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Design of Internal FM Radio Antenna For Mobile Terminal

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***Abstract* - This paper presents a design of internal frequency modulation(FM) radio antenna for mobile terminal. The antenna is matched by using R, L chip component to control resonance frequency, and backside patch of the antenna is applied for exactly resonance frequency. Stubs are used for bandwidth and decrease of the antenna size. A designed antenna size is 40 x 70 mm. The return loss, the bandwidth and the impedance of a fabricated antenna are -22 dB, 89 ~ 111 MHz below -10 dB and 50 – j7 Ω, respectively. The radiation pattern is observed omni-directional one at 100 MHz, and the gain is about -17 ~ -40 dB.**

I. Introduction

According to development of wireless communication, mobile terminal markets are increased significantly over the world. Because many people use mobile terminal for communication, e-mail, mobile game, music, and etc. In addition, they demand high speed transmission as well as compact size with multiple applications such as global positioning system (GPS), camera, bluetooth, frequency modulation (FM) radio broadcasting and digital multimedia broadcasting (DMB). The antennas for GPS, satellite DMB (S-DMB), Cellular and/or personal communication service (PCS) are already developed and used for internal type. However in case of terrestrial DMB (T-DMB) and FM radio antennas, it is not developed internal type yet. Because the operating frequency of T-DMB ($\lambda/2 \approx 0.8$ m) and FM radio ($\lambda/2 \approx 1.5$ m) is very low as 174~216 MHz and 88~108 MHz, respectively[1].

Recently, it is progressing to develop internal antenna for T-DMB in companies, institutes, scholars, and etc. actually. But development of FM radio antenna for internal type is very difficult because the resonance frequency is lower than T-DMB. In this reason, general FM radio antenna is usually used by earphone type. Therefore it needs to develop FM radio antenna as well as T-DMB antenna for internal type for convenience and multi-function of mobile terminal. So in this paper, internal FM radio antenna is proposed. The antenna is matched by using R, L chip elements and stubs. Section II, III, and IV describe antenna design, measurement results, and conclusion, respectively.

II. Antenna Design

The size of conventional antenna is 40 x 80 mm because of the standard size of mobile terminal. Fundamental antenna is designed as shown in Fig. 1(a) to decrease antenna size [2][3]. This antenna characteristic is very capacitive because the impedance of antenna is 2.4 –j230 Ω at 100 MHz. According to equation (1), ± j imaginary value of impedance means that the characteristic of antenna depends on the inductive and capacitive values, respectively.

$$Z = R + jX = R + jwL - \frac{1}{jwC} \ \Omega \qquad (1)$$

Therefore the fundamental antenna is matched by using R and L chip component as shown Fig. 1(b). The values of R and L for impedance matching are 48 Ω and 215 nH, respectively.

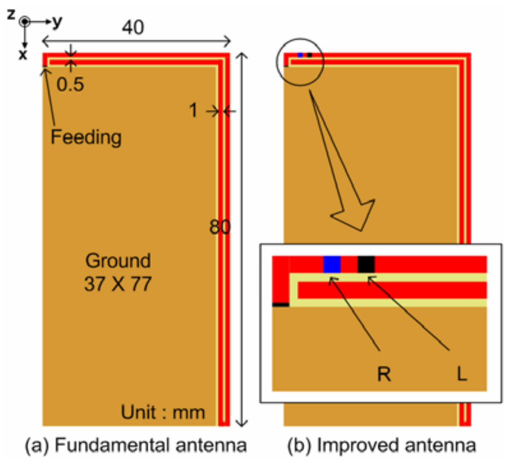

Fig. 1 Fundamental & improved antenna structure.

Fig. 2 shows the return loss of proposed antenna. In Fig. 2, dotted line is return loss of fundamental antenna and solid line is the one of improved antenna. Return loss of the improved antenna is -35 dB at 125 MHz. The impedance of antenna is 52 – j94 Ω at 100 MHz as shown Fig. 3. It means that the antenna is matched by R and L value. In other words, imaginary part of

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the impedance becomes to -j94 Ω by added L component. Real part of the impedance could be 52 Ω by R value.

