

Four-port printed MIMO Dipole Antennas at Wi-Fi 6E/7 Bands for Wireless Modem Applications

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Abstract—A design of four-port MIMO (multiple-input multiple-output) dipole antennas at Wi-Fi 6E/7 bands (2.4 - 2.484 GHz, 5.15 - 7.125 GHz) for wireless modem applications is proposed. The printed dipole is printed on an FR4 substrate with a dielectric constant of 4.4, a thickness of 1.6 mm and a loss tangent of 0.0245. Positioned around the base plate, four printed dipole antennas are employed. The dipole antenna consists of a two-arm dipole and a parasitic C-shaped strip. The dipole is excited by a mini-cable. The two-arm dipole antenna is responsible for exciting Wi-Fi 6E/7 bands and enhancing low-frequency matching by using a parasitic C-shaped strip around the two-arm dipole. The dipole antenna with a reflector improves antenna gain and directivity. The distance between the dipole antenna and the reflector is 15.625mm. The overall dimensions of the design are 123.2 mm x 81.6 mm x 71.6 mm. From the measured results, The S parameters within the frequency bands are all lower than -10dB, and the measured isolation parameters are all lower than -15dB. The simulated gain falls within the range of 3.6 - 4dBi for low frequencies and 4.1 - 6.4dBi for high frequencies. The design exhibits good performances is good for wireless modem applications at the Wi-Fi 6E/7 bands.

Keywords—Dipole antennas, Wi-Fi 6E/7, Wireless modem, MIMO antennas

I. INTRODUCTION

Dipole antenna is with its simple structure, omnidirectional radiation, and property of against interference from external objects, which is well known in wireless applications. In recent years, wireless network modems [1] have gained popularity as a product combining modem and router functionalities. The wireless modem needs more frequency bands and high transmission rate. Therefore, it is need of wireless modem with MIMO technology and Wi-Fi 6E/7 application bands.

There are several dipole antennas [1-6] for wireless applications published. The papers of Ref. [1-2] are single-port WLAN antennas. The design [1] enhances antenna matching and achieves the frequency band of WLAN 2.4GHz through a U-shaped path for wireless modem application. The design [2] improves the low and high-frequency bandwidth by using two vertical metal plates on both sides of the antenna, with good antenna gains of about 7dBi for 2.4 GHz and 5 GHz bands. The designs of Ref. [3-4] are MIMO WLAN antennas with vertically

placement. The study of Ref. [3] adopts an F-type structure to achieve a design of 8 x 8 MIMO antennas at Wi-Fi 6E application band. The design with Sii (i = 1 to 8) are below -6dB. However, the impedance match of the design is not good enough for applications. Ref. [4] employs a three-dimensional design, where internal microstrip lines excite the external three-dimensional dipole for the Wi-Fi 6E/7 bands. Simulated results of the case show the S11 below -10dB with the operating band and with omnidirectional radiation patterns. The designs of Ref. [5-6] are MIMO antennas applied to WLAN (2.4 GHz and 5 GHz) and WiMAX (3.5 GHz) for multibeam applications. In the paper, a design of 4 x 4 MIMO antennas operated at Wi-Fi 6E/7 systems for wireless modem applications.

II. ANTENNA DESIGN

The design utilizes ANSYS HFSS for simulation and exploration of various parameters. The design is implemented on an FR4 substrate with a dielectric constant of 4.4, a loss tangent of 0.0245, and a thickness of 1.6 mm. The antenna is fed by mini-cable line. The overall view of the design is shown in Fig. 1. There are four antennas with four reflectors in the design. These antennas are positioned at the edge of the baseboard, with the overall dimensions of 123.2 mm x 81.6 mm x 71.6 mm. Fig. 2 illustrates the structure of the dipole antenna and the reflector. The reflector used in the dipole antenna enhances antenna gain and directivity, with a total size of 70 mm x 30 mm x 18.825 mm. The antenna substrate is smaller than that of the reflector substrate, and the distance between them is 15.625 mm. The two-arm dipole produces the bands of 5.2/5.8/6GHz. The antenna using a parasitic C-shaped strip achieves good impedance matching of the 2.45GHz band. The metal plate of 20mm by 3mm on the backside of the dipole antenna is used to connect with the baseboard. Fig. 3 shows the detailed structure of the parasitic C-shaped strip, which enhances low-frequency matching. Fig. 4 shows the detail structure of the dipole antenna. Table 1 summarizes the parameters of the antenna structure of the design.

