300 Hz which is proportional to the amplitude. It means once the highest amplitude (±15 Vpp) is set then it also uses the highest power in this frequency range, i.e. ± 42.5 mW. Different values can be seen for power density value. The power density value was depended upon the wavelength and the power. The wavelength value is related to the used frequency. The more frequency value is set, the shorter wavelength is get. From Figure 2, power density in frequency 300 Hz with Power 43.05 mW and Amplitude 15 Vpp is 34.44×10^{-9} mW/cm^2 while in frequency 30 Hz its value is 0.342×10^{-9} mW/cm^2.

For the frequency 300 kHz, the apparatus is limited by the availability of capacitance component (main component to produce particular frequency) in the Indonesian market hence the range that can be produced is between about 80 kHz to 500 kHz. However, because of the limitation of oscilloscope specification, the current measurement is difficult to read the current once the apparatus was applied for frequency above 231 kHz since the current was very low. Therefore, the described data in Figure 3 for electrical apparatus characteristic are in the frequency range from 81 kHz until 231 kHz. For the lowest frequency in this range, the power and power density are highest once the amplitude is also the highest.

Those values will decrease if the amplitude decreases as well. In the frequency above 200 kHz, the amplitude becomes lower than in the lower frequency. It made the value of power and power density drastically decreased. The slightly decrease of power can also be seen once frequency of electromagnetic waves apparatus higher than 90 kHz, while the similar case appears also on power density once the frequency higher than 100 kHz. These cases happen since the current decrease in the higher frequency.

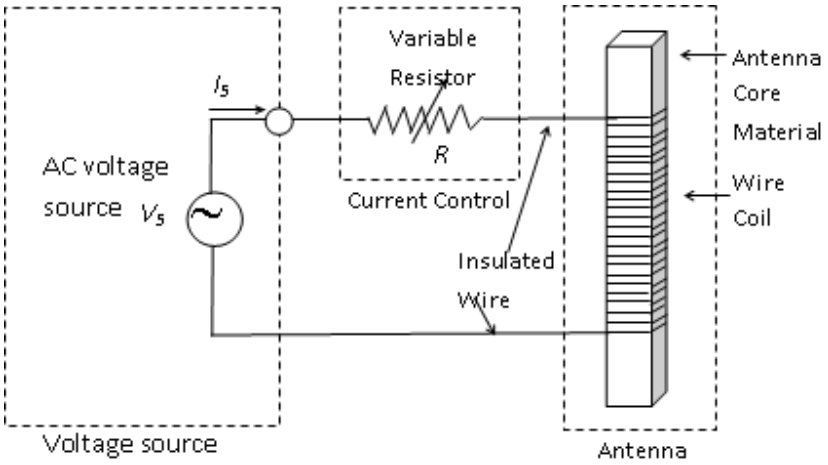

Figure 1. Electromagnetic waves apparatus.

