Performance Comparison Test of Conventional and Metamaterial Antenna

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***Abstract*— In this paper, the performance of conventional and metamaterial antennas (microstrip rectangular patch antenna with V-shape and using Circular Ring defected ground structure and rectangular microstrip patch antenna with nine squares of Electromagnetic Band Gap (EBG) structure on the ground plane) in Wi-Fi application which having the frequency of 2.45GHz is tested. The performance and distance coverage is determined after testing done by AirMax Bullet M2 Hp and software AirMax AirOS by Ubiquiti Networks. The scope of project includes recording time duration to transfer small-size of video (16.6Mb) and medium-sized movie (369Mb) files from a local to remote host by varying output power of the transceiver, distance and type of antennas at both transmitting and receiving ends. The performance of the conventional antenna is better than metamaterial antenna. At 20 meter, both antenna is still working with the same signal strength -58 dBm but conventional antenna have higher transfer rate and shorter time taken to transfer files compare to metamaterial antenna. As for two metamaterial antenna tested, it is conclude that EBG antenna is better than DGS antenna because of it higher signal strength and time taken to transfer file is shorter compare to DGS antenna which is 7.83 second (16.6Mb) and 143 second (369Mb) for DGS antenna and 5.7 second (16.6Mb) and 143 second (369Mb) for EBG antenna. This result will help to add market value to antenna tested.**

***Keywords*— Metamaterial, signal strength, microstip rectangular antenna, transfer rate,**

I. INTRODUCTION

The microstrip rectangular patch antenna is suitable to be mounted on a flat surface [1].It is an antenna with a very thin metallic patch above a conducting ground-plane with dielectric in between. Dielectric constant of substrate is normally in the range of $2.2 < r\varepsilon < 12$ [2]. There are 3 characters that are important when designing an antenna which is *length L, width W* and thickness *h*, as in Figure 1 below.

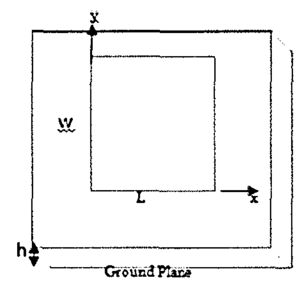


Fig. 1 Antenna overview

Microstrip antenna is widely use because it have a small dimensions, light weight, easy manufacturing, low cost. But, the microstrip antenna has a narrow bandwidth and low overall efficiency due to dielectric losses. Various techniques can be used to improve bandwidth of microstrip antenna such as using slot antenna and E-shaped patch antenna. Metamaterials is founded to be most suitable technique [2,3]. Metamaterials exhibit negative permittivity; negative permeability and negative refractive index [4].It also can cover wide frequency range. According to [5],the additional requirement for the metamaterial to be regarded as an effective medium, the cellular size need to be smaller or equal to the sub-wavelength. Therefore, the presence of the defected ground structure make the metamaterial is realizable.

The concept of Metamaterial was published in 1968 by Victor Veselago a Russian physicist [6]. By using metamaterial the radiated power of antenna can be enhanced, it can also improve bandwidth and efficiency performance [6]. Metamaterial is a man-made materials to provide properties that cannot be found in available materials in nature [4].

In this paper, the performance of the conventional microstrip antenna and metamaterial antenna will be tested and measured using Ubiquiti Bullet M2 Hp. It is a wireless radio with an integrated type N RF connector that can be directly plugged in to any antenna to create an outdoor access point, client, or bridge [7]. The configuration of the device will be done by using AirOS software. From the software, we can observe the signal strength of the antenna by varying the distance between the transmitter and the receiver. The main concern in this project is the signal strength between the transmitter and receiver. This project aims to test performance over a range of distance and compare between the conventional and metamaterial antenna then finally produce datasheet for the antenna. This project will benefit the antenna designer to test the designed antenna and have market value added to the antenna.

In recent years, there have been several methods applied for the testing and analysis of antenna performance. An automatic test system of antenna characteristics was introduced by Wu Ran et. al. [8] by using C++ Builder software. The parameters that can be tested including antenna impedance, standing wave ratio and radiation characteristics aside from providing different antenna orientation picture and compiled into a report. The system built is convenient as we just enter a few data and obtain all direction's pictures with final report. The result is obtained despite having difficulties in the programming some parts of this test system can be improved

From [9], detail testing method and results for the testing of in-house antenna can be seen from Martin's website. Using Enterasys driver, the test run by using two laptops one for the driver and the other is for client utility used to monitor link strength with each test configuration being monitored. When the link had stabilized, both local and remote end of the link SNR, signal strength and noise level were recorded. The antennas were tested in the same environment to minimize any factors that may affect the results. For his testing, only the link strength was tested.