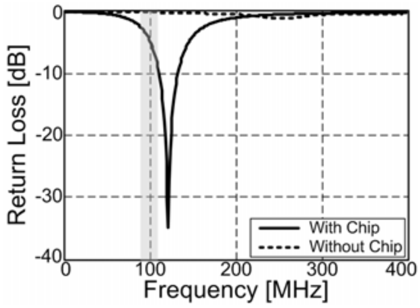


Fig. 2 The return loss of proposed antenna.

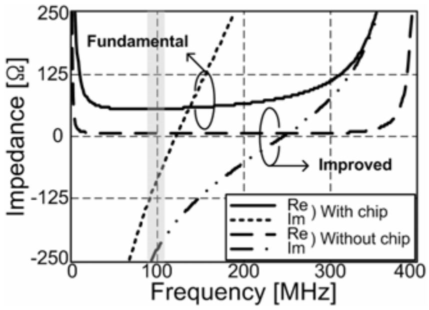


Fig. 3 The impedance of proposed antenna.

The characteristic of antenna is still capacitive as 52 – j94 Ω. Therefore it needs more inductance component for good performance at FM radio band. The antenna structure is modified for impedance matching as shown in Fig. 4. 'W' is width of backside patch for adding inductance component. 'L' is length of stub for bandwidth control. 'D' is distance between two stubs for decrease of antenna size and 'H' is total length of antenna for control of resonance frequency.

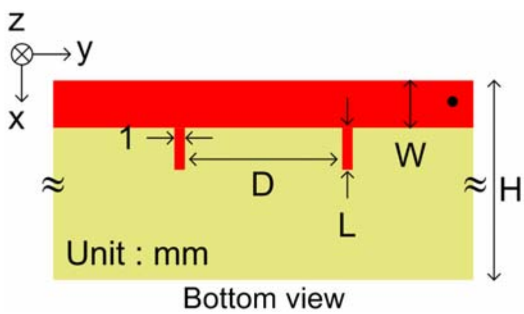


Fig. 4 Antenna matching structure.

The backside patch is connected by using via to increase inductance component. Fig. 5 shows the results of return loss with 'W' variation. When 'W' is increase, the antenna could be inductive and resonance frequency moves to low frequency band because physical length of antenna is expanded. When 'W' is 4.5 mm, return loss of the antenna is -28 dB and impedance is 52 + j2 Ω at 100 MHz. It is satisfied with FM Radio frequency band. However bandwidth is a little shifted as 91 ~ 109 MHz compare with FM radio frequency band.

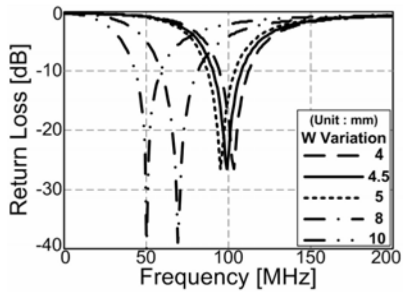


Fig. 5 Return loss & impedance [W change].

The stub is added for bandwidth control on the backside patch. The width of stub is fixed to 1 mm. Fig. 6 shows the return loss depending on 'L' change. It confirms that the bandwidth is controlled by 'L'. When 'L' is 4 mm, bandwidth of the antenna is satisfied FM radio frequency band (88 ~ 107 MHz). The return loss of the antenna is -27 dB at 97 MHz and impedance is 53 + j10 Ω at 100 MHz.

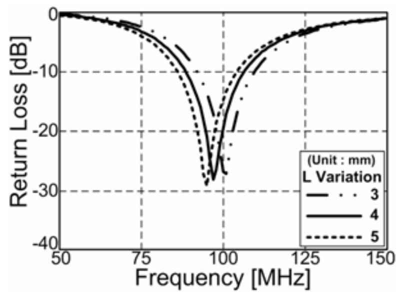


Fig. 6 Return loss [L change].