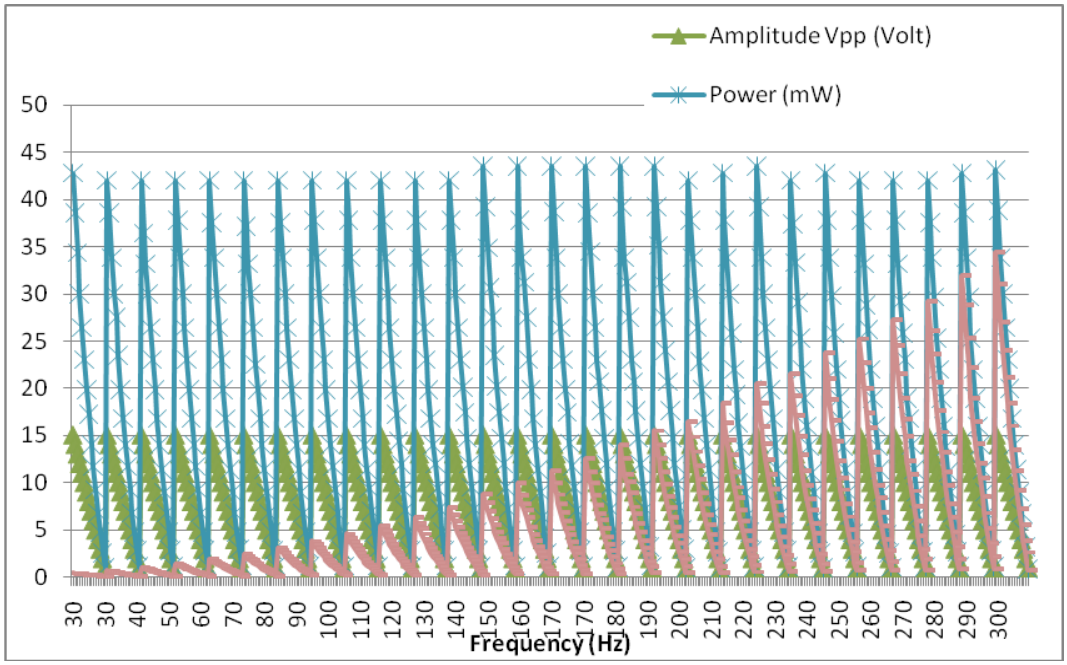

Figure 2. The value of amplitude, power, and power density regarding the frequency 300 Hz.

Thermal Difference

In the irradiation test, thermal difference based on temperature of acrylic box as container for termites, measured before and after irradiation. This measurement was evaluated to know whether the electromagnetic waves apparatus taking effect on termites based only from magnetic field or both from magnetic field and the increasing of temperature. The result showed that no significant different on temperature before and after irradiation. The temperature varies from 27ºC to 27.3ºC until 27.5ºC. The obtained results suggested that electromagnetic waves used in this study could not raise the temperature high enough to kill termites and the effect during irradiation was only from magnetic field. The electromagnetic waves had different mechanism with microwave and did not increase the temperature during the exposure. Fuji (2001) reported that surface temperature of termites body increased during the exposure of microwave inside the wood. The similar result was achieved on Kaestner and Baath (2005) research. They reported that the temperature inside the wood increased during microwave exposure. Table 1 shows the differences temperature in the acrylic box between before and after irradiation.

Nakai *et al.* (2009a) reported that the body temperatures of *C. formosanus* increased logarithmically with exposure time (0~60 min) and they varied within 5.5ºC without any death of termites. His research used microwave irradiation at two frequencies, 2.45 GHz and 5.8

GHz. Nakai also reported that this could be attributed to the fact that termites do not efficiently absorb microwaves. However, mode of action of electromagnetic waves irradiation was quite difference to microwave irradiation. Electromagnetic waves are a combination of electric field and magnetic fields to generate electromagnetic fields that oscillate and propagate through space and carry energy from one place to another (Supriyanto 2007). Electromagnetic waves do not need a medium for its propagation, not because the medium does not exist, but because the scientists have not found a form of electromagnetic waves intermediary medium till now. The behavior of electromagnetic radiation depends on the wavelength. If the frequency is higher, then the wavelength is shorter. Thide Bo (2008) said that the lower frequencies of electromagnetic fields are related to a greater wavelength.

Mortality of Termites after Irradiation and Filter Paper Consumption.

The average value of termites mortality was range between 25.45~82.27% and the average value of termites filter paper consumption was range between 8.89~39.44%. Meanwhile on control treatment, the average value of termites mortality was 14.05% and the average value of termites filter paper consumption was 79.88%. The results with the control treatment was significantly different with the no-control treatment, hence it was concluded that electromagnetic waves have an effect on the termites. The average of termites mortality on control treatment was less than 15%, which indicated that the environment and room for culture termites during the experiment was suitable and comfort for termites. Results of the research are shown in Figure 4.

The highest average value of termites mortality was at frequency 300 kHz with 60 min irradiation time (82.27%), and the lowest average value of termites mortality was at frequency 300 Hz with 15 min irradiation time (25.45%). In vice versa, the highest average of termites filter paper consumption was at frequency 300 Hz with 15 min irradiation time (39.44%) and the lowest average of termites filter paper consumption was achieved on termites after irradiation at frequency 300 kHz with 60 min irradiation time (8.89%). The frequencies of electromagnetic waves have a linier effect to the value of termites mortality. The highest frequencies of electromagnetic waves caused the highest average value of termites mortality. The average value of termites mortality at frequency 300 Hz was 29.32% and at frequency 300 kHz was 66.02%. On the other hand, the higher frequency of electromagnetic waves the lower average value of filter paper consumption. The average value of termites filter paper consumption after irradiation with electromagnetic waves at frequency 300 Hz was 34.72% and at frequency 300 kHz was 13.61%.

