Design of Directional, High Bandwidth, High Gain Antenna for 2.4 GHz WiFi Data Card

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Abstract: **With increase in the automation and communication in our daily life, wireless technology has evolved a lot. For this reason, WiFi technology has also received a lot of attention from scientists and engineers from various domains. Miniaturization of WiFi transceivers has also lead to the researches in reducing the size of antennas involved. The work here targets wall mounted mini WiFi access points commonly available nowadays. Present work designs an antenna that is small in size and is also at the same time very good in its performance. It has always been a challenge for antenna designers to improve gain and bandwidth at the same time. This antenna design manages to achieve very good gain and bandwidth. The antenna design is inspired from parasitic antennas. It is a directional antenna with operating frequency ranging from 2.32 GHz to 3.32 GHz. Bandwidth of 1 GHz is achieved. Maximum gain is more than 5 dB.**

Keywords: **Quasi-Yagi, return loss, input impedance, VSWR, Directionality, front to back ratio.**

1. Introduction

IEEE 802.11 protocol has allotted 2.4 GHz band as the commercial band for Wi-Fi. WLAN used under 2.4 GHz is developed in the name of 802.11 b/g/n. 802.11b uses 4 non overlapping channels of channel width of 22 MHz. It uses DSSS (Direct Sequence Spread Spectrum) as the modulation technique. There is another version 802.11g uses 4 channels of 20 MHz each with 16.25 MHz used by sub-carriers. Orthogonal Frequency Division Multiplexing (OFDM) is used as a digital multi-carrier modulation method. 802.11n uses OFDM with 2 channels each 40 MHz channel width. 33.75 is used by sub-carriers.

The widespread use of 2.4 GHz for Wi-Fi all over the world is the reason why this work concentrates on this band. This paper successfully designs an antenna that achieves a bandwidth of 1 GHz over 2.4 GHz band. Nowadays, mini data card/dongle are used that can be plugged in on any power source. It takes internet from any wireless source like 3G GSM, CDMA EVDO or 4G LTE and distributes it through Wi-Fi transmitter. Problem with these Wi-Fi transceivers is that they are small in size and still they have to cover the area of a house. Since traditionally antennas in these data card are omnidirectional they have to be placed at the center of the home.

The antenna designed in this work is a Yagi inspired directional that has high bandwidth and good gain. If used in a Wi-Fi data card it can be placed at one end of the house and complete coverage is expected. Moreover directional antenna tend to have more bandwidth and gain.

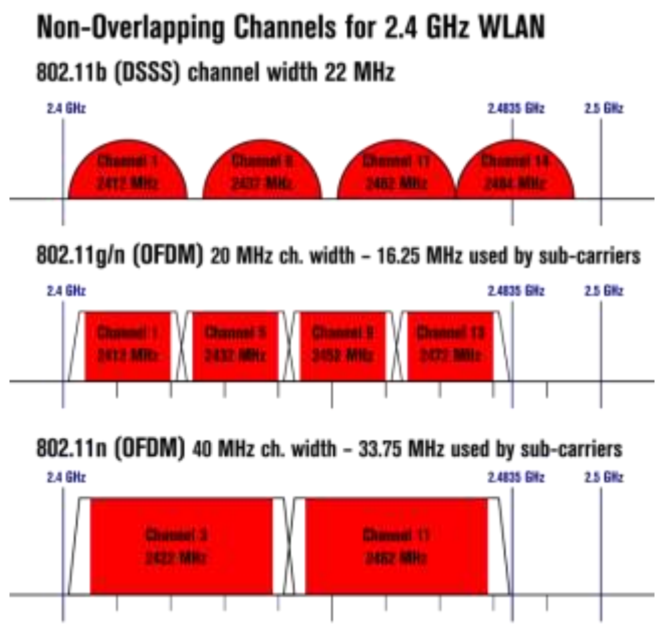


Fig. 1 Non Overlapping Channels for 2.4 GHz WLAN

2. Antenna Design

The substrate used is Roger RT/duroid 5880 of 0.8 mm thickness. There is an L–section on each side of the substrate, making it a two sided dipole with length L_L = 24 mm and L_W = 25 mm. One side also contains a ground plane. Ground plane here acts as a reflector. Length of reflector on both side of the dipole is R_L = 29 mm. Width of the reflector strip is R_W = 6 mm. The feed line is attached to the centre of this reflector. A niche is cut at the centre of the reflector to make an inset of dimension N_L = N_W = 3 mm (Fig. 2). There are 3 directors after dipole at a separation of 1 mm. Width of the dipole is 4 mm each. Lengths of the directors are D_1 = 35 mm, D_2 = 32 mm and D_3 = 27 mm. Designed antenna is an end-fire antenna. It is apparent from the components of the designed antenna that it is inspired from Yagi Uda design. However, it differs from the Yagi Uda antenna in that it is able to produce an end fire radiation pattern by using the grounded portion of the antenna substrate as the reflecting element rather than relying on an additional reflector dipole or metal plate, making the overall structure compact in size.