Besides that, in [10] an experimental test methodology used to characterize performance of in-house antenna within a wireless sensor network node in open-field test environment. The results obtained some useful data for comparing performance of antennas. The information also useful to select suitable antenna for wireless sensor network

II. METHODOLOGY

Ubiquiti Bullet M2 Hp is hardware that will be used to test the antenna. The Bullet M2 is ideal for long-distance links, it will be using POE adapter by using Ethernet cable.

At first, the study on understanding the antenna and performance test method is done before continuing with the testing. The testing environment will then be established between transmitter and receiver for conventional and metamaterial antenna. Two type of data transfer; small and medium size files are used at different output power and variable distance that act as transmitter and receiver. The performance result from the test will be compared to determine whether conventional antenna or metamaterial antenna has a better performance in term of the signal strength, data rate and duration of data transfer as well as which of the antenna a better distance coverage. Lastly, all the data obtained will be compiled in a proper documentation.

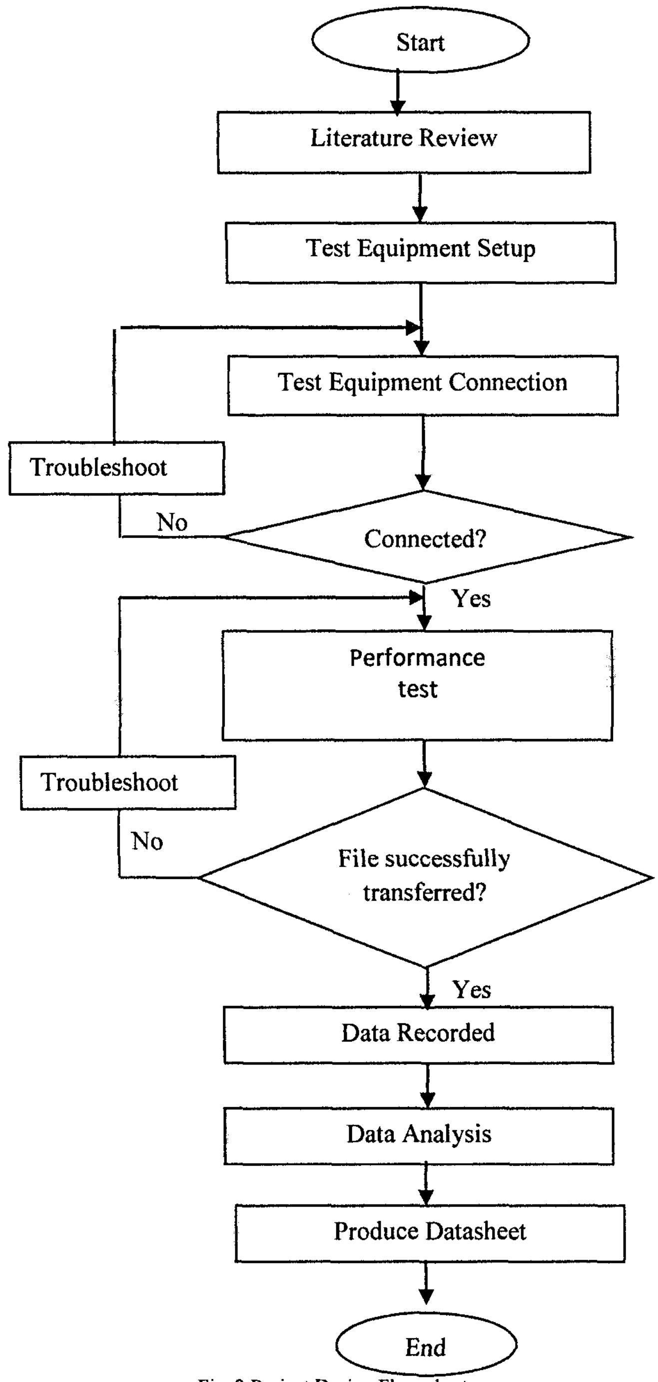


Fig. 2 Project Design Flow chart

A. *Project Research*

Most researchers only conduct measurement testing to confirm their research theory, only few that do performance analysis. Hence, this project will be focus more on the performance testing for antenna. The theory of the performance analysis has been carefully studied and understood. From the researched, antenna characteristics can be improved by using the metamaterial structure [14].

Two different type of metamaterial structure Electromagnetic Band Gap (EBG) and Defected Ground Structured (DGS) is use for the testing.

