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MICROWAVE SIGNAL PROPAGATION ON OIL PALM TREES: MEASUREMENTS AND ANALYSIS

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Abstract- This paper presents the study of microwave signal attenuation on oil palm trees at 0.9 GHz, 1.8 GHz and 2.3 GHz frequencies. The main objective is to investigate the characteristics of propagation phenomenon by analysing the received signal strength. The experiments were made at the estate where there are straight line uniform canopies of mature oil palm trees. The measurements were carried out on the same transmission paths with different number of trees and height at trunk, leaves and fruits which obstructing the signal paths. The results have shown that excessive attenuation is due to scattering, depolarisation, fluctuation and absorption. It is strongly aggrees with the previous studies. Further studies on other types of vegetation and environments, and its seasonal differences are important as future research.

Index terms: **Attenuation, frequency, microwave, oil palm tree, propagation.**

I. INTRODUCTION

Attenuation is the signal reduction in radio systems [1]. The degradation of received signal strengths suffered by the radio waves is caused by the excess propagation loss. It is due to the presence of trees along a radio path [2, 3, 4, 9, 13].

There are many factors in terms of parameters and variations involved in the attenuation, one of it is trees. The tree can be considered as a random medium which consists of many dielectric objects such as trunk, leaves, fronds, twigs, branches etc. These tree constituents attenuate and scatter an incident electromagnetic field. The extent of scattering depends on the canopy particle size, height, density, type of tree species, location, moisture content, signal frequency, polarization etc [19]. The attenuation can be external and internal. Dense large leaves at the end of branches are the dominant contributor for attenuating microwave signals [3, 7, 11, 12].

The oil palm tree is selected as a sample of the measurements to evaluate the signal propagation loss through vegetation. It is one of very famous type of trees in Malaysia. The oil palm tree has a distinct shape and looks like a sphere which consist of the trunk, leaves and fronds. The tree has leaves which are distributed around the axis very accurately and they are on the top of the trunk [8].

The purpose of this paper is to obtain information on the propagation phenomenon of microwave signals through oil palm trees. The main objective is to measure and analyze the strength of received signals in different frequencies. The additional objective is to determine oil palm tree attenuation caused by shadowing with respect to line of sight on a basis of the received signal versus number of trees and received signal versus distances.

II. YAGI UDA ANTENNA

An antenna is used in transmitting or receiving radio waves in a telecommunication system. The size and the design of an antenna depends on the frequency or wavelength of the transmission or reception radio waves, directivity, radiation mechanism, radiation pattern and polarization. The type of antenna used for both transmitting and receiving radio waves are normally the same [14].

A Yagi Uda or Yagi antenna is commonly used and is very practical antenna. It has advantageous features such as large gain, high directivity, cheap cost, low weight and uncomplicated profile. The Yagi Uda antenna is a propagating wave antenna which consists of one or more dipoles mounted on a crossbar. The dipoles are of different lengths and different frequencies used in television broadcasting. Additional pieces of metal called directors and reflectors are placed on the crossbar in front and the back of the dipoles. The directors and reflectors reflect and concentrate the radio waves towards the directors. The Yagi Uda antenna is often mounted on a rotating tower or base. So, it can easily be turned towards the source of the desired transmission. The Yagi Uda antenna can radiate radio waves as both horizontal and vertical polarized signals, as shown in Figure 1 [14].