Fig. 5 and 6 depict the simulation and measurement S parameters and isolation parameters for the 2-3 GHz band. From the results, it is evident that the values of S parameters are all below -10dB within the frequency band, and the antenna isolation is below -15dB. Due to antennas 2 and 3 without vertical polarization characteristics, their isolation is comparatively lower than other antennas. Fig. 7 and 8 illustrate the simulation and measurement S parameters and isolation parameters for the 5-8 GHz band. From these results, it can be observed that the S

parameter values are all below -10dB within the frequency band, and the measured isolation parameters for antennas is all below -30dB. Fig. 9 explores the S parameters with and without the parasitic C-shaped strip. From the figure, it can be observed that the design without the parasitic C-shaped strip, the matching at low-frequency does not reach the design goal. Adding the parasitic C-shaped strip on the dipole antenna can enhance low-frequency matching.

Fig. 10 depicts the simulated gain and efficiency at 2-3 GHz under Port 1 excitation. The gain is in the range of 3.6 – 4 dBi, and the efficiency ranges from 95 – 96%. In Fig. 11, depicts the simulated gain and efficiency at 4-8 GHz under Port 1 excitation. The gain is in the range of 4.1 – 6.4 dBi, and the efficiency ranges from 93 – 97%. Fig. 12 displays the simulated current distribution at 2.45 GHz under Port 1 excitation. From the image, it can be observed that the 2.45 GHz frequency is achieved through mutual coupling between the two-arm dipole and the parasitic C-shaped strip. Similarly, Fig. 13 shows the simulated current distribution at 5.15 GHz under Port 1 excitation, revealing that this frequency band is excited by the inverted L-shaped structure below the feeding point. Fig. 14 and 15 illustrate the simulated current distribution at 6.1 GHz and 7.1225 GHz under Port 1 excitation, indicating that the high-frequency components are realized through coupling between the path above the feeding point and the slot. Fig. 16 to 19 plot the simulated 3D radiation patterns at various frequencies (2.45 GHz, 5.15 GHz, 6.1 GHz, and 7.1225 GHz) under Port 1 excitation. From these figures, it can be found that the radiation is suitable for application of wireless modem application. And, the radiation patterns are oriented in the negative Y direction for all frequency bands.