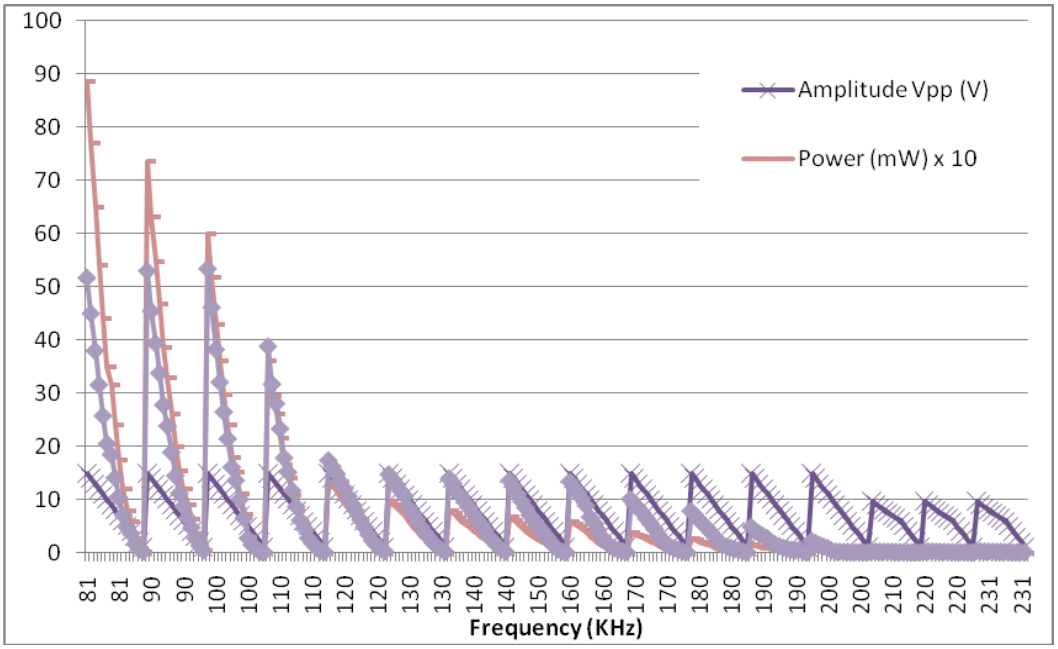

Figure 3. The value of amplitude, power, and power density regarding the frequency 300 kHz.

Table 1. Variation of surface temperature (ºC) of termites *Coptotermes curvignathus* on acrylic box (mean ± SE) between before and after electromagnetic waves irradiation at frequency 300 Hz and 300 kHz for 0~60 min.

Frequency	Temperature	Exposure time (min)				
	(ºC)	0	15	30	45	60
300 Hz	Before	27.0 ± 1.2	27.0 ± 1.3	27.0 ± 1.2	27.0 ± 1.3	27.0 ± 1.2
	After	27.2 ± 1.1	27.3 ± 1.6	27.3 ± 1.3	27.5 ± 1.2	27.5 ± 1.3
300 KHz	Before	27.0 ± 1.3	27.0 ± 1.1	27.0 ± 1.2	27.0 ± 1.3	27.0 ± 1.2
	After	27.3 ± 0.8	27.3 ± 1.1	27.4 ± 1.3	27.5 ± 1.1	27.5 ± 0.9

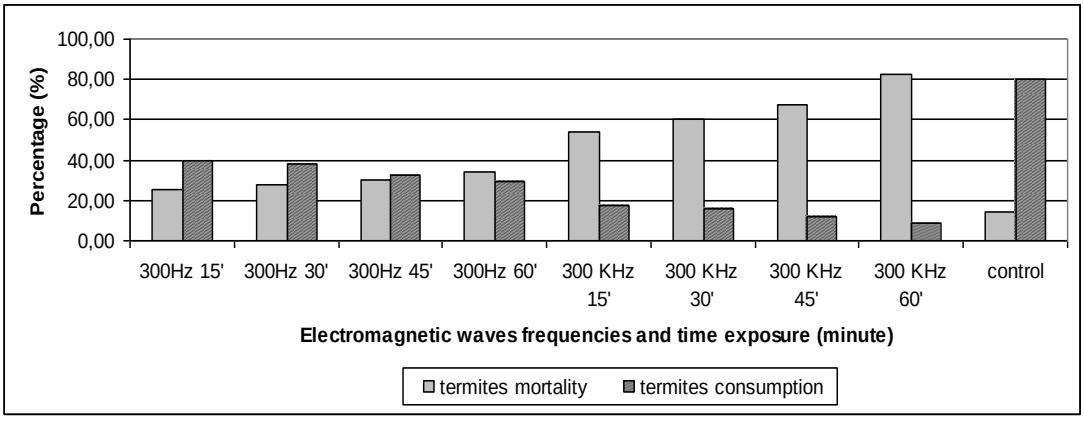

Figure 4. Termites mortality and termites consumption after irradiation with electromagnetic waves with various frequencies and exposure time.