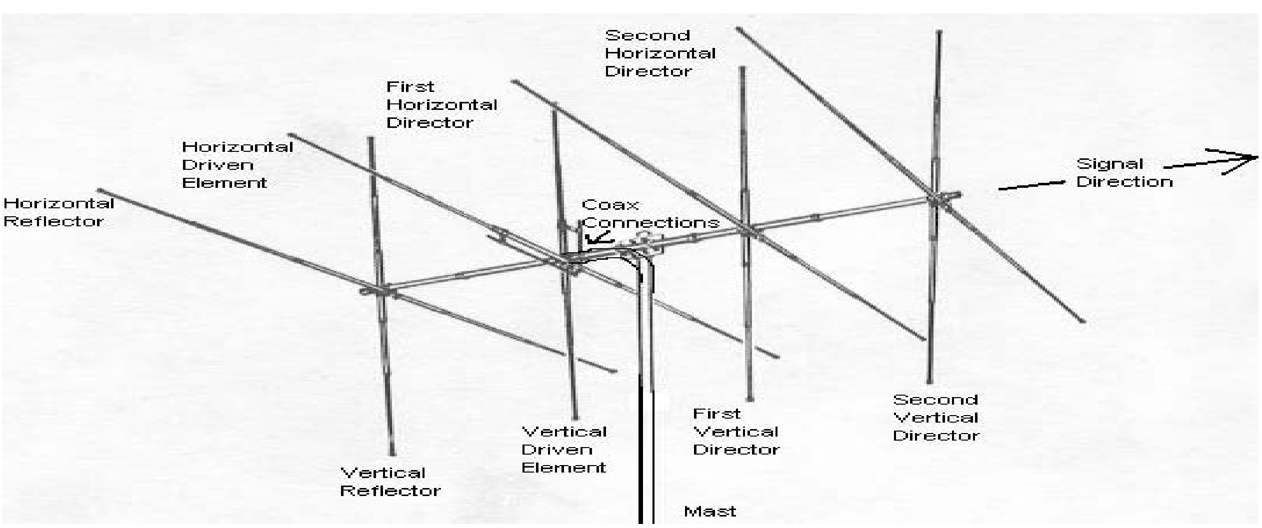

Figure 1. Horizontal and vertical polarization of 4 Yagi elements

A transmitting antenna receives waves in the form of electrical signals. The electrical signals, which is also known as radio frequency (RF) energy, flows from a transmitting station to the transmitting antenna, and converts it to radio waves that travel in the free space. The antenna then generates a magnetic field around it. Subsequently, the magnetic wave propagates towards and is received by the receiving antenna where it induces a current. The receiving station converts the electrical impulse to produce an output. The waves produced by the electrical signals in the devices are called guided waves. The guided waves can propagate through the transmission lines such as cables or wires. The waves that propagate in a space are known as free space waves. It propagates through the air or outer space without using a transmission line. The receiving antenna receives the free space waves and converts it to guided waves which are ultimately used to produce an output [14].

The driven part of the antenna, as shown in Figure 2 below, drives the antenna and is connected directly to the consumer devices. The other 2 outer elements namely, the reflector and the director are known as parasitic elements. The reflector reflects the RF energy whilst the director directs the RF energy. Normally, the driven is 5% shorter than the reflector and the driven is 5% longer than the director. The middle element is the simple half wave dipole antenna [14].

