Development of Dual-Frequency CPW-fed Monopole Antennas on the Al_2O_3 Substrates

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Introduction

In the last few years, the development of the communication products was quite fast, and the main requirements of the peripheral consumption products are miniaturization, low profile, low cost, and multi-band operation. Comparing to other kinds of microstrip line devices, the coplanar waveguide (CPW) devices exhibit better advantages such as low radiation loss, less dissipation, uni-planar configuration, easy to integrate with RF or other microwave components, and enabling a miniature hybrid or monolithic microwave integrated circuit (MMICs) [1]. From the previous reports about the dual-frequency monopole antenna with rectangular notch that fed by CPW [2-3], the use of a rectangular notch could change the surface current path, and hence the antennas with dual-frequency operations could be obtained.

In Ref. [4], two various lengths of the CPW-fed monopole antenna were used to accomplish the dual-frequency operations. In Ref. [5], different electric lengths were adopted to reach the multi-band applications. In [6], the authors used various meandered current paths to reach the multi-band operations of a CPW-fed monopole antenna, and that did not influence the characteristics of the fabricated antennas by removing half of the ground plane. In this paper, a novel and simple type of CPW-fed dual-frequency monopole antenna is proposed. The most CPW antenna was designed on the FR4 substrate (ε_r=4.2) and it would take a larger area. For the purpose of miniaturization, Al_2O_3 ceramics with the higher dielectric constant of ε_r=9.8 were used as the substrates of the designed antennas. Because of high quality factor (Q×f= 300,000, the Al_2O_3 ceramics is hard to design the high bandwidth (BW, -10 dB measured from the return loss (S_{11}) value) and with high S_{11} value, and that let the antenna is suitable for the applications of wireless local area network (WLAN) IEEE 802.11b/g (2400~2484 MHz) and IEEE 802.11a (5150~5350 MHz).

Antenna Design and Fabrication

The width of the signal strip, the gap spacing between the signal strip, and the coplanar ground plane were all computed to match 50Ω. The performances of the antenna were simulated by high-frequency structure simulator (HFSS), and the mask was done according to the simulated patterns. The antenna patterns were printed on the Al_2O_3 ceramic substrates by the screen-print technology, and then the printed patterns were fired at 800^{o}C for 30min. Finally, SMA connectors were soldered to the feed points of the antennas, and the return losses were measured by a network analyzer (Agilent N5230A) and the radiation characteristics and gain were measured in the chamber. The geometry of the designed dual-frequency CPW-fed monopole antenna is shown in Fig. 1. It just like an empty rectangle metal covering and with four rectangular disturbed elements at four corners. The thickness of Al_2O_3 ceramic substrate is 1 mm. The parameters of L_3, L_4 and W_4 will be changed to find

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the optimal characteristics of designed antennas, and other parameters are fixed as the detailed dimensions listed in Table I (in millimeters).

Simulated and Measured Results and Discussion

Figure. 2 shows the simulated results due to the variation of the disturbed element of W_4, where the length of L_4 is fixed at 5.2 mm and the length of W_4 is changed. As the length of W_4 increases from 1.6mm to 2.0mm, the BW value of the second resonant frequency (f_H), the value of f_H and the maximum return loss (S_{11}) increase from 4%, 5.22GHz and -17.46 dB to 4.2%, 5.25GHz and -20.49 dB. Further increasing the length of W_4 to 2.4mm, the BW and the value of f_H are increased to 4.71% and 5.53GHz, the S_{11} value is decreased to -14.68dB. However, for first resonant frequency (f_L), the BW, the value of f_L and the S_{11} value are almost unchanged as the length of W_4 is changed. Therefore, the length of W_4 is an important inference factor on the characteristics of f_H.

Table II shows the influences of the length of L_4 on the characteristics of f_H, and W_4 is fixed at 2 mm. From the simulated results, for the characteristics of f_L, the BW, the value of f_L and the S_{11} value are also unchanged as the length of L_4 is changed. Table II shows the S_{11} characteristics for f_H, the BW, the value of f_H and the S_{11} value have little changes as the length of L_4 is increased. The results shown in Fig.1 and Table II have the important inferences that the disturbed elements of L_4 and W_4 have no apparent influences on the characteristics of f_L and have slight influences on the characteristics of f_H. Therefore, the errors of L_4 and W_4 in the fabricated procedures would not have apparent influence on the characteristics of the fabricated antennas. From the simulated results, the optimal lengths for L_4 and W_4 are 5.2mm and 2mm, respectively.

