Design and Performance of 800MHz/2GHz Dual Band Small Planar Antenna

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Abstract — We designed and fabricated electrically small antenna (ESA) with a coplanar transmission line-based matching circuit on a printed circuit board. The matching circuit is realized by applying band-pass filter (BPF). Moreover, we designed a dual band antenna by connecting two ESAs with BPF-based duplexer. Our proposed dual band antenna is designed and simulated by using commercial three-dimensional electro magnetic (EM) field simulator. Also, we fabricated this dual band antenna on FR4 substrate and measured the frequency characteristics.

Index Terms — planar antenna, slot antenna, small antenna, dual band, matching circuit, duplexer.

I. INTRODUCTION

For the minimized wireless-communication devices such as ubiquitous network systems, it becomes a problem that an antenna occupies large area. So, there are many reports about small antenna [1-2]. However, input impedance of the small antenna is much lower than the characteristic impedance of the input port of the signal source (ex. 50Ω), because the small antenna has only low radiation resistance. Difference between these two impedances causes reflection of electric power at the signal-injecting point. This type antenna needs impedance matching circuit between antenna and signal source. We already have realized the matching circuit by transmission line and interdigital gap [3-11]. The proposed matching circuits have similar performances to band pass filter (BPF). Interdigital gap and half wavelength line act the admittance inverter (J -inverter).

Dual band antenna is another approaches for size reduction of the communication devices. For example, 2GHz/5GHz bands are for wireless LAN (IEEE 802.11b, g and n/11a), and 800MHz/2GHz bands are for cellular phone. These type devices for dual band must have two antennas, which work in two frequencies. We already realized the planer type duplexer by using coplanar waveguide (CPW) and interdigital gap [12].

In this paper, we proposed a dual band planar antenna for 800MHz/2GHz bands cellular phone. The proposed antenna is composed of two small antennas with impedance matching circuits and CPW duplexer.

The size of this antenna is 25mm x 50mm and gain is 0 dBi at both frequency bands (2GHz 800MHz). At first, the design method of the small antennas with matching circuit by EM field simulator (Ansoft; HFSS ver. 10) is shown. Next, design method of dual band antenna is also shown.

Moreover, we fabricated the dual band antenna on the FR4 printed circuit board and measured the frequency characteristics.

II. SMALL ANTENNA WITH MATCHING CIRCUIT

Fig.1 shows the circuit model of a small antenna with matching circuit. This matching circuit is based on BPF [13]. In the figure, between 1-1' and 2-2' is the impedance matching circuit and L -type J inverter is composed of two capacitors C_{JL} and $-C'_{JL}$. In order to realize J inverter, $-C'_{JL}$ should have minus capacitance. However, we cannot fabricate such capacitor by applying gap. To realize the minus capacitance, we shorten the feed line (electrical length) of the antenna (left side of 1-1' in Fig.1) [9-13]. In this situation, we can realize the impedance matching of complex impedance. In Fig. 1, the right side of 2-2' is connected the coaxial cable, which has input impedance Z_0 equal 50 Ω.

Fig. 1 Circuit model of antenna with matching circuit

Fig.2 is the cross section of printed circuit board (FR4). The feed line has the coplanar waveguide (CPW). FR4 substrate has dielectric constant $\epsilon_r=4.25$ and $\tan\delta=0.015$. The thickness of the top metal and the substrate are 0.018 μm and 1.6mm.

Fig. 2 Cross section of printed board

Fig.3 shows the 800MHz-band slot antenna with impedance matching circuit. This antenna has center frequency is 850MHz in design. The antenna size is 31.8mm x 25mm included in the impedance matching circuit. In the figure, a close up of interdigital gap is also shown. The interdigital gap is the capacitor in Fig.1 (C_{IL}). The gap and coplanar line work as matching circuit, and large white area is radiation part of slot antenna.

Fig.4 shows the 2GHz antenna with impedance matching circuit. The size of this antenna is 12.4mm x 25mm.