Two stubs are added for decrease of antenna size. It has same length and symmetric. The operating frequency of the antenna shifts to more low frequency band than FM radio band by control of distance between two stubs. Fig. 7 shows the results of return loss with 'D' variation. When 'D' is 15 mm, it is most advantageous for decreasing size of the antenna. If 'D' is shorter than 15 mm, this antenna operates at higher frequency than FM radio frequency. Because when the distance is closer than 15 mm, the characteristic of the antenna becomes more capacitive. Therefore when 'D' is 15 mm, it is optimum condition. Return loss of the antenna is -39 dB at 54 MHz.

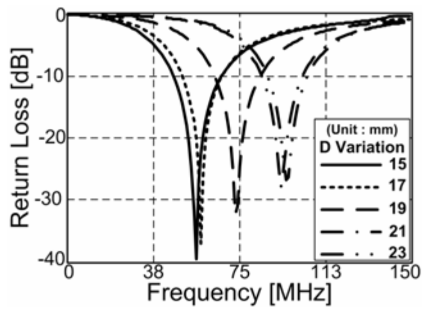


Fig. 7 Return loss [D change].

The 'H' is considered for decrease of antenna size. The size of antenna can decrease because this antenna operates at 54 MHz when 'D' is 15 mm. Fig. 8 shows the return loss depending on 'H' value. According to Fig. 8, 'H' can reduce to 60 ~ 70 mm. When 'H' is 70 mm, the return loss is -28 dB at 99 MHz and impedance at 100 MHz is 54 + j3 Ω. The bandwidth is satisfied to 89 ~ 108 MHz. The characteristic of designed antenna is shown in Table 1.

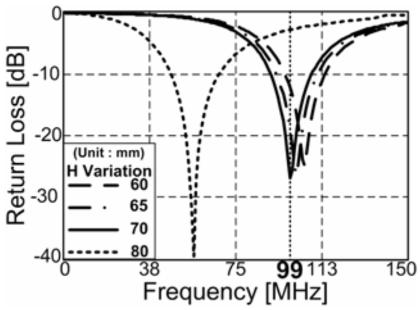


Fig. 8 Return loss [H change].

Table 1 Characteristic of designed antenna.

Return loss	-27 dB
Impedance	54 + j3 Ω
Bandwidth	89 ~ 108 MHz
Maximum gain	-44 dB

Fig. 9 shows the radiation pattern of optimized antenna. The E-plane is a little tilted to y-direction. Because the radiator of antenna is placed to (ㄱ) shape. Therefore the E-plane is formed to symmetric by ground.

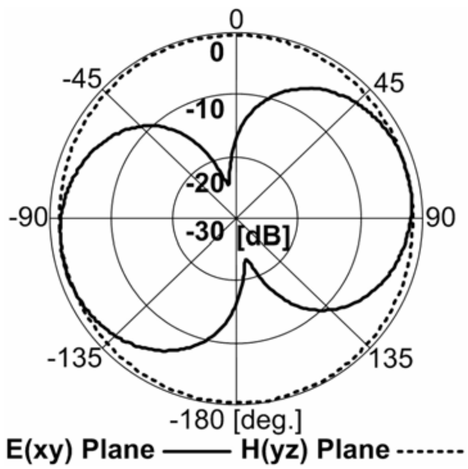


Fig. 9 The calculated radiation pattern at 100 MHz.

As shown by Table1 and Fig. 9, this antenna is satisfied the standard specification of FM radio band. However the gain is not enough for FM radio receiving. The gain of standard FM Radio antenna is demanded about -17 ~ -20 dB. The reason of low gain is that the antenna is very small and omni-directional. The gain of antenna is decided by radiation efficiency and directivity. In addition, the radiation efficiency is decided by input and output power. The power of proposed antenna is consumed much at R and L chip components.

III. Measurement Results

In this research, a FR4(ε_r = 4.4, thickness = 1 mm) dielectric substrate is used for the antenna design due to its low price and reasonable permittivity constant. The antenna analysis is achieved by Ansoft HFSS v9.1.

Fig. 10 shows the structure of optimized antenna from Fig. 5 ~ 8. The size of antenna is reduced 12.5 % than fundamental antenna. Fig. 11 shows the fabricated antenna.