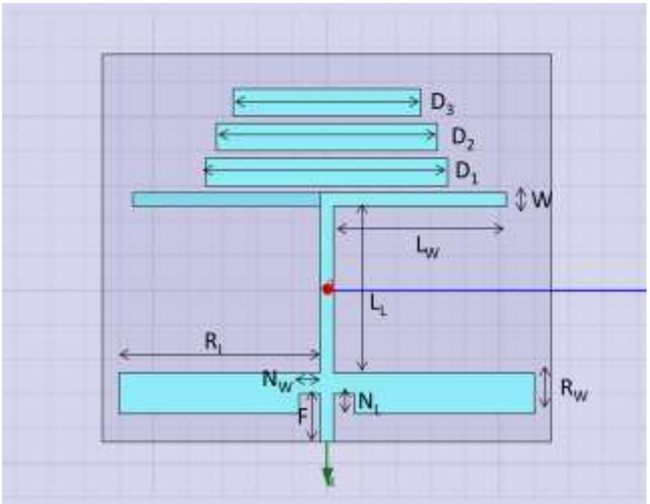


Fig. 2 Dimensions of the designed antenna

Table 1 Dimensions of the designed antenna

Dimension	Size (mm)
R_W (Length of reflector)	6
R_L (Width of the reflector)	29
N_W (Width of the niche)	3
N_L (Length of the niche)	3
F (Length of the feed line)	7
L_L (Horizontal length of the L-section)	24
L_W (Vertical length of the L-section)	25
W (Width of the L-section)	2
D1 (Length of the director 1)	35
D2 (Length of the director 2)	32
D3 (Length of the director 3)	27
D_W (Width of all director strips)	4

3. Working of the Antenna

The designed antenna is a Microstrip line fed planar antenna. Dipole strips on both the side of the substrate guide the electromagnetic wave from the feed point to the end of the structure. The length of the dipole here plays a very important role in impedance matching. The niche made at the feed point adds up to impedance matching process. The large ground plane attached to one of the dipole acts as a reflector. Parasitic elements etched near the antenna are called directors. These directors induce electromagnetic wave from the active antenna and radiate in turn. This effect makes the radiation pattern directional. Fig 3 shows how the electric field starts from the feed and reaches till the tip of the L-section. Further induction of the em waves on the director can also be seen. Colored spectrum in Fig 3 shows the intensity of electric field at different spots on antenna surface. Red color is the highest intensity and blue color being the lowest intensity.

Highest electric field intensity is 2.317×10^4 V/m.

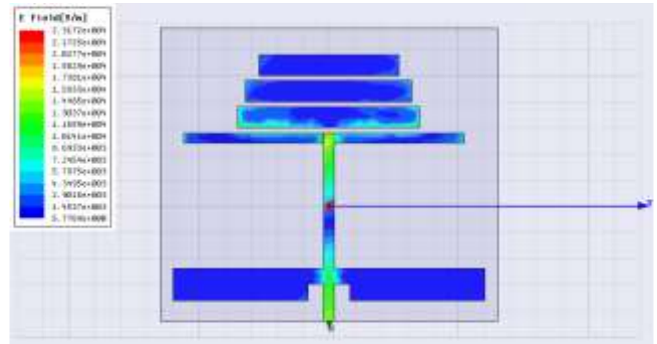


Fig. 3 Electric field distribution over the antenna

4. Simulation results

Design and simulation are done on HFSS 11.1.1. It is one of the many standard EM-CAD tools.

A. Return loss (S11)

The designed antenna operates at 2.32 GHz to 3.32 GHz The lowest value of return loss is approximately -21 dB.