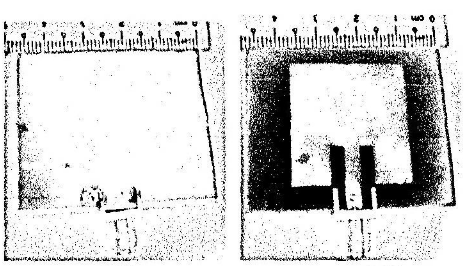
TABLE 1. Properties of Defected Ground Structured (DGS) antenna

Antenna	Conventional	Metamaterial
Gain (dB)	3.36	3.12
Directivity (dBi)	6.09	6.1
Center Frequency (GHz)	2.45	2.45
Bandwidth (MHz)	40	42
Return Loss, S_{11} (dB)	-16.191	-26.832
VSWR	1.467394	1
Substrate Area, W x L (mm)	47.21 x 39.84	46.76 x 39.84
Patch Area, W x L (mm)	37.61 x 29.17	19.89 x 29.17

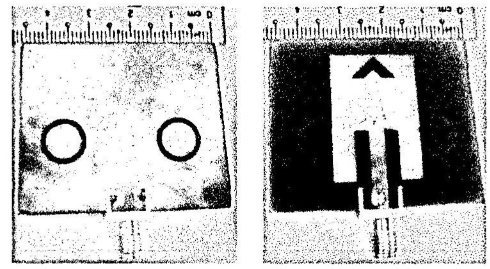
TABLE 2. Properties of Electromagnetic Band Gap (EBG) antenna

Antenna	Conventional	Metamaterial
Gain (dB)	4.429	4.117
Directivity (dBi)	5.925	4.908
Center Frequency (GHz)	2.45	2.45
Bandwidth (MHz)	26.3	52.0
Return Loss, S_{11} (dB)	-25.38	-33.78
Beamwidth (-3dB)	96.8	88.4
Substrate Area, W x L (mm)	46.93 x 38.94	40.92 x 38.94
Patch Area, W x L (mm)	42.43 x 34.24	37.53 x 29.70

Table 1 and 2 shows two type of antenna properties that obtained during measurement using Vector Network Analyzer. It shows that the gain and directivity of conventional antenna is better than the metamaterial antenna. But the return loss showed an improvement for both metamaterial antennas.

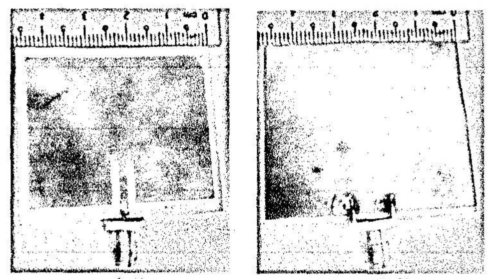


(a1) (a2)

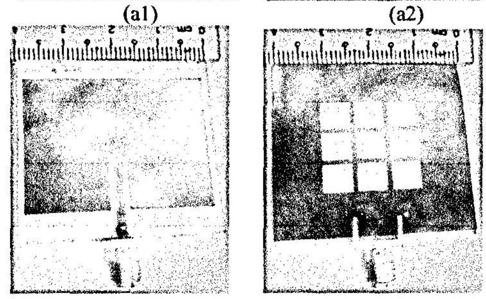


(b1) (b2)

Fig. 3
Conventional antenna (a1) Front view (a2) back view
Metamaterial DGS antenna (b1) Front view (b2) back view



(a1) (a2)



(b1) (b2)

Fig. 4
Conventional antenna (a1) Front view (a2) back view
Metamaterial EBG antenna (b1) Front view (b2) back view

B. *Test Equipment Setup*

The test equipment setup consists of two laptops (as local host and remote host), Ubiquiti Bullet M2, AirOS software and Ethernet cable. The IP address of the laptops will be configured first before testing begins. The antennas tested are the conventional and metamaterial antenna (EBG and DGS) structure operating at 2.45GHz.

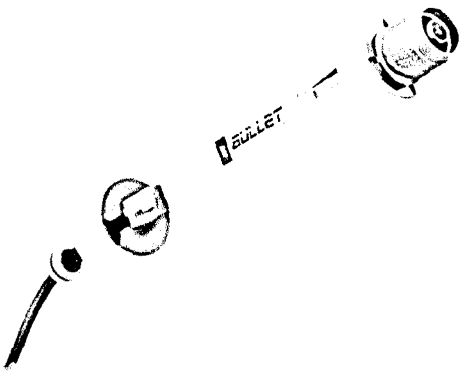


Fig. 5 Ubiquiti Bullet M2 Hp

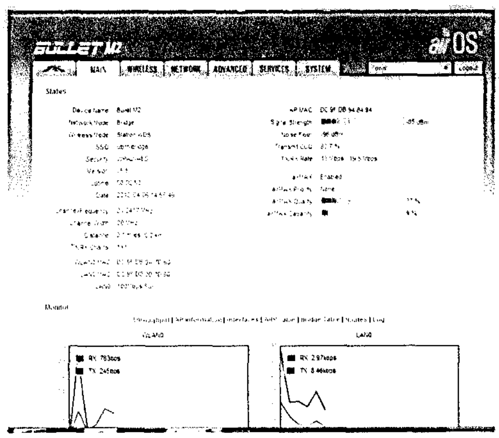


Fig. 6 AirOS

The antenna to be tested is connected to Bullet M2 by using male-to-N female connector since the antenna cannot be mounted directly to the device. The device is place on a table with height of approximately 1meter initially.

