The Capacity of Banana Trees to Absorb Radio Frequency Waves

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***Abstract*—This paper presents the case study about the capability of banana tree to absorb radio frequency (RF) waves. The results were classified into three particular types of medium propagations such as fruits, leaves and trunks. This research was conducted using spectrum analyzer and a simple set-up on the Yagi-Uda antenna. The distances and height of banana tree from the transmitting antenna are taking into consideration in this data collection techniques. Comprehensive results were performed to find the relationship between the *line-of-sight (LOS)*, antenna (Yagi-Uda), power radiation and also the distance between the transmitter and receiver that will affect the signal strength reception. From the results obtained, it shows that fruits have more capability to absorb RF waves followed by the leaves and trunk.**

Keywords-Radio frequency (RF) waves, banana tree, antenna(Yagi-Uda), spectrum analyzer, line-of-sight (LOS).

I. INTRODUCTION

The compatibility of the electronic devices with various electromagnetic environments becomes an important issue in recent year. Electromagnetic energy offers many new and exciting possibilities in agriculture. It is used for example, to change the vegetables taste by reducing acidity. The electromagnetic devices include antenna, transmission lines, optical fibers, radars and lasers. Free space propagation of electromagnetic waves is often called radio-frequency (RF) propagation or simply called *radio propagation* [1, 2].

According to B.-K.Chung and H.-T Chuah [3], a proper model of RF absorber must be developed based on information such as absorber reflectivity, in magnitude and phase, for various angle incidences and for parallel and perpendicular polarizations. For Abdullah H.*et al.* [4] was conducted studies about the designation of portable mini anechoic chamber using low cost composite absorber. Experiments were performed in three conditions. First, to study the comparison of power received of different plywood thickness. Second, comparison of absorption of cardboard coated with carbon material and without coated. Third, performance of power received in mini chamber design. Theoretically, any structure can radiate electromagnetic waves but not all structure can serve as efficient radiation mechanism. Because no such study had ever been carried outs at the plants such the banana tree, the extensive measurements of RF waves were conducted in Malaysian Agriculture Research and Development and Institute (MARDI) to develop suggested empirical formula models to deal with the RF waves absorption at the banana plants and explained the associated phenomenon that cause the reduction of the RF signal. Since, one of the objectives of this project to study the potential research of banana tree as a RF absorption, therefore the experiments were performed by simple set-up of the equipments which consists the antenna (Yagi-Uda) and the spectrum analyzer which can be functioned as a measurement device to receive power (dBm).

II. RELATED WORK

From the previous literature research, the study about the RF waves on the plants has been implemented by Hashim N.M. [5]. The papaya tree is use as a medium to study the RF wave's absorption. This research was constructed by a simple set-up consisting of the Yagi-Uda (VHF signal) antenna. The RF signal has examined two conditions which is signal from the free space (existing signal) and also the signal generated by the RF generator. The results from the RF wave's absorption were collected in three types of medium propagation (fruits, leave and trunk). From the three parts of the propagations, leave do not have much capability to absorb the RF signal compared with the trunk and the fruits even though the signal was transmitted from the free space (existing signal) or by the RF generator. In general, it can be seen that the fruits absorb the most, followed by the trunk and the leaves.

III. TEST METHODOLOGY

This experimental work was planned as follows. First, the both transmitting and receiving antenna were setting up within 1 to 3.5 meter. Secondly, the measurement was taken directly between transmitter and receiver without the sample or based on the concept of *line-of-sight (LOS)*.Thirdly, measurement for one tree. Finally, measurement was taken for more than one tree according to the decided distance. Data was collected on the three particular types of propagation medium such as fruit, leave and trunk. All the measurements were performed using the spectrum analyzer and Very High Frequency (VHF) antenna.

- The measurements of the signals of *line-of-sight (LOS)* with several distances using the spectrum analyzer and Very High Frequency (VHF) antenna.
- *The measurements of the signals on the several of* medium propagations (fruits, leave and trunk) when the banana tree was located between the transmitter and receiver antenna.

The plantation is a rectangular shape, which has a 150 feet's in length along the north and south area and 42 feet's in length along east and west area. Average height of the banana trees was estimated about 5 meters height. Majority of the trees in with admix of little undergrowth of bushes. The entire outside signal that may interfere in the spectrum analyzer, are assumed to be neglected due to the consideration about the signal that had been transmitted by the transmitter antenna. The carrier frequency suitable on that area is 200MHz. The antenna height was estimated about 3 meters height.