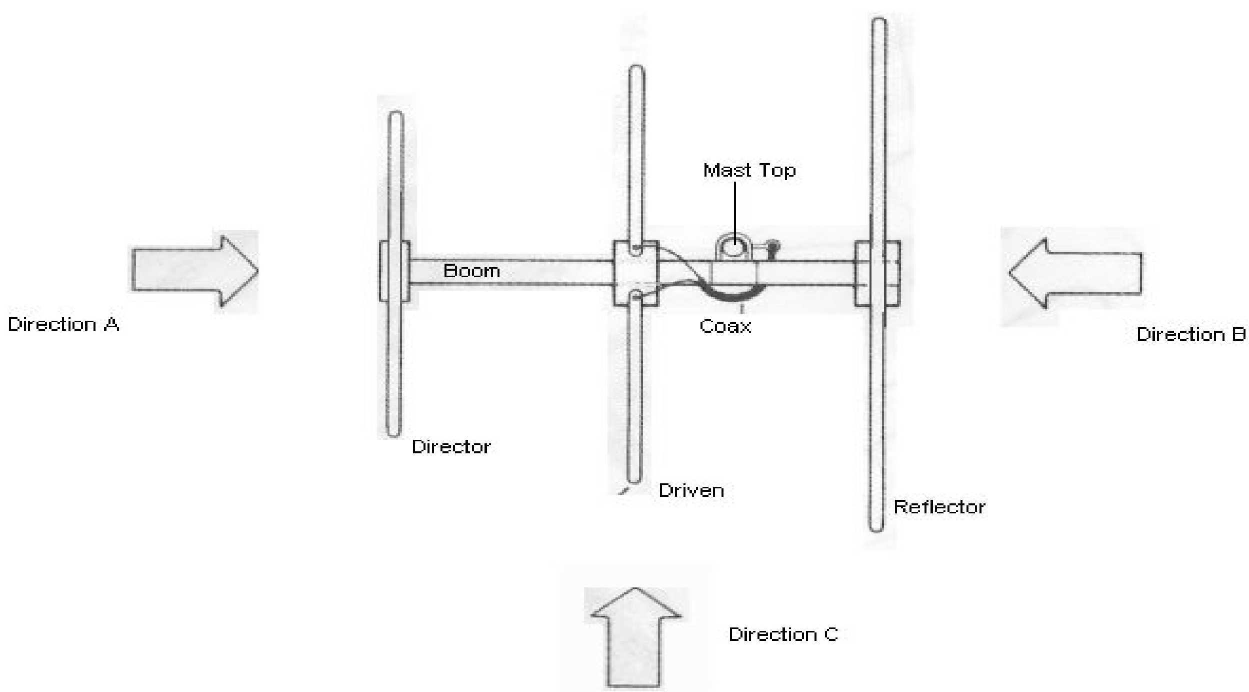

Figure 2. Top view on 3 elements of Yagi beam

When a signal propagates through 3 elements from direction A, it produces a small current. The current is induced on the antenna and re-radiates off the antenna again. The signals are re-radiated by the director and the reflector. Then, it arrives at the driven in the same phase as one another between 2 re-radiated signals and the original signal. The signals reinforce each other and make the incoming signal much stronger than the original signal arriving from direction A.

For signal B and C, the situation is the same as with the signal from direction A. The signals arrive at the driven in an opposite phase with one another. It makes them cancel out each other. Therefore, the signals from direction B and C are reduced. This significant effect of signals arriving in same phase or opposite phase are caused by the spacing and length of the director, reflector and driven [14, 15].

III. METHODOLOGY

A transmitter terminal of 1 kHz modulation frequency signal generator was used to produce different continuous-wave carriers. It was fed to a transmitter antenna angled at 45°. The antenna with a height of 1.5 m above the ground, is mounted on an adjustable mast. It was located in the estate and directed towardss the oil palm trees. The transmitted power of the signal generator is set to 0 dBm.

The receiver antenna is also mounted on a mast with the same level of height as the transmitter antenna. It received the signal from the transmitter terminal. The height was adjusted and the receiver was tried at different locations inside the estate at different distances from the transmitter but still maintaining the same straight line formation. The direction of the antenna angle was set to 225°. The received signal from the receiver antenna was displayed on a spectrum analyzer.

The measurements were carried out on an estate of straight line identical oil palm trees which are 8 m high. The leaves are 5 cm wide and 11 cm long. The trees, with a trunk diameter of 25 cm, have spacing between columns and rows of trees of approximately 7 m and 8 m, respectively. The experimental set-up and the equipments used are shown in Figure 3, Figure 4 and Figure 5.