Before the testing process is conducted, the configurations of the laptops at both local and remote host need to be done. The IP was setup into 192.168.1.21 and 192.168.1.31 for laptop A and laptop B. The IP must be setup different from each other to avoid any IP conflict that will prevent the point-to-point link to be established resulting in no file can be transferred.

After configuring the IP for the laptop network, next step was to configure the transceiver IP address. The default IP of the bullet 192.168.1.20 was pasted into the browser in order to use the AirOS user interface from the Ubiquiti after the transceiver is connected to the laptop. IP configuration for each transceiver was done using AirOS.

Point-To-Point Link (P2P) was setup for the purpose of performance testing. Bridge was set as the network mode of both transceivers. Wireless modes were set as Access Point and Station at transmitter and receiver ends respectively.

C. Performance Testing

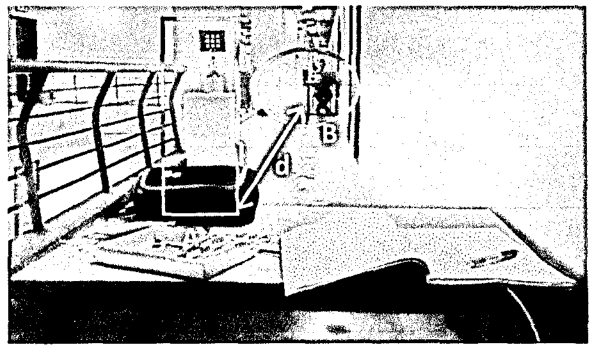


Fig. 7 Testing setup A) Transmitter B) Receiver

Figure 7 shows the setup for the performance testing. The output power of the Bullet is varied from 5, 10, 15 and 20 dBm and the distance between the antennas is varied from 1, 5, 10, 15 and 20 meters for the testing.

The minimum output power is chosen as 5dBm because it is the lowest output power which stable when testing for 1 meter of distance. While the 20 dBm output power is the maximum power that the Bullet can provide.

The Bullet need to be stabilizes for a few moments after choosing the output power. By using stopwatch, the signal strength and the time taken to completely transfer from file A to B were recorded. The small sized file (16.6Mb) represent the average size of music video file while the medium sized files (369Mb) represent the average movie file.

Data transfer rate can be calculated by using below formula:

$$r = \frac{b}{t} \qquad (1)$$

Where
r = transfer rate
b = file size (Mb)
t = time (s)

Conversion from power (mW) into power (dBm);

$$power(dBm) = 10\log_{10}\frac{power\ (mW)}{1mW} \quad (2)$$

During testing, there must be no disturbance at the line of sight (LOS) of transmitter and receiver to achieved best result from the testing.

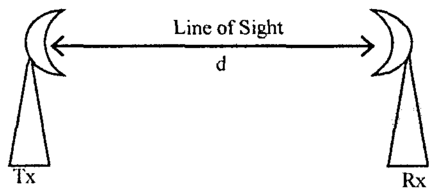


Fig. 8 Line of Sight between Transmitter and Receiver

II. RESULT & DISCUSSION

The testing results obtained through the AirOS firmware is recorded and tabulate as below.

A. Result: Defected Ground Structure(DGS) antenna

Conventional Antenna as Transmitter

From table 3, the transfer time for 16.6Mb and 369Mb file is reduce as the output power increase. This shows that the higher the output power, the faster the file transferred from transmitter to receiver. The time will increase over distance. From the tabulated data, it can be seen that the time taken to transfer both file is inversely proportional to output power.

TABLE 3. Signal strength and time taken to transfer file by using conventional antenna as transmitter

Distance (m)	Bullet Output Power (dBm)	Signal link strength (dBm)	Time taken to transfer files (s)	
			16.6MB	*369MB*
1	5	-53	7.1	192
	10	-39	6.63	138
	15	-31	6.23	129
	20	-29	4.95	119
5	5	-71	6.59	149
	10	-57	4.9	100
	15	-53	4.71	93
	20	-46	4.68	92
10	5	-68	9.24	150
	10	-54	6.08	89
	15	-50	4.58	86
	20	-43	4.33	83
15	5	-71	8.1	166
	10	-58	6.97	165
	15	-53	4.62	134
	20	-44	4.3	99
20	5	-82	14.65	295
	10	-72	7.04	112
	15	-66	6.49	101
	20	-58	5.75	89

Table 4 shows the transfer rate for both files from the local to remote host. The transfer rate was increased over the increasing of output power and was decreased over a different distance. From the above data, it can be concluded that the transfer rate is directly proportional to output power applied but inversely proportional to distance.