IV. RESULTS AND DISCUSSIONS

The study about RF wave's absorption can be divided into two types of measurement method. There are the measurements on the *line-of-sight (LOS)* and also the measurements during the banana trees sample located between the transmitter and receiver antenna. The differences between these two methods will result the reading on the RF wave's absorption.

A. Measurements of the Yagi-Uda Elements (by Practical)

The Table I is the measurements on the antenna that had been used at the site. The measurements were at various types such as driven elements, reflector, and directors. To prove that the antenna is suitable to use at the site, there are some proven measurements to calculate the value of the driven elements is similar or not to the measurements that had been taken. The measurements were taken at the driven elements, director, reflector and boom/holder. All the measurements had been recorded in the Table I. The measurements were collected in two types of International Standard (SI) unit which is in meters (m) and centimeters (cm).

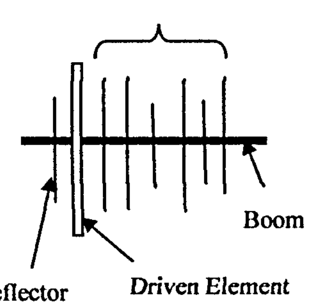

Figure 1: The Yagi-Uda Elements

Table I: Measurements for Yagi-Uda elements

Yagi-Uda Elements	Length (cm)	Length (m)
Director	57.5	0.575
Driven Element	73.5	0.735
Reflector	81.5	0.815
Boom / Holder	118.0	1.180

B. Calculation of the Yagi-Uda antenna (by Theoretical)

Besides taking the measurements on the Yagi antenna, the value of driven element will be calculated using the formula below when the value of wavelength, λ has determined. This is important to prove that the antenna that had been chosen is the correct antenna. The Yagi-Uda antenna is used to conduct this research. It is also called half-wave dipole antenna. The expressions below prove that the antenna is the half-wave dipole antenna:

$$\lambda = \frac{c}{f} \qquad (1)$$

where

$c - speed\ of\ light\ in\ vacuum,\ 2.99792458 \times 10^8 m/s$

$\lambda - wavelength\ (m)$

$f - frequency\ (Hz)$

Since the value of frequency chosen at site is 200MHz and it is suitable on that area, hence the wavelength, λ will determine from equation (1):

$$\lambda = \frac{3 \times 10^8}{200M}$$

$$= 1.5m$$

The value of Yagi-Uda elements can be calculated as mentioned below:

$$Driven\ element = 0.473 \times \lambda \qquad (2)$$

$$= 0.473 \times 1.5$$

$$= 0.7095m$$

According to G.R. Jessop [6], the value of 0.473m is the value of resonant length which is suitable at Yagi-Uda antenna. Hence, the equation (2) is use to find the length of driven element. From Table I, the measurement on the driven element is equal to the 0.735m. Therefore, it is proved that the measurement on this antenna is similar to the calculation of driven element by using the formula.

C. Measurements on the frequency at the laboratory.

This is the way to predict suitable frequencies of the VHF range before the suitable frequency are choosing at the site. This is important to ensure that frequency at the laboratory is quite similar to the frequency at site. The range of VHF varies from 30MHz-300MHz. The value of frequency chosen must approach to the 0dBm value. This will indicate that the strongest signal strength received by the receiver. But, the chosen frequency is depends on the frequency which is suitable to the environment on that area. It is means that the different area will gives the different frequency value due to the environment's factor. So, the prediction value of the frequency at the laboratory is important to estimate the suitable value choose at the site.

Table II: The frequencies measurements

Frequency (MHz)	Frequency (dBm)	Frequency (mV)
190	-31.16	5.898
200	-33.05	4.546
210	-31.61	5.521
220	-33.52	4.769
230	-33.81	4.722
240	-31.48	5.562
250	-43.10	1.654
260	-61.69	0.198
270	-52.10	0.523
280	-50.37	0.754