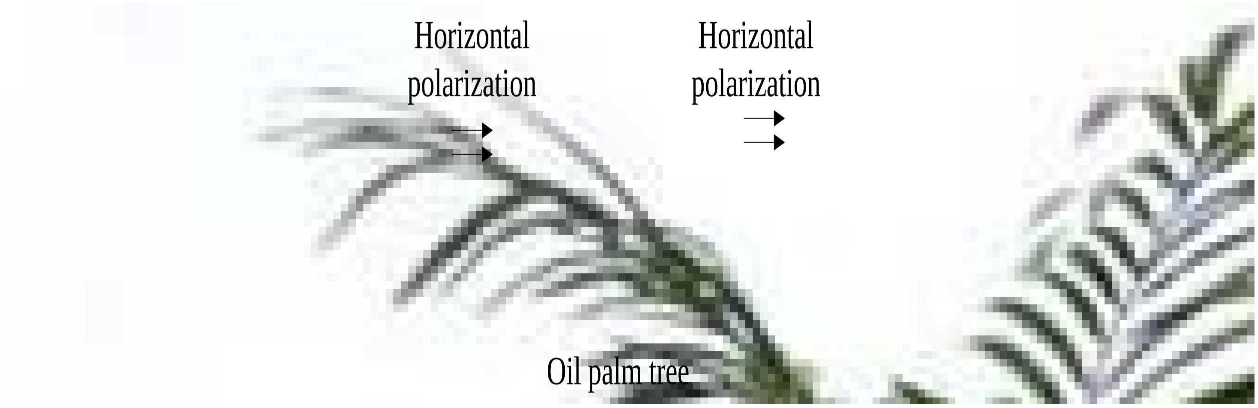

Figure 3. Experimental set-up

Figure 4. Marconi 2024 9 kHz to 2.4 GHz signal generator

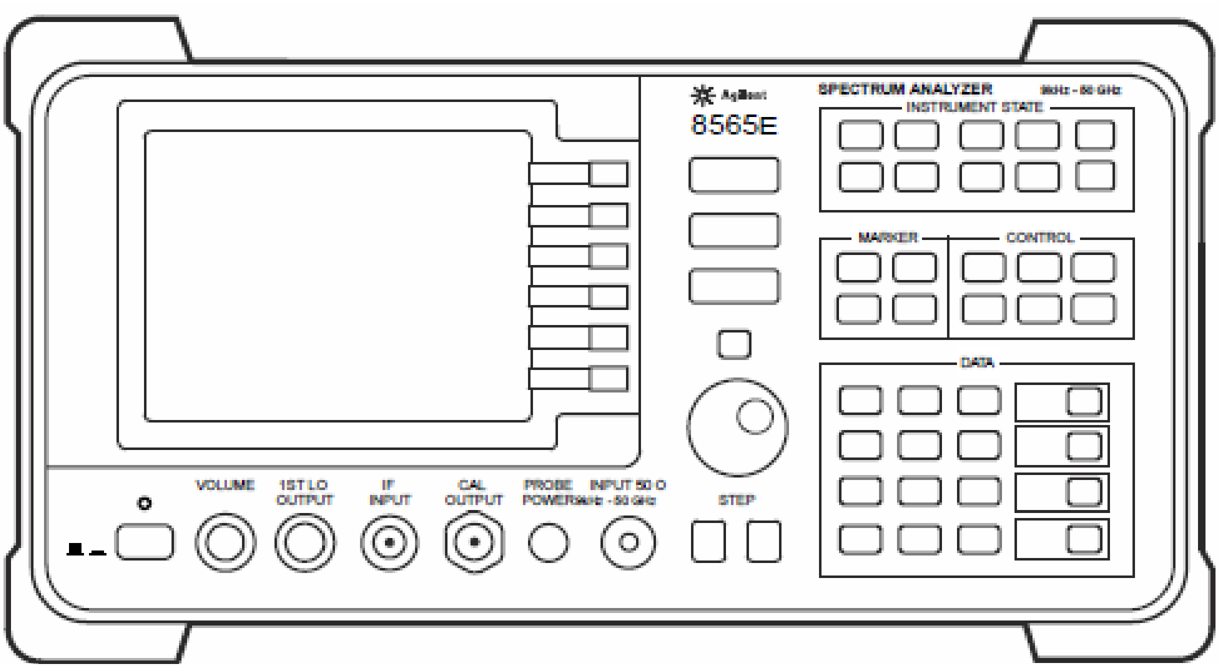

Figure 5. Agilent 8560E 30 Hz to 2.9 GHz spectrum analyzer

IV. MEASUREMENTS

Measurements were performed through the palm oil trees medium which focuses on the propagation mechanisms generated by the vegetation element. It analyses the contribution of the tree constituents namely, the trunk, fruits and leaves. The transmitter terminal was located inside the estate at a fixed distance of about 4 m from the first line of trees and in the center of the line. The received terminal was also placed inside the estate, at various positions, and usually such that the line-of-sight followed one row of trees. For each test run, both transmitting and receiving antennas were placed at equal heights above the ground where both antennas are pointing out to each other, so that the line-of-sight followed a horizontal path with different levels of height. At the 4 and 5 m heights, significant fruits and leaves were present and vegetation density was fairly high while mostly trunk was exposed at the 1.5 m height. Between two trees, the measurements were taken at three different receiver positions, i.e. at 2, 4, and 6 m from the first tree as shown in Figure 6.