Fig. 3 800MHz antenna with matching circuit

Fig. 4 2GHz antenna with matching circuit

III. DESIGN OF DUAL BAND ANTENNA

Fig.5 shows the circuit model of proposed dual band antenna. In the figure, the marching circuits are considered as band pass filter (BPF). Two antennas with matching circuits, which have different pass band each other, namely duplexer, are connected with signal source, respectively. When 2GHz signal is generated from the signal source, only 2GHz antenna is excited, however, 800MHz antenna is not excited because this antenna looks like open end. So this dual band antenna works as 2GHz antenna. It is similar for 800MHz.

Fig. 5. Circuit model of proposed dual band antenna.

Fig.6 shows the EM-simulated layout of 800MHz/2GHz dual band antenna. The left side of the figure is 800MHz antenna (Fig.3), and the right side of the figure is 2GHz antenna (Fig.4), respectively. The total antenna size is 25mm x 42.6mm.

Fig. 6.Layout of the 800MHz/2GHz dual band antenna.

RF signal is injected at the middle of the both antennas. Fig.7 shows the photograph of the connector we use. In order to suppress the non-equilibrium mode of the feed line, we chose the surface mount type connector (Hirose U-FL). Fig.8 shows the layout and model of the connector and coaxial cable for EM simulation.

Fig. 7. Photograph of the connector.

Fig. 8.Simulation model matching circuit, connector and coaxial cable, respectively.

Fig.9 shows the frequency versus return loss of the proposed dual band antenna. We can see the two matching frequencies at 800MHz and 2GHz, respectively, namely, this antenna works as dual band antenna. Table 1 shows the antenna parameters at 850MHz and 2GHz. The antenna gains at both frequencies are about 0dBi.

Fig. 9. Simulated frequency characteristic of dual band antenna.

Table 1. The antenna parameters at 850MHz and 2GHz.

Frequency	Radiation efficiency	Directivity	Gain
@850MHz	53.1%	2.48dBi	-0.27dBi
@2GHz	53.1%	2.86dBi	0.11dBi

Fig.10 shows the radiation patterns of the dual band antenna at 850MHz and 2GHz, respectively. We can see the dipole type radiation pattern at both frequencies, and also, no non-equilibrium radiations are shown.

Fig. 10. Simulated radiation patterns at 850MHz and 2GHz.

IV. EXPERIMENTALS AND RESULTS

We also fabricated the proposed antenna on FR4 substrate by using board making equipment (MITS; FP-21T model 40), which has 100, 200, 300 μm -diameter milling cutters. Fig.11 shows its photograph and close-up of milling section.

Fig.12 shows the photograph of the proposed dual band antenna. The connector is soldered in the middle point of both antennas.

Fig.13 shows the comparison of frequency characteristics between the simulation and experimental result. In the figure, the broken line is simulation result, and the solid line is the experimental result. There are completely similar, so we can realize the dual band planar antenna.

Fig. 11. Photograph of the Board making equipment.

Fig. 12. Photograph of the proposed dual band antenna.

Fig. 13. Experimental result of return loss of the dual band antenna.

V. CONCLUSION

In this paper, we designed and tested the dual band planar antenna with impedance matching circuit. Our antenna is composed of two antennas with different frequencies and duplexer. In this paper, the input impedance is 50Ω , but we can match the input impedance of the low noise amplifier or output impedance of the power amplifier, which have

complex impedances. Fig. 14 shows the photograph of the conventional 800MHz/2GHz dual band antenna. Table 2 shows the comparison of the conventional antenna with proposed antenna. Proposed antenna has higher antenna gain in spite of the same dimension.

Fig. 14. Photograph of the conventional 800MHz/2GHz dual band antenna.

Table 2. Comparison of the antenna properties.

	size	gain
our antenna	25mm x 42.6mm	about 0 dBi
compared antenna	25mm x 50mm	about -6 dBi

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