Figure. 3 shows the inferences of the simulated results due to the variation of the length of the ground planes L_3, and W_3, L_4 and W_4 are fixed at 8 mm, 5.2mm and 2mm, respectively. As the length of L_3 is increased from 3.5mm to 4mm and 4.5mm, the value of f_L increases from 2.31GHz to 2.35GHz and 2.36GHz, the maximum S_{11} value of f_L increases from -15.93dB to -18.67dB and -20.91dB, and the BW value of f_L increases from 28.6% to 31.1% and 31.3%, respectively. Figure.3 also shows that as the length of L_3 is increased from 3.5mm to 4mm and 4.5mm, the value of f_H and the BW value of f_H are and almost unchanged, he maximum S_{11} value of f_H decreases from -23.35dB to -20.49dB and -18.19dB. Using FR4 as the substrates, the variations of the lengths of disturbed elements and ground plane would have large influences on the characteristics of dual-band antennas. But in this study, using Al_2O_3 ceramic as the substrate and after finding the parameters for the design of CPW dual-band antennas, the variations of the lengths of disturbed elements and ground plane have no large influences on the characteristics of CPW dual-band antennas.

The optimal parameters of L_3, L_4 and W_4 are 4mm, 5.2mm and 2mm, respectively. The size for the proposed dual-band monopole antenna is only 29 mm $\times$ 20 mm, which is much smaller than the antenna fabricated on FR4 substrate and small enough for the applications of WLAN systems. The simulated and measured results of the proposed antenna are shown in Figure. 4. The simulated and measured BW values are 15 % and 18.5% for 2.35 GHz and 4.4 % and 4.8% for 5.27 GHz, and the simulated and measured maximum S_{11} values are -18.7dB and -27.5dB for 2.35 GHz and -20.5dB and -20.1dB for 5.27 GHz, respectively. As Figure.4 shows, the measured results are good agreed with the simulated ones. As Figure.5 shows, the peak gains of F_L and F_H are 1.29 dBi and 3.96 dBi, respectively. The measured y-z plane and x-z plane patterns of the antennas are shown in Figure. 6. The radiation patterns in y-z planes are approximately omni-directional.

Conclusions

A simple and compact dual-frequency monopole antenna is presented and investigated and which is suit for the applications of WLAN IEEE802.11b/g (2400-2484 MHz) and IEEE802.11a (5150-5350 MHz). The screen-print technology is used, to print the CPW-fed dual-frequency antennas on Al_2O_3 ceramic substrates. The proposed antennas have the advantages of small size (29 mm×20 mm×1 mm), dual-frequency operation (2.4 and 5.2 GHz), good radiation characteristics (near omni-directional radiation pattern in y-z plane) and large gain (1.29 dBi at 2.35 GHz and 3.96 dBi at 5.27 GHz).

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Table I Dimensions of the proposed antenna (units in millimeters, mm).

parameter	L_1	W_1	L_2	W_2	L_3	W_3	L_4	W_4	L_5	W_f	W_s	h
value	29	20	12	10	3.5~4.5	8	4.9~5.5	1.6~2.4	11.5	1	1.5	1

Table II Simulated results due to the variations of L_4, W_4 is fixed at 2 mm.

Disturbed Element (L_4 mm×W_4 mm)	f_H(GHz)	Return Loss (f_H) (dB)	BW (f_H)(%)
4.9×2	5.27	–20.52	4.37
5.2×2	5.25	–20.49	4.2
5.5×2	5.25	–19.83	4.2

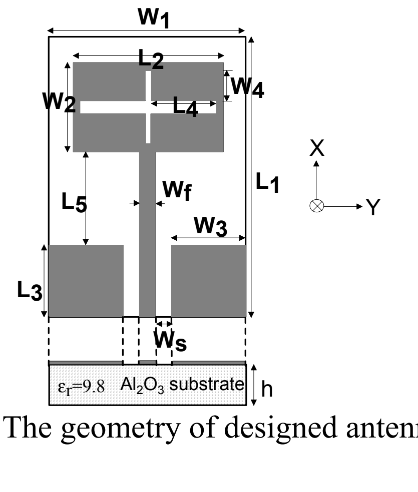


Figure 1. The geometry of designed antenna.