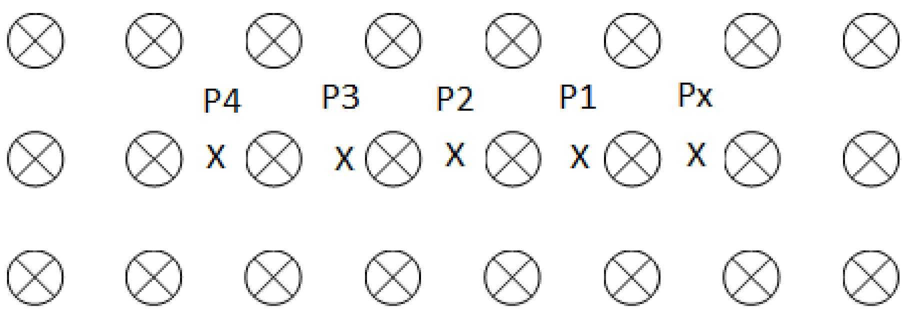

Figure 6. Transmitter and receiver positions in test site

 : oil palm tree

P_1, P_2, P_3 and P_4 : receiver position

P_X : transmitter position

V. RESULTS

Table 1: Received signal for different distances at frequency of 0.9 GHz

Distances (m)	Received signal (dBm)			Power level (pW)		
	trunk	fruits	leaves	trunk	fruits	leaves
-6	-69.31	-71.58	-75.42	99.12	78.41	55.47
-4	-70.50	-72.33	-76.67	84.79	76.38	52.12
-2	-71.63	-73.49	-77.16	71.83	69.25	43.58
2	-72.14	-74.63	-77.63	56.27	45.17	23.48
4	-73.27	-75.18	-78.27	47.14	37.52	18.53
6	-75.38	-76.59	-78.91	39.58	23.64	14.82
10	-76.42	-77.12	-79.38	25.47	15.38	9.26
12	-77.33	-78.67	-79.83	18.24	10.79	8.57
14	-78.56	-79.38	-81.52	13.85	9.14	7.15
18	-78.34	-80.49	-83.45	9.98	7.26	5.37
20	-79.17	-81.67	-85.17	7.63	6.80	4.54
22	-81.59	-83.51	-86.72	5.41	5.37	3.69
26	-83.47	-85.24	-87.14	4.57	4.18	2.73
28	-85.33	-86.67	-88.83	3.98	3.04	2.15
30	-87.56	-88.31	-89.58	2.61	2.69	1.85

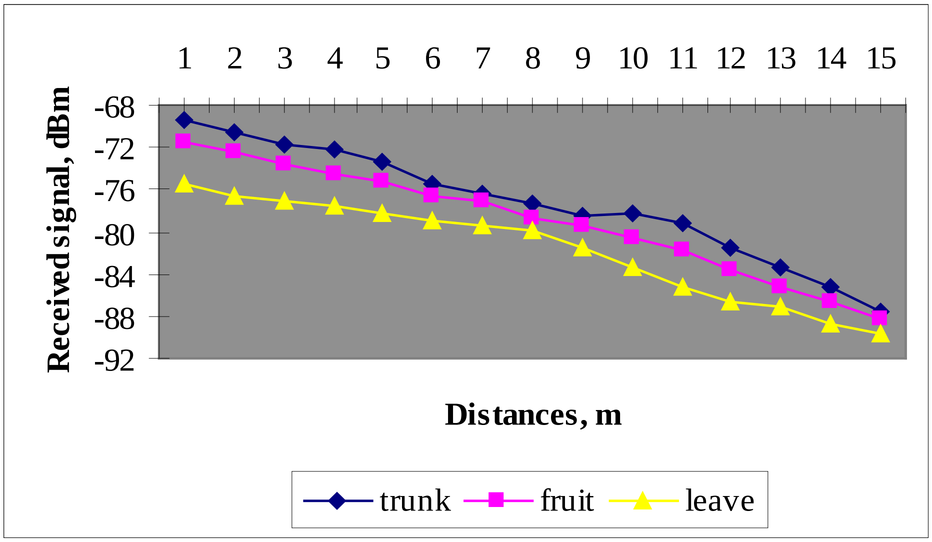

Figure 7. Received signal for different distances at frequency of 0.9 GHz

Table 2: Received signal for different distances at frequency of 1.8 GHz

Distance (m)	Received signal (dBm)			Power level (pW)		
	trunk	fruits	leaves	trunk	fruits	leaves
-6	-81.47	-82.47	-83.65	7.49	6.39	5.31
-4	-82.30	-83.33	-84.83	6.56	5.21	4.64
-2	-83.59	-84.59	-85.17	5.72	4.62	3.72
2	-84.37	-85.63	-86.21	4.72	4.81	3.42
4	-85.42	-86.94	-87.46	3.91	3.57	3.58
6	-86.59	-87.21	-88.19	2.38	3.41	2.71
10	-86.14	-87.62	-88.24	2.37	3.28	2.63
12	-87.67	-88.17	-89.33	2.58	2.04	2.89
14	-87.38	-88.43	-89.58	2.69	2.17	1.52
18	-88.47	-89.15	-90.47	1.43	2.58	1.47
20	-88.53	-89.73	-90.53	1.69	1.36	1.28
22	-89.26	-90.28	-91.68	1.25	1.42	1.93
26	-89.14	-90.47	-91.48	1.72	1.21	0.89
28	-90.67	-91.35	-92.57	0.89	0.97	0.97
30	-90.28	-91.82	-92.63	0.67	0.63	0.65