Since the value of the wavelength, λ was determined path loss will be calculated using the formula below:

$$Lp = \left(\frac{4\pi d}{\lambda}\right)^2 \quad (3)$$

This formula will extend to become as mentioned below:

$$Lp = \left(\frac{4\pi df}{\lambda}\right)^2 \quad (4)$$

In dB, the calculation will be as mentioned below:

$$Lp = 10\ log\left(\frac{4\pi df}{c}\right)^2$$

$$Lp = 20\ log_{10}\ d_{(km)} + 20log_{10} f_{(MHz)} + 32.45 \quad (5)$$

Hence, the calculation of free-space path loss will be determined by using that formula from (4) and (6). By taking the one example of the value free-space path loss is,

$$Lp = \left(\frac{4\pi(2.5)(200M)}{3\times10^8}\right)^2$$

$$= 438.6491m$$

From equation (5), the value of path loss will determined in dB,

$$Lp = 20\ log_{10}\ (0.0025) + 20log_{10}(200) + 32.45$$

$$= 26.42dB$$

Notice that, the value of free-space path loss will change when the value of distance is changes. The larger of the distance's separation between antenna set-up, the larger of path loss. The value of path loss is depends on the frequency, antenna height, received signal location, the environment area and also the link distance. In this research, the equation (5) was used where there is only distance and the frequency. Table III shows the changing of path loss due to changing of distances.

Table III: The path loss measurements

Distances (m)	Path loss (m)	Path loss (dB)	Path loss (dBm)
1.0	70.184	18.46	48.46
1.5	157.914	21.98	51.98
2.0	280.735	24.48	54.48
2.5	438.649	26.42	56.42
3.0	631.655	28.00	58.00
3.5	859.752	29.34	59.34

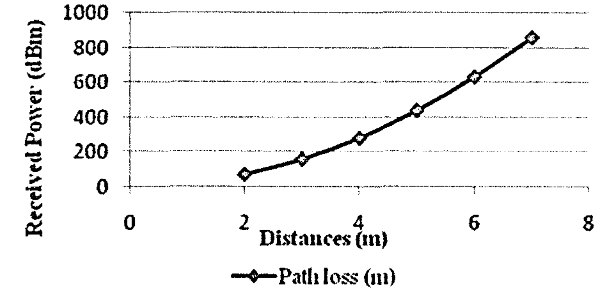

Figure 2: The path loss measurements

The value of path loss in dB was added by the 30dBm to get the value in dBm. This explanation will described as in the equation (6) below:

$$dBm = 10\ log\frac{1}{1\times10^{-3}} \quad (6)$$

$$= 30dBm$$

Hence,

$$dBm = dB + dBm \quad (7)$$

For example in the distances of 1 meter, the path loss in dBm will be calculated as below:

$$\begin{aligned} Path\ loss\ (dBm) &= 18.46dB + 30dB \\ &= 48.46dB \end{aligned}$$

Line-of-sight (LOS) is actually the direct propagation of radio waves between antennas that are visible to each other, this is the most common of radio propagation modes at VHF. So, the relationship between the *line-of-sight (LOS)*, antenna (Yagi-Uda), power radiation and also the distances between the transmitter and receiver was studied to find out the factors that affect the signal strength reception.

D. Measurements on the Line-of-Sight (LOS)

Table IV is the measurements of the average *line-of-sight (LOS)*. The measurements of *LOS* were determined based on the different distance which varies from 1.0 meter to 3.5 meter. The values of received power (dBm) will increase when the distances increases. It is because there is a path loss occurred during the power being transmitted directly between the transmitter and receiver. The received power (dBm) was constantly increase as the distance increase.

Table IV: The measurements of *line-of-sight (LOS)*

Distances (m)	Received Power (ηW)
1.0	1161.449
1.5	1018.591
2.0	716.143
2.5	603.949
3.0	519.996
3.5	456.586

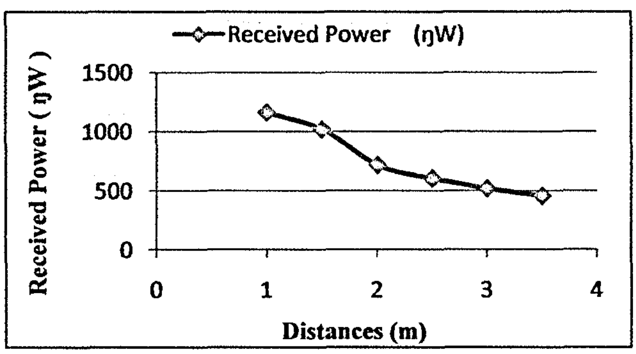

Figure 3: The *line-of-sight (LOS)* measurements

E. Method to Measure RF Absorption Capacity for One Banana Tree Sample

Based on Table V, the measurements for banana tree were recorded using the spectrum analyzer. Since the banana's fruit grows in bunches, so both transmitter and receiver antenna were positioned directly on top of the banana's bunch, where the measurement was taken. This is the limitation that might cause the lack of knowledge about the RF wave's absorption to the banana's fruit. From the results, the strongest signal strength (dBm) received by the trunk, followed by the fruit and leave respectively.