TABLE 4. Transfer rate of conventional antenna as transmitter

Distance (m)	Bullet Output Power (dBm)	Signal link strength (dBm)	Transfer rate (Mbps)	
			16.6MB	*16.6MB*
1	5	-53	1.34	1.34
	10	-39	2.50	2.50
	15	-31	2.69	2.69
	20	-29	2.93	2.93
5	5	-71	2.13	2.13
	10	-57	2.42	2.42
	15	-53	3.88	3.88
	20	-46	3.94	3.94
10	5	-68	1.89	1.89
	10	-54	3.61	3.61
	15	-50	3.66	3.66
	20	-43	3.85	3.85
15	5	-71	2.09	2.09
	10	-58	2.99	2.99
	15	-53	3.14	3.14
	20	-44	3.62	3.62
20	5	-82	1.13	1.13
	10	-72	3.04	3.04
	15	-66	3.15	3.15
	20	-58	3.16	3.16

Metamaterial Antenna as Transmitter

Table 5 shows the transfer rate for both files from the local to remote host. The transfer rate was increased over the increasing of output power and was decreased over a different distance. From the above data, it can be concluded that the transfer rate is directly proportional to output power applied but inversely proportional to distance.

The time taken will increased as the distance of transmitter from receiver is increasing. This shows that the longer the distance between the transmitter and receiver, more time will be taken to successfully transfer the file.

Table 6 shows the transfer rate when metamaterial antenna is set as the transmitter. The transfer rate was increasing significantly as the output power is increased. The transfer rate will be increase from 1 meter to 5 meter distance, but will be gradually decrease as the distance varies from 10 meter, 15 meter and 20 meter.

TABLE 5. Signal strength and time taken to transfer file by using metamaterial antenna as transmitter

Distance (m)	Bullet Output Power (dBm)	Signal link strength (dBm)	Time taken to transfer files (s)	
			16.6MB	*369MB*
1	5	-53	1.34	1.34
	10	-39	2.50	2.50
	15	-31	2.69	2.69
	20	-29	2.93	2.93
5	5	-71	2.13	2.13
	10	-57	2.42	2.42
	15	-53	3.88	3.88
	20	-46	3.94	3.94
10	5	-68	1.89	1.89
	10	-54	3.61	3.61
	15	-50	3.66	3.66
	20	-43	3.85	3.85
15	5	-71	2.09	2.09
	10	-58	2.99	2.99
	15	-53	3.14	3.14
	20	-44	3.62	3.62
20	5	-82	1.13	1.13
	10	-72	3.04	3.04
	15	-66	3.15	3.15
	20	-58	3.16	3.16

TABLE 6. Transfer rate when metamaterial antenna acts as a transmitter

Distance (m)	Bullet Output Power (dBm)	Signal link strength (dBm)	Transfer rate (Mbps)	
			16.6MB	*16.6MB*
1	5	-53	2.14	2.86
	10	-39	2.84	3.02
	15	-31	2.87	3.15
	20	-29	3.48	3.24
5	5	-71	3.03	3.45
	10	-57	3.55	3.88
	15	-53	3.58	4.10
	20	-46	3.82	4.34
10	5	-68	2.92	3.39
	10	-54	3.11	4.10
	15	-50	3.31	4.34
	20	-43	3.42	4.61
15	5	-71	2.73	3.32
	10	-58	3.44	4.19
	15	-53	3.72	4.24
	20	-44	3.82	4.61
20	5	-82	1.18	1.19
	10	-72	1.96	2.12
	15	-66	2.63	3.15
	20	-58	2.91	3.80

B. Result: Electromagnetic Band Gap (EBG) antenna

Conventional Antenna as Transmitter

Table 7 the transfer time for 16.6Mb and 369Mb file is reduce as the output power increase. This shows that the higher the output power, the faster the file transferred from transmitter to receiver. The transfer time will be decrease as the distance getting longer but at 20 meter the time taken will be increasing. It shows that at long distance the time to transfer data will consume more.

TABLE 7. Signal strength and time taken to transfer file by using conventional antenna as transmitter

Distance (m)	Bullet Output Power (dBm)	Signal link strength (dBm)	Time taken to transfer files (s)	
			16.6MB	*369MB*
1	5	-48	12.41	157
	10	-40	6.64	155
	15	-36	6.18	147
	20	-24	5.67	142
5	5	-68	7.79	118
	10	-57	6.86	94
	15	-53	4.28	94
	20	-47	4.21	85
10	5	-62	8.79	146
	10	-53	4.6	91
	15	-49	4.53	88
	20	-43	4.31	85
15	5	-66	7.93	101
	10	-56	5.55	90
	15	-52	5.29	86
	20	-47	4.59	80
20	5	-77	14.63	323
	10	-70	5.46	124
	15	-67	5.27	112
	20	-59	5.26	100

Table 8 shows the transfer rate for both files transferred from the local to remote host. The transfer rate was increased over the increasing of output power and different distance, but at 20 meter the transfer rate will be slightly decreased.