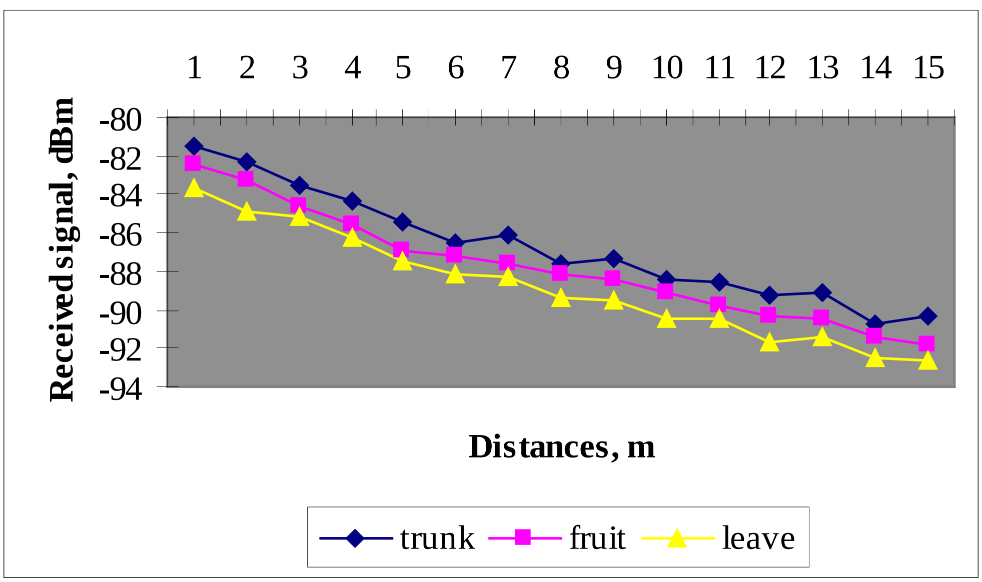

Figure 8. Received signal for different distances at frequency of 1.8 GHz

Table 3: Received signal for different distances at frequency of 2.3 GHz

Distance (m)	**Received signal (dBm)**			**Power level (pW)**		
	trunk	**fruits**	**leaves**	**trunk**	**fruits**	**leaves**
-6	-84.38	-85.41	-86.49	3.69	3.85	2.58
-4	-85.17	-86.67	-87.17	2.81	2.41	1.99
-2	-85.51	-86.58	-88.35	2.53	2.73	1.63
2	-86.72	-86.52	-89.72	2.73	2.93	1.53
4	-86.14	-87.14	-90.15	2.85	2.47	1.84
6	-87.59	-87.38	-90.84	1.42	1.62	1.92
10	-87.21	-87.58	-90.72	1.47	1.28	1.24
12	-88.33	-88.67	-91.33	1.12	1.76	1.65
14	-88.64	-88.23	-91.58	1.63	1.49	0.98
18	-89.47	-89.17	-91.41	1.52	1.35	0.79
20	-89.53	-89.69	-92.25	0.71	0.86	0.63
22	-90.26	-90.38	-92.73	0.98	0.94	0.45
26	-90.72	-90.71	-92.64	0.63	0.71	0.81
28	-91.54	-91.35	-93.79	0.58	0.53	0.65
30	-91.38	-91.82	-93.83	0.47	0.48	0.32