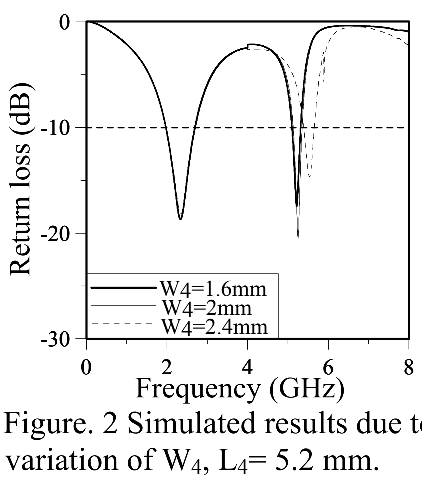


Figure. 2 Simulated results due to the variation of W_4, L_4= 5.2 mm.

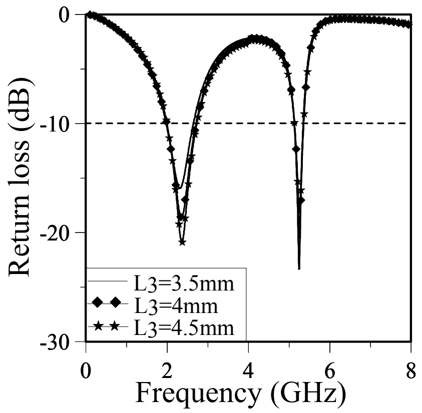


Figure. 3 Simulated results due to the variation of L_3, W_3 = 8 mm.

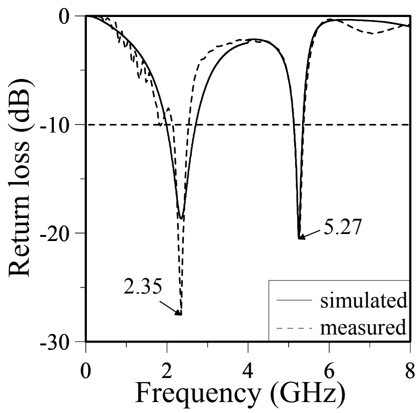
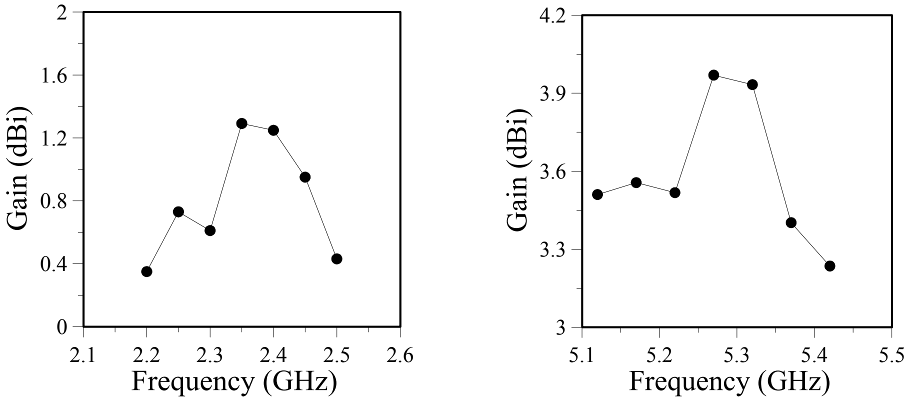
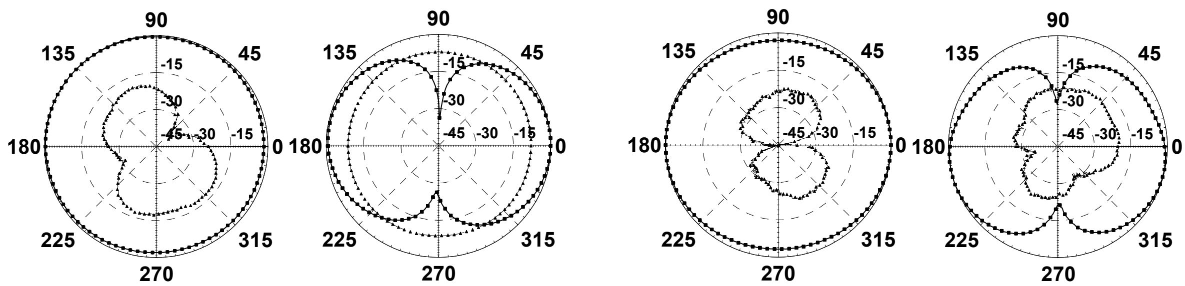


Fig. 4 Measured and simulated results of the proposed antennas.



(a) (b)

Figure. 5 Measured peak antenna gains for (a) 2.35 GHz (b) 5.27 GHz.



y-z plane (a) x-z plane y-z plane (b) x-z plane

Figure. 6 Measured y-z plane and x-z plane radiation patterns for (a) 2.35 GHz (b) 5.27 GHz.