TABLE 8. Transfer rate when conventional antenna acts as a transmitter

Distance (m)	Bullet Output Power (dBm)	Signal link strength (dBm)	Transfer rate (Mbps)	
			16.6MB	*16.6MB*
1	5	-53	2.34	2.35
	10	-39	2.50	2.38
	15	-31	2.66	2.51
	20	-29	3.35	2.60
5	5	-71	2.52	3.13
	10	-57	3.39	3.93
	15	-53	3.52	3.93
	20	-46	3.55	4.34
10	5	-68	1.80	2.53
	10	-54	2.73	4.05
	15	-50	3.62	4.19
	20	-43	3.83	4.34
15	5	-71	2.05	3.65
	10	-58	2.38	4.10
	15	-53	3.59	4.29
	20	-44	3.86	4.61
20	5	-82	1.13	1.14
	10	-72	2.36	2.98
	15	-66	2.56	3.29
	20	-58	2.89	3.69

Metamaterial Antenna as Transmitter

Table 9 shows that the time duration decreasing as the output power was increasing. This shows that the higher the output power is selected, the faster the file can be transferred at the same distance.

TABLE 9. Signal strength and time taken to transfer file by using metamaterial antenna as transmitter

Distance (m)	Bullet Output Power (dBm)	Signal link strength (dBm)	Time taken to transfer files (s)	
			16.6MB	*369MB*
1	5	-51	7.77	160
	10	-40	5.85	151
	15	-35	5.79	121
	20	-29	4.77	120
5	5	-69	5.47	137
	10	-54	4.68	89
	15	-49	4.64	88
	20	-44	4.35	85
10	5	-66	5.69	139
	10	-51	5.33	99
	15	-48	5.02	98
	20	-41	4.86	91
15	5	-69	6.09	347
	10	-55	4.83	229
	15	-50	4.46	223
	20	-45	4.34	126
20	5	-80	14.07	443
	10	-71	8.45	273
	15	-69	6.32	146
	20	-59	5.7	143

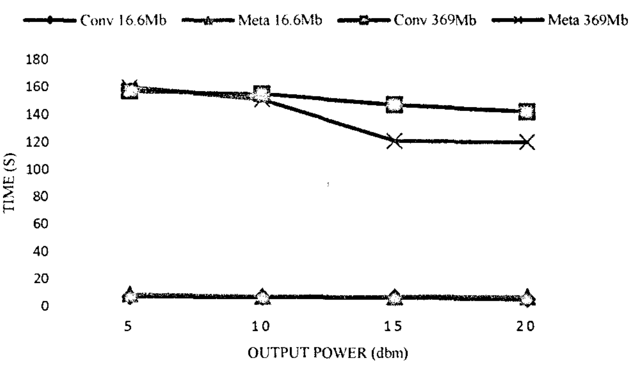
Table 10 shows the transfer rate when metamaterial antenna is set as the transmitter. The transfer rate was increasing significantly as the output power and distance is increased. But at 20 meter, the transfer rate will be gradually decresing.

TABLE 10. Transfer rate when metamaterial antenna acts as a transmitter

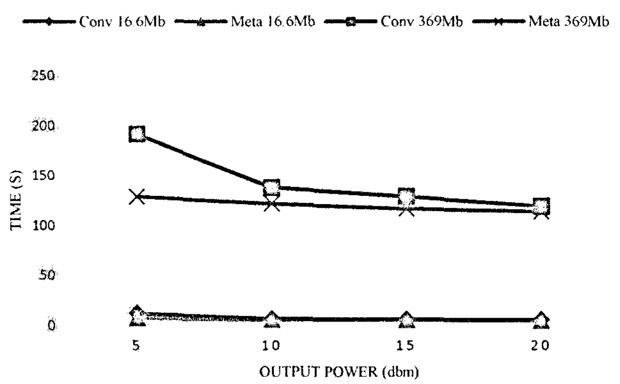
Distance (m)	Bullet Output Power (dBm)	Signal link strength (dBm)	Transfer rate (Mbps)	
			16.6MB	*16.6MB*
1	5	-53	2.34	2.35
	10	-39	2.50	2.38
	15	-31	2.66	2.51
	20	-29	3.35	2.60
5	5	-71	2.52	3.13
	10	-57	3.39	3.93
	15	-53	3.52	3.93
	20	-46	3.55	4.34
10	5	-68	1.80	2.53
	10	-54	2.73	4.05
	15	-50	3.62	4.19
	20	-43	3.83	4.34
15	5	-71	2.05	3.65
	10	-58	2.38	4.10
	15	-53	3.59	4.29
	20	-44	3.86	4.61
20	5	-82	1.13	1.14
	10	-72	2.36	2.98
	15	-66	2.56	3.29
	20	-58	2.89	3.69