Table V: The RF measurements for one banana tree

Distances (m)	Fruit (ηW)	Leaves (ηW)	Trunk (ηW)
1.0	413.048	431.519	716.143
1.5	239.332	248.313	374.973
2.0	205.116	208.929	224.388
2.5	190.546	196.336	199.526
3.0	162.929	176.198	190.546
3.5	133.968	152.757	154.525

Table VI shows the capacity of RF absorption obtained after applying the empirical suggested formula:

$$RF\ Absorption = a - b \qquad (8)$$

where

$a - measured\ data\ for\ Table\ I\ V$

$b - measured\ data\ for\ Table\ V$

Table VI: The absorption's capacity for one banana tree

Distances (m)	Fruits (ηW)	Leaves (ηW)	Trunk (ηW)
1.0	748.401	729.930	445.306
1.5	779.259	770.278	643.618
2.0	511.027	507.830	491.755
2.5	413.403	407.613	404.423
3.0	357.067	343.798	329.450
3.5	331.618	312.829	311.061

Table VII shows the value of RF absorption when the distance at 1 meter. The measurements can be displayed into various types of signal level which are in dBm, ηW and mV. The highest absorption of RF waves occurred at fruits is the highest value followed by leaves and trunk.

Table VII: The measured value for one banana tree at 1.0m separation

Types of propagations	Power Level (ηW)	Received Power (dBm)	Voltage Level (mV)
Fruits	748.401	-31.26	7.50
Leaves	729.930	-31.37	7.40
Trunk	445.306	-33.51	5.78

Besides that, the measurements on the ηW can be converted into dBm and mV using equation (9)

$$dBm = 10log\frac{P}{1\times10^{-3}} \qquad (9)$$

where

$P - power\ (\eta W)$

While, the equation (10) can be used to find the value of voltage level (mV) by taking the resistance of the antenna is 75Ω.

$$P = \frac{V^2}{R} \quad (10)$$

where

$P - power\ (W)$
$V - voltage\ (V)$
$R - resistance\ (\Omega)$

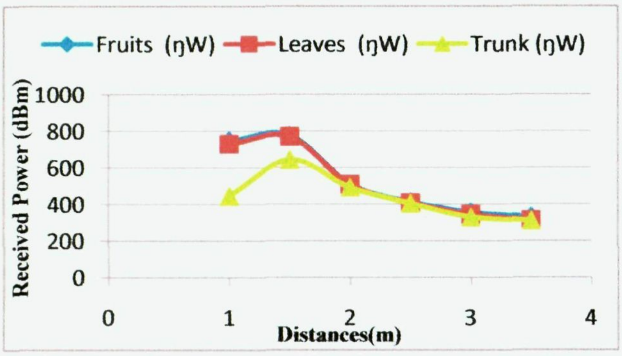

Figure 4: The absorption's capacity for one banana tree.

As mentioned in the Figure 4, fruits have a more capability to absorb the RF signal as compared to the trunk.

F. Method to measure RF absorption capacity for more than one banana tree sample.

The RF measurements for more than one banana tree were recorded as mentioned in the Table VIII. This reading refers to the measurements on the spectrum analyzer without considering the *line-of-sight (LOS)* value. The difference between the *LOS* value and the Table VIII will results the capacity of RF absorption. All the units of the measurements on the graph were recorded into the International Standard (SI) unit in decibels relative to one miliwatt or simply called dBm.

The RF wave absorptions for more than one banana trees were collected from the given empirical suggested formula:

$$RF\ Absorption = a - c \quad (11)$$

where

$a - measured\ data\ for\ Table\ IV$
$c - measured\ data\ for\ Table\ VIII$

Table VIII: The RF measurements for more than one banana tree

Distances (m)	Fruits (ηW)	Leaves (ηW)	Trunks (ηW)
1.0	190.546	205.116	206.063
1.5	162.930	196.336	205.116
2.0	126.183	133.968	154.525
2.5	64.417	101.625	108.393
3.0	31.477	32.434	57.279
3.5	0.013	3.319	31.477

The Table IX displayed the exact results for the absorption after considering the *line-of-sight (LOS)* had been calculated. From the results, fruits show the capability to absorb RF absorption followed by the leaves and trunks.