The time exposure of electromagnetic waves to termites has a linier effect to the value of termites mortality. The longest time exposure of electromagnetic waves caused the highest average value of termites mortality. The average value of termites mortality after irradiation with electromagnetic waves for 15 min was 38.48%, with 30 min was 42.27%,with 45 min was 46.52% and with 60 min 53.64%. In vice versa, on the average value of termites filter paper consumption, the longest time exposure of electromagnetic waves caused the lowest average of termites filter paper consumption. The average value of termites filter paper consumption after irradiation with electromagnetic waves apparatus for 15 min was 28.33%, with 30 min was 26.30%, with 45 min was 22.59% and with 60 min 19.63%.

During the exposure of electromagnetic waves, termites was tended to move from the antenna, loss of stability, lying and on 45 and 60 min of exposure, we found some workers of termites death. This could be indicated that electromagnetic fields were affecting the physiology of termites and repellent to termites. Kevin *et al* (2007) reported that termites movement was positive directed by radio waves, and electromagnetic waves could be used as control apparatus for termites.

The filter paper consumption has a linier tendency that the highest frequency of electromagnetic waves caused the lowest filter paper consumption. This indicated that after electromagnetic waves irradiation, termites was weak and could not feed the filter paper as usual. Exposure time of electromagnetic waves also has a linier tendency that the longest irradiation time caused the lowest filter paper consumption. Similar result was achieved on Nakai *et al* (2009b) research, which applied microwave energy with two frequencies, i.e. 2.45 GHz and 5.8 GHz to control subterranean termites *Coptotermes formosanus* Shiraki and drywood termites *Incisitermes minor*. Nakai *et al* (2009b) reported that the mortality of termites was higher at the higher microwave energy and longest irradiation time. The highest termites mortality value, both on *Coptotermes formosanus* and *Incisitermes minor* termites was achieved when termites were exposed to microwave energy on frequency 5.8 GHz than 2.45 GHz. Moreover the average value of termites mortality was higher on irradiation time 60 min than 30 min, and 15 min respectively.

Safeties of Electromagnetic Waves Apparatus

The electromagnetic waves apparatus that we designed has been evaluated for their effects on human beings. At frequency 300 kHz and amplitude 15 Vpp (peak-to-peak), the average values of magnetic field near the apparatus in x-axis and y-axis were the same (i.e. 0.1815 µT), while in z-axis was 0.1037 µT. The complete results are shown in Figure 5. These magnetic field values were then compared to the standard of representative power frequency magnetic fields from common household appliances (Kato 2006). For instance, hair dryers have a magnetic field from 0.1 to 70.0 µT; coffee makers from 0.4 to 1 µT; mixers from 3.0 to 60 µT; washing machines from 0.4 to 10 µT; and fax machines 0.4 to 0.9 µT. Those applications has been considered to have safe magnetic fields related to