C. Time taken for Conventional and Metamaterial antenna to Transfer File

Fig. 9a and 9b below shows the comparison of the time taken for file transfer using conventional antenna and metamaterial antenna for 1 meter distance. From the graph, it can be seen that the time taken for 16.6Mb file transfer for both DGS antenna and EBG antenna have not much difference. Meanwhile, for 369Mb data transfer using metamaterial antenna as the transmitter is much faster than using conventional antenna. It can be said that at 1 meter distance, metamaterial has better performance than conventional antenna.



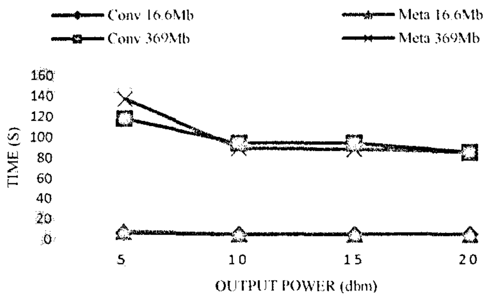
(a)



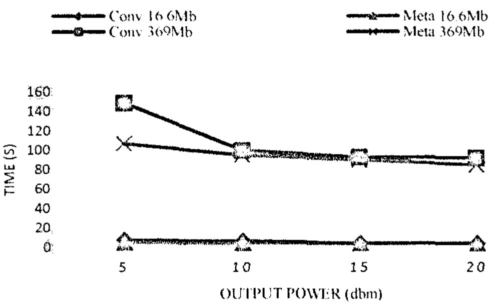
(b)

Fig. 9 Time taken to Transfer file at 1 meter
(a)Comparison between conventional and metamaterial DGS antenna
(b) Comparison between conventional and metamaterial EBG antenna

Fig. 10a and 10b, the time taken for 16.6Mb and 369Mb file transfer for both DGS antenna and EBG antenna also have not much difference same as 1 meter distance. While for 369Mb data transfer using metamaterial antenna as the transmitter show slightly faster time taken than using conventional antenna.



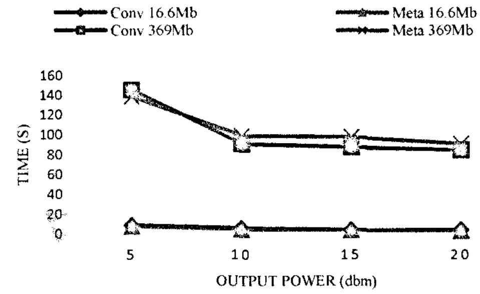
(a)



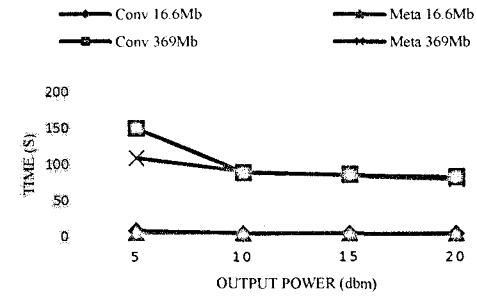
(b)

Fig. 10 Time taken to Transfer file at 5 meter
(a)Comparison between conventional and metamaterial DGS antenna
(b) Comparison between conventional and metamaterial EBG antenna

Fig. 11a and 11b shows that file transfer duration for 10 meter distance. The time taken for 16.6Mb and 369Mb file transfer for both DGS antenna and EBG antenna still have not much difference from the 5 meter distance. For 365Mb file, time taken to transfer file for DGS is better at low output power 5dBm, but as the output power increasing conventional antenna have better performance. While EBG shows a better performance compare to conventional antenna for varies distance.