Table IX: The absorption's capacity for more than one banana tree

Distances (m)	Fruits (ηW)	Leaves (ηW)	Trunks (ηW)
1.0	970.903	956.333	955.386
1.5	855.661	822.255	813.475
2.0	589.960	582.175	561.618
2.5	539.532	502.324	495.556
3.0	488.519	487.562	462.717
3.5	465.573	462.267	434.109

From the Figure 4, it was shown clearly that the fruits have more capability to absorb the RF wave followed by leaves and also trunk.

Table X: The measured value for more than one banana tree at 1.0m separation.

Types of Propagation	Power Level (ηW)	Received Power (dBm)	Voltage Level (mV)
Fruits	970.903	-30.128	8.533
Leaves	956.333	-30.193	8.470
Trunk	955.386	-30.198	8.465

From the Table X, the value of each types of medium propagation was displayed. The equation (9) and (10) is use again in this table to find the various types of signal levels. The highest absorption occurred at fruits followed by leaves and trunk.

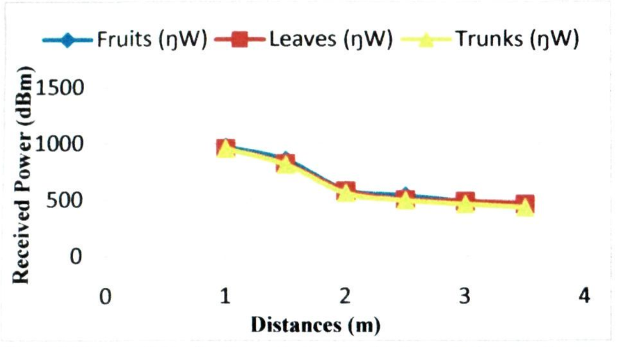

Figure 5: The graph for the absorption's capacity for more than one banana tree

V. CONCLUSION

This research reported on the experimental study of RF wave's absorption by a banana tree. Tests have been performed to determine the RF absorption on the three types of particular medium of propagations. From the experimental result obtained, there are several factors that may possibly affect the RF transmission range.

The possible factors that might affect the RF transmission include the geographical factors and the climate factor such as humidity (rainy) and salty (sea shore). This is a reason why the experiments were conducted during the hot weather to avoid the RF transmission disturbed by these factors. It is also important to calculate the path loss and consider the *line-of-sight (LOS)* path during the experiment at the site. Before the experiment was conducted at the site, the types of antenna used must be suitable to the frequency range which is varies from 30-300MHz. Hence, the theoretical calculation about the driven element must be matched to the driven element used. This is important to ensure that the research done successfully. In order to get better results on the RF wave's absorption, the types of the plants need to consider.

This will be the most important part before the plants had been chosen as a medium to conduct this experiment. In these types of plants, it is also includes the characteristic on the plants itself such as soft texture and blandness. The entire precautions step should be taken during the measurements to avoid the failure use on the equipment and also the prevention from the lightning strikes if this research was conduct during the rainy day.

In conclusion, from the three types of propagation medium the capability of banana tree to absorb the RF waves in this research depends on the distances where the transmitting antenna was placed and also the carrier frequency. The distances is actually has a relationship with the path loss. These two factors were proven by using the calculation as mentioned on the result's part. From the results obtained, fruits absorb the highest capacity of RF waves followed by leaves and trunk.

VI. RECOMMENDATION FOR FUTURE WORK

From the experiment and research that had been done, there are some recommendations to improve the research in the future for the better results. From the results, it is clearly shown that the absorption by fruits is much better when the antenna was transmitted on more than one banana tree. The capability of RF waves absorption will be increase when the area of plantations is more bigger than the existing area which is 150 feet's × 42 feet's.

In this research, the existing signal from the environments is not considered. Hence, it is recommended to consider first the signal from the environment to find the best position angle for the strongest signal. There are some limitations during the experiments that had been taken, for instance, the separation distance between the trees is too close to each other. The other types of banana tree also can be replaces to conduct this study. These research focusing on the banana tree from the types 'pisang tanduk'. Perhaps it will give different result due to different size of fruits.

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