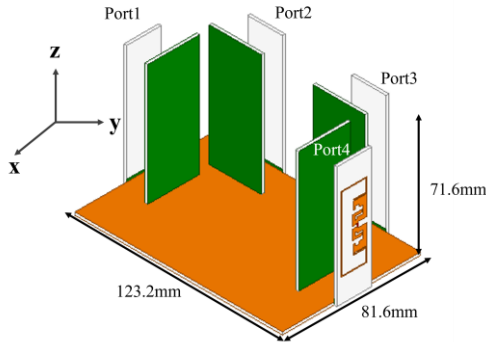


Fig. 1. Overall view of the design

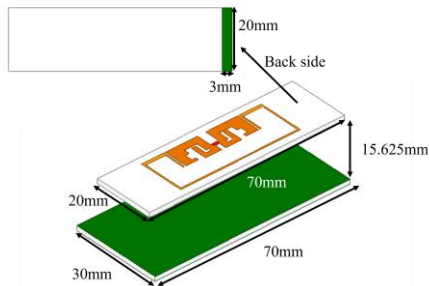


Fig. 2. Structure of a dipole antenna with a reflector

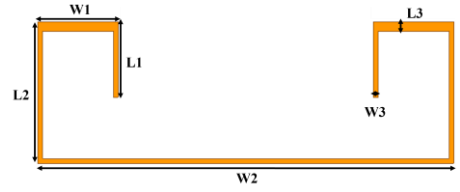


Fig. 3. Detailed structure of the parasitic C-shaped strip

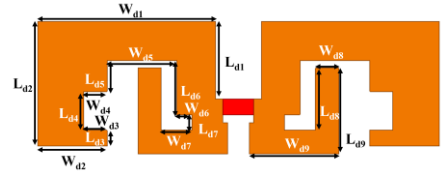


Fig. 4. Detail structure of the dipole antenna

Table 1. Summarizes the parameters of the antenna

Parameter	W1	W2	W3	W _{d1}	W _{d2}	W _{d3}
Unit (mm)	8.5	43	0.5	11.5	4.5	1.5
Parameter	W _{d4}	W _{d5}	W _{d6}	W _{d7}	W _{d8}	W _{d9}
Unit (mm)	1.5	4.5	1	2	1.5	5.8
Parameter	L1	L2	L3	L _{d1}	L _{d2}	L _{d3}
Unit (mm)	8	15	1	5	8	1
Parameter	L _{d4}	L _{d5}	L _{d6}	L _{d7}	L _{d8}	L _{d9}
Unit (mm)	2.5	2	3.5	1	4	5.5

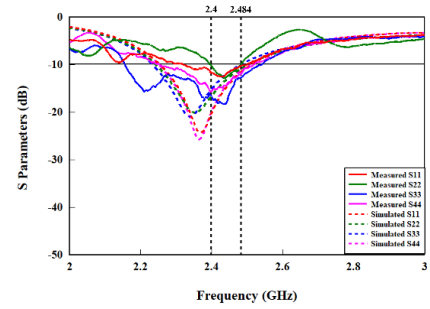


Fig. 5. Simulation and measurement Sii parameters (when i=1-4) of the design at 2-3 GHz band

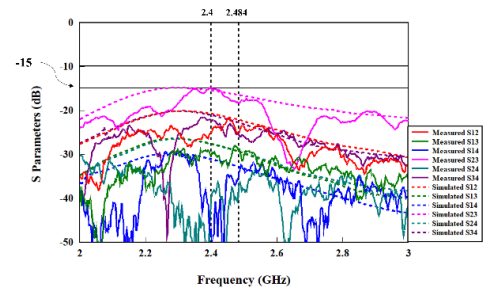


Fig. 6. Simulation and measurement isolation parameters of the design at 2-3 GHz band

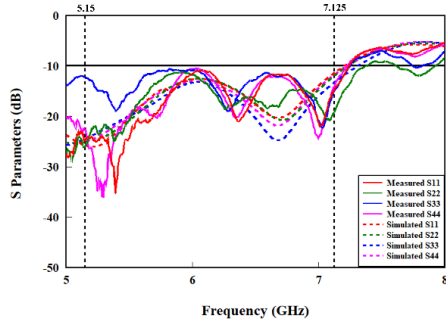


Fig. 7. Simulation and measurement Sii parameters (when $i = 1-4$) of the design at 5-8 GHz band

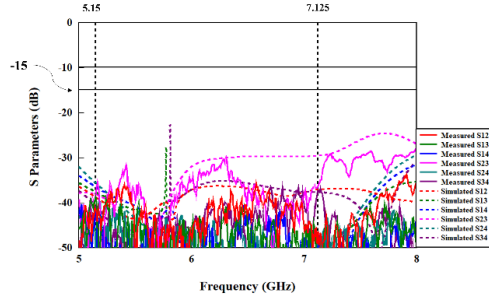


Fig. 8. Simulation and measurement isolation parameters of the design at 5-8 GHz band