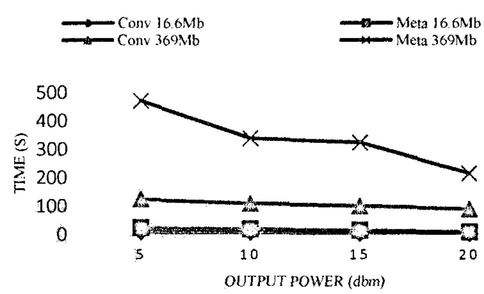
(a)



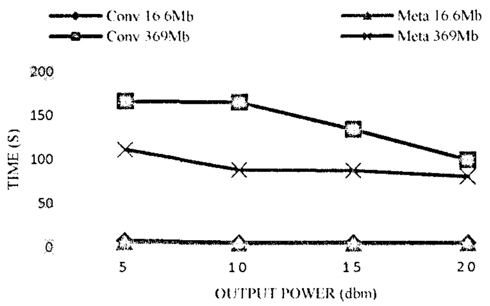
(b)

Fig. 11 Time taken to Transfer file at 10 meter
(a)Comparison between conventional and metamaterial DGS antenna
(b) Comparison between conventional and metamaterial EBG

Fig. 12a and 12b shows that for 16.6Mb file transfer the time taken is almost the same over varies distance for conventional and metamaterial antennas. But, there is a huge difference for the time taken to transfer file for 369Mb file transfer. The conventional antenna is faster compared to DGS antenna due to higher signal strength of conventional antenna. While EBG antenna transfer time for 369Mb file faster than conventional antenna based on the graph.



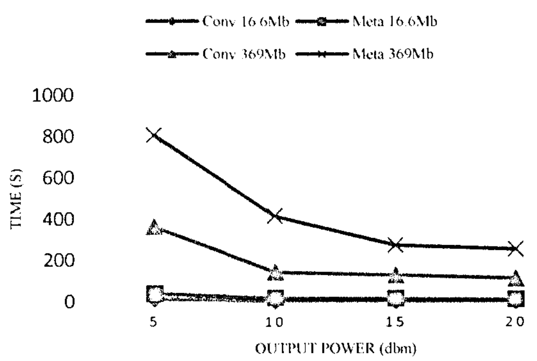
(a)



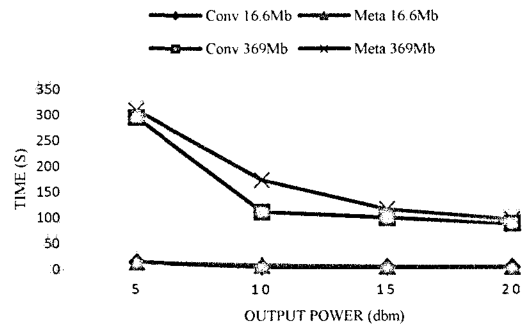
(b)

Fig. 12 Time taken to Transfer file at 15 meter
(a)Comparison between conventional and metamaterial DGS antenna
(b) Comparison between conventional and metamaterial EBG antenna

Fig. 13a and 13b shows the duration of file transfer at 20 meter distance. The time duration for 16.6Mb have no difference same as other distance 1 meter, 5 meter. 10 meter and 15 meter.. The conventional antenna is faster compared to metamaterial antenna for 369Mb file transfer. This mean that conventional antenna work better at longer distance than metamaterial antenna.



(a)



(b)

Fig. 13 Time taken to Transfer file at 20 meter
(a)Comparison between conventional and metamaterial DGS antenna
(b) Comparison between conventional and metamaterial EBG antenna

III. CONCLUSION

In this paper, two conventional and metamaterial antennas have been tested in term of signal strength, file transfer rate and time taken to transfer different file size. It can be concluded that the metamaterial is best used in short distance while the conventional can transmit up to 20 meters and still maintaining good signal quality. The performance of the conventional antenna is better than metamaterial antenna in term of signal strength and its ability to transfer small and medium sized data in shorter time. At 20 meter, both antenna is still working with the same signal strength -58 dBm but conventional antenna have higher transfer rate which is 3.16 Mbps and 2.89 Mbps (16.6Mb) and 3.16 Mbps and 3.69 Mbps (369Mb) compare to DGS antenna 2.91 Mbps (16.6Mb) 3.8 Mbps (369Mb) and also EBG antenna 2.89 Mbps (16.6Mb) and 3.69 Mbps (369Mb). Conventional antenna also better than metamaterial antenna in term of time taken to transfer the file which is 5.75 second and 5.26 second (16.6Mb) and 89 second and 100 second (369Mb) compared to metamaterial antenna which is 7.83 second and 5.7 second (16.6Mb) and 143 second and 143 second (369Mb). From the data it can also be conclude that EBG antenna is better than DGS antenna because it have higher signal strength and can transfer file in shorter time compare to DGS antenna.. The market value of the antenna is added by carry out the performance. The testing and comparison were met the objectives of this study.

IV. FUTURE DEVELOPMENT

Some improvements can be done to improve the testing method for the future research. The line of sight must be free of physical obstruction so that the signal received by the receiver antenna can be maximize and the interference can be minimized. To get a better result, the testing can be done at higher place so that any reflected noise can be minimized. Different device with higher range of distance also should be use so that the maximum distance of the antenna can be operated can be determined. The testing also can be done in an area with low wireless network densities, as Radio frequency can affect signal quality.

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