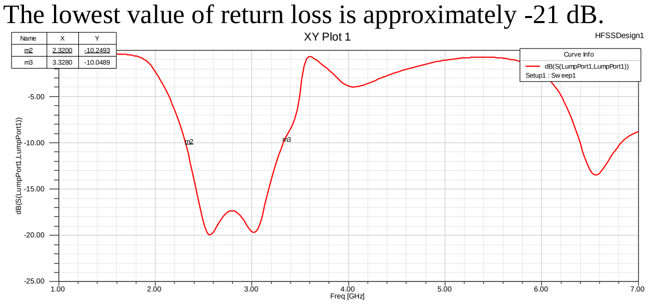


Fig. 4 Bandwidth

B. Bandwidth

Fig 4 shows the operating bandwidth of the designed antenna. Bandwidth is traditionally measured in return loss graph between the two intersections of -10 dB with return loss. The bandwidth of the antenna is 1 GHz.

C. Input Impedance

The input impedance of the antenna is 50 ohm approximately. Input impedance is 50 ohms over the entire operating frequency. So impedance bandwidth is also good.

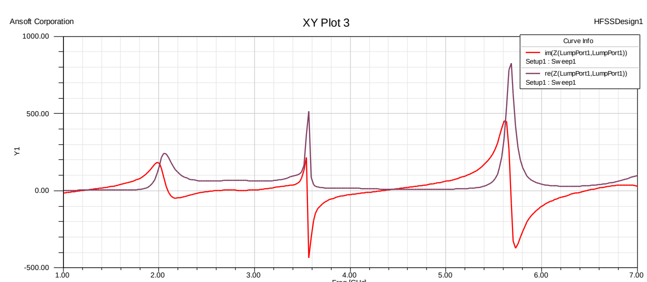


Fig. 5 Input Impedance

D. VSWR

Voltage standing wave ratio tells how much of supplied power is actually utilized. It should be as close to 1 as possible. The minimum value of VSWR for the present work it is 1.2.

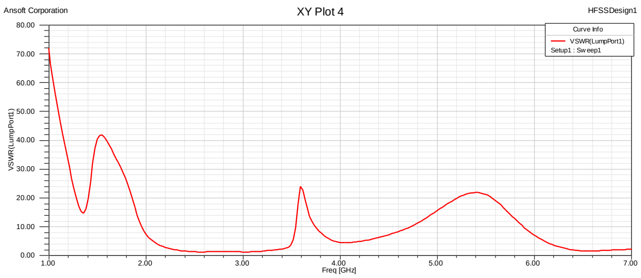


Fig. 6 VSWR

E. Radiation Pattern

Radiation pattern of the present antenna is end fire because it is a parasitic array based antenna. The radiation pattern is directional and pulled towards directors. Fig 7 and 8 show the 2D and 3D radiation pattern respectively. 3D radiation pattern also shows that maximum gain is 5.38 dBi.

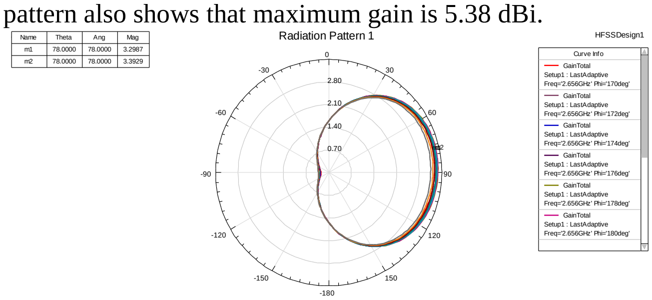


Fig. 7 2D radiation pattern

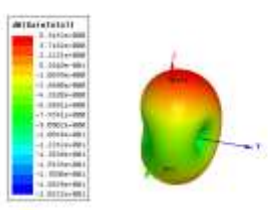
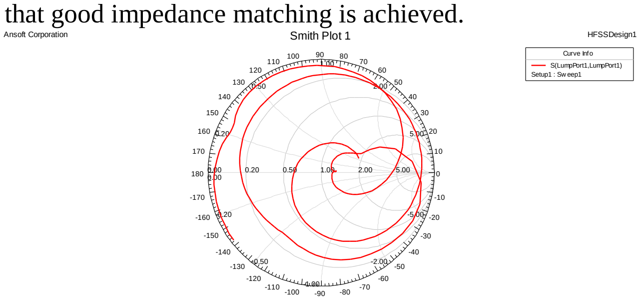


Fig. 8 3D radiation pattern

F. Smith Chart

Smith chart is used to show the normalized input impedance of the antenna over the frequency sweep. The circulation of graph in a spiral shape around center shows that good impedance matching is achieved.



5. Conclusion

The work presented here is the simulation of a 2.4 GHz antenna for Wi-Fi access points. It achieves very good impedance, return loss and gain over a bandwidth of 1 GHz. Front to back ratio of the antenna is 1.24 and directivity of the antenna is 1.85.

6. References

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