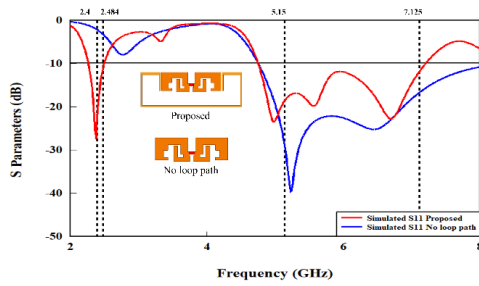


Fig. 9. Simulated S11 parameters with and without the parasitic C-shaped strip

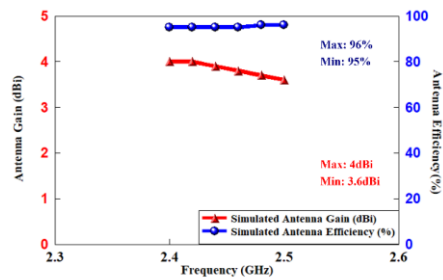


Fig 10. Simulated gain and efficiency at 2-3 GHz under Port 1 excitation

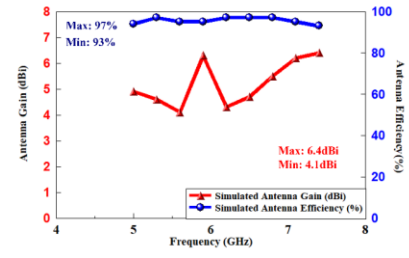


Fig. 11. Simulated gain and efficiency at 4-8 GHz under Port 1 excitation

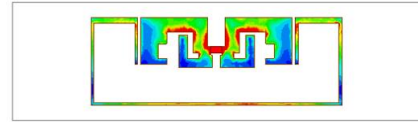


Fig. 12. Simulated current distribution at 2.45 GHz under Port 1 excitation

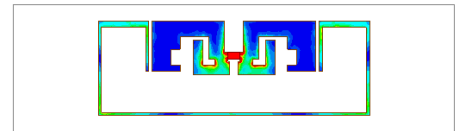


Fig. 13. Simulated current distribution at 5.15 GHz under Port 1 excitation

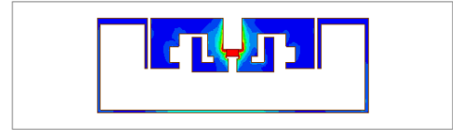


Fig. 14. Simulated current distribution at 6.1 GHz under Port 1 excitation

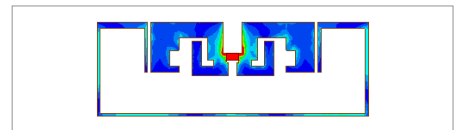


Fig. 15. Simulated current distribution at 7.1225 GHz under Port 1 excitation

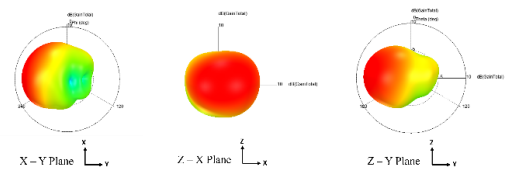


Fig. 16. Simulated 3D Radiation patterns at 2.45 GHz under Port 1 excitation

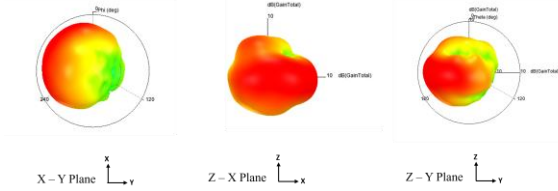


Fig. 17. Simulated 3D Radiation patterns at 5.15 GHz under Port 1 excitation

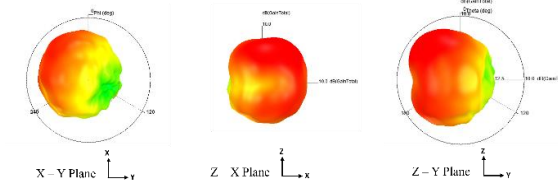


Fig. 18. Simulated 3D Radiation patterns at 6.1 GHz under Port 1 excitation

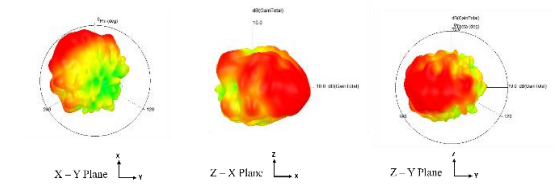


Fig. 19. Simulated 3D Radiation patterns at 7.1225 GHz under Port 1 excitation

A design of four-port printed MIMO dipole antennas at Wi-Fi 6E/7 bands (2.4 - 2.484 GHz, 5.15 - 7.125 GHz) for wireless modem application has been proposed. There are four dipole antennas with four reflectors in the design. The antenna design utilizes dipole antenna to cover the operating bands, and a parasitic C-shaped strip is employed to achieve impedance matching at lower frequencies. The simulated gain of the antenna at lower frequencies ranges from 3.6 to 4dBi, with an efficiency range of 95 to 96%. At higher frequencies, the simulated gain is between 4.1 and 6.4dBi, with an efficiency range of 93 to 97%. The addition of introduction reflectors on the design is implemented to enhance the antenna's gain and directivity. This design is suitable for wireless modem applications in Wi-Fi 6E/7 networks.

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