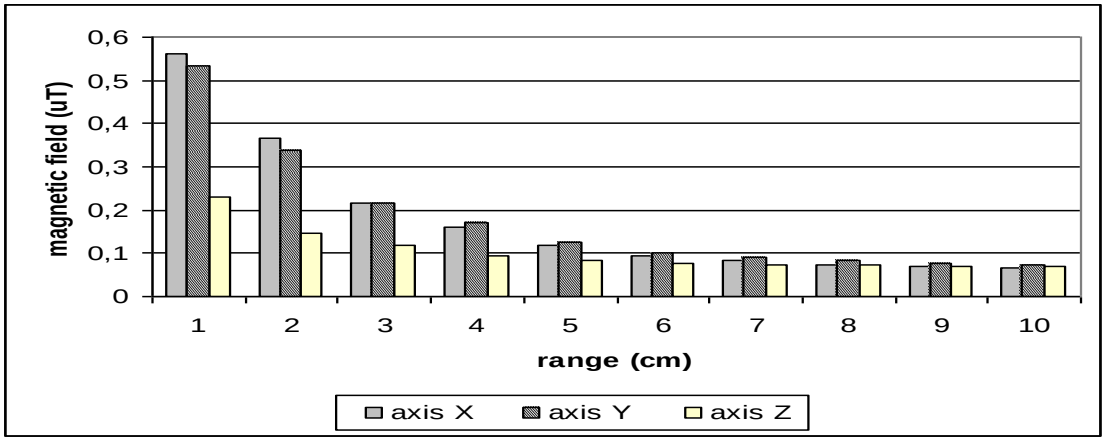

Figure 5. Magnetic field from electromagnetic apparatus at frequency 300 kHz.

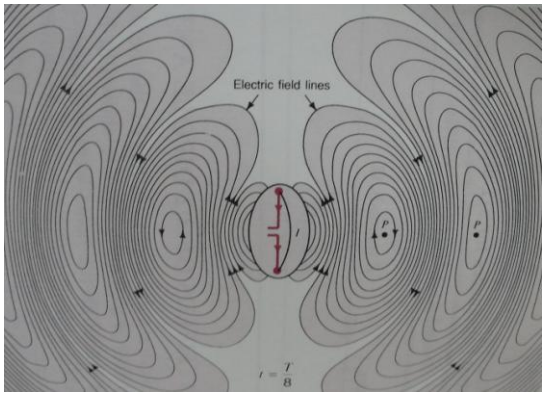

Figure 6. Electric field configuration from wire in the coil (Kraus 2006).

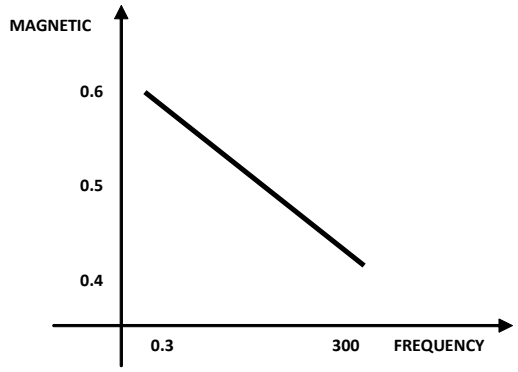

Figure 7. The relation between magnetic field and frequency of electromagnetic waves apparatus.

human beings. We prove the designed electromagnetic waves apparatus in this research is also safe to use and does not have an influence on human beings since the magnetic fields are under those that were measured on the household electronic appliances.

Kato (2006) said the electromagnetic fields have relation with bio-electromagnetic. This field is a relatively new area of science that deals with the interaction of electromagnetic energy with biological systems. Kraus (2006) reported that electromagnetic waves result in magnetic field which forms closed circular loops around the wire. The electrical field configuration that produces magnetic field to control termites is shown in Figure 6.

In relation to the safety analysis of the apparatus, Figure 7 shows the relationship between the magnitude field and the frequency of electromagnetic waves. The highest frequency will produce the lowest magnetic field. From the measurement, the magnetic values produced by the developed apparatus were safe for human and application in buildings.

Conclusions

The use of termites control based on electromagnetic waves is very beneficial since it is odorless, noiseless, friendly to environment, easy to apply, and also cheap. The average value of termites mortality was range between 25.45~82.27% and the average value of termites filter paper consumption was range between 8.89~39.44%. Meanwhile on control treatment, the average value of termites mortality was 14.05% and the average value of termites filter paper consumption was 79.88%. The present results indicated that high absorption of electromagnetic waves irradiation can cause high mortality of termites. At exposure time 15 min, electromagnetic waves were not enough to absorb, whereas it resulted in complete mortality. Meanwhile at exposure time 60 min, electromagnetic waves were strong enough and affected the mortality of some termites during the exposure. The magnitude field from the developed apparatus was range between 0.1037~0.1815 μT, which means the apparatus is safe to be applied around the human body. The best result was achieved on electromagnetic waves apparatus at frequency 300 KHz and irradiation time 60 min. Further studies are needed to understand the relationship between electromagnetic waves mechanism on termites mortality and other features of electromagnetic waves irradiation.

Acknowledgements

The authors are grateful to Ministry of National Education, Directorate of Research and Development Community, Directorate General of Higher Education (DP2M DIKTI) for funding this research in Program Collaborative Research and International Publication Grant No 437/SP2H/PP/DP2M/VI/2010.

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