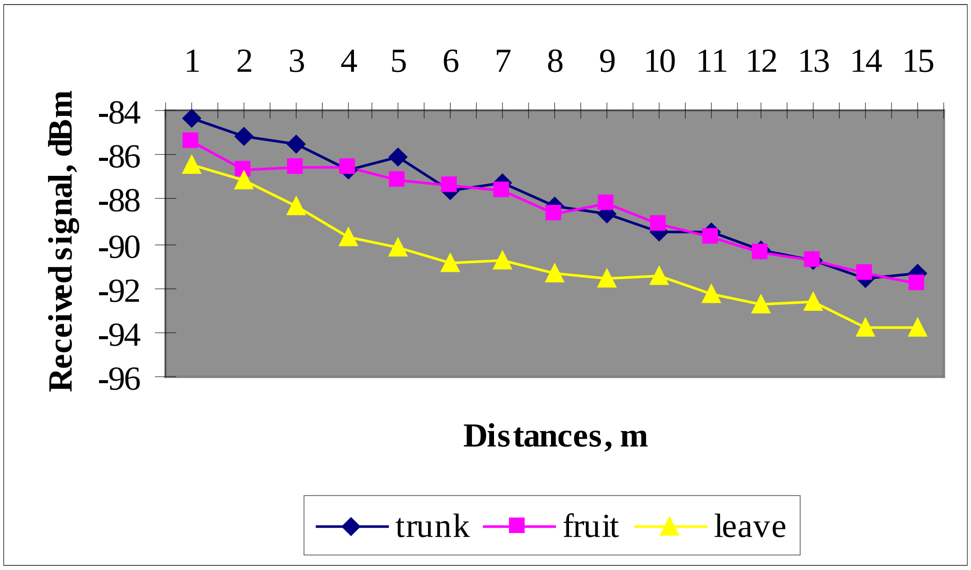

Figure 9. Received signal for different distances at frequency of 2.3 GHz

VI. DISCUSSION

The distinct effects have been identified from the analysis of the measured data. The received signals with increasing the distance and number of trees obstructing the signal path is decayed at a considerably slow rate at the trunk, fruits and leaves for 0.9 and 1.8 GHz. But, for frequency at 2.3 GHz, the signal strength decreases at a nearly constant and smooth rate. The values of the received signal for the trunk and fruit are almost same when measurement is done at second row of trees. It seems that the received signal at 0.9 GHz is better and stronger compared with the propagation measurements at 1.8 and 2.3 GHz. The range of received signals for both frequency at 1.8 and 2.3 GHz are almost the same.

The received signal with a small number of trees obstructing the signal path decayed at a considerably faster rate relative to that measured when more trees obstructed the path. The change in attenuation rate occurs because, at small foliage depth, propagation between the transmitter and the receiver is primarily by a strongly attenuated line-of-sight component, while at relatively large distances inside the estate multiple scattering of radio waves by the various constituent parts of the trees become the major contributor to the received signals.

As the frequency increases, the number of fruits and leaves have a greater effect upon the signal received as their physical size approximates to the wavelength of the transmitted signal, leading to a higher probability of signal blockage [19].

VII. CONCLUSIONS

In conclusion, the results indicate that the strongest signal strength of the medium propagation are received by the trunk, followed by fruits and lastly leaves. The leaves is the best medium propagation to block the received signal.

The absorption of microwave signal is significant while propagating through the dense oil palm trees. The excess attenuation occurs because of four main propagation phenomenon, that are scattering, depolarisation, fluctuation and absorption [5, 12].

From the results, it is evident that the microwave signal attenuated exponentially while transmitting. This is due to attenuation which is proportional to the frequency [6]. The microwave signal is attenuated as it propagates through the oil palm trees. The longer the distance of the microwave signal travels, the more it gets attenuated until it fades completely [1]. This is due to atmospheric loss, absorption loss [16] and loss caused by transmission lines [18].

The channel capacity varies with the changes in the propagation medium and channel obstructions. This is due to channel fading. Channel here means not just a physical medium for propagation; it also covers the position of the transmitter and the receiver in the presence of local obstructions. Because of both absorption and scattering, high attenuation rate dominates at short distances into the vegetation. The radio link will undergo fading and will be attenuated. The channel capacity decreases as the depth of the vegetation increases. The vegetation depth proportionally increases the attenuation, and as the elevation angle increases, the channel capacity also increases [6].

The attenuation of trees depend on the frequency, polarization, electrical and geometrical characteristics of branches and leaves, biophysical parameters of a tree, and statistical distribution of branches and leaves in reference to the angle of incidence of the plane wave [3, 7, 11, 12, 19]. The signal fades at a much higher rate when the trees have large leaves and the wooden trunk has dense foliage due to scattering effect of re-radiation of the canopy [5, 10].

Further studies and analysis in other vegetation environments, different type of vegetation, and its seasonal differences are important for future development. Hopefully, this paper can be as a reference for telecommunication network providers company in Malaysia so that they are able to optimize and offer good coverage especially for mobile phone users.

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