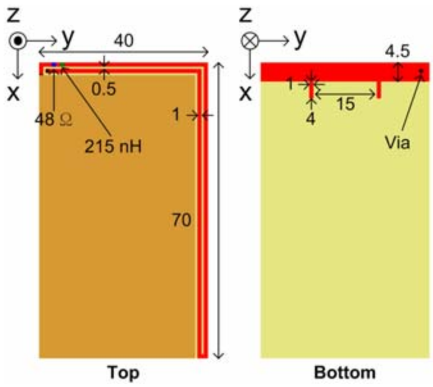
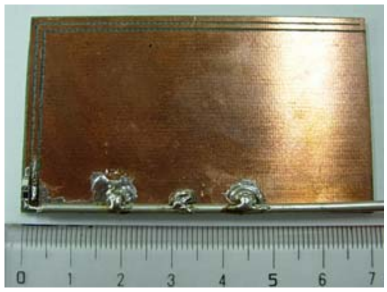
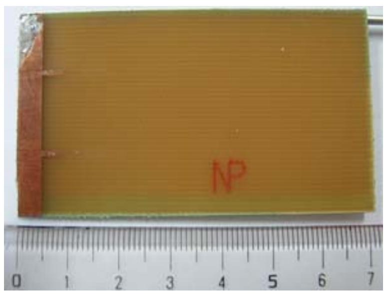


Fig. 10 Final Model.



(a) Top View



(b) Bottom View

Fig. 11 Fabricated antenna.

The return loss, impedance, radiation pattern and gain of fabricated antenna are presented as follow Fig. 12 ~ 15, respectively. Return loss of the fabricated antenna is -23 dB at 99 MHz. Measured bandwidth is 89 ~ 111 MHz. Impedance of the antenna is 55 – j7 Ω at 100 MHz. The return loss, impedance and radiation pattern are good agreement with simulation results. However the gain is higher than simulation results as -17 dB. In practical measurement, the cable and feeding connector also affect to receiving power. Although the power loss of antenna is occurred by R, L chip component, the power is increased by measurement cable and connector.

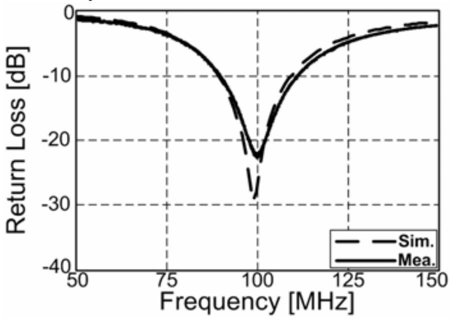


Fig. 12 The return loss of proposed antenna.

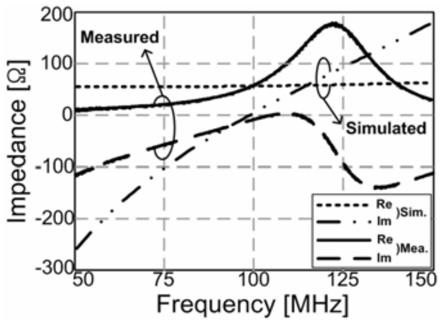


Fig. 13 The impedance of proposed antenna.

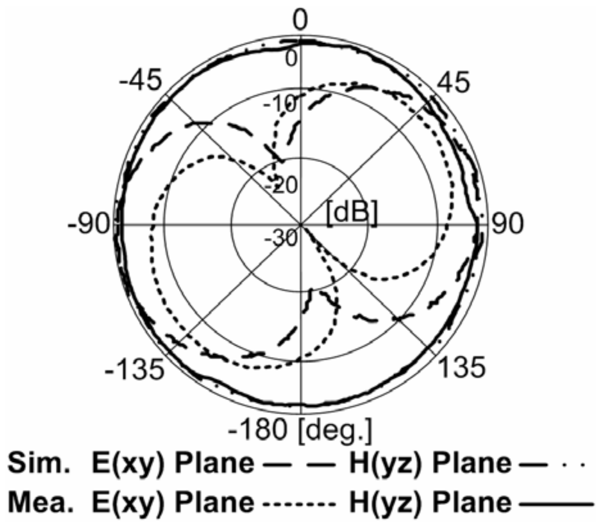


Fig. 14 Measured radiation pattern of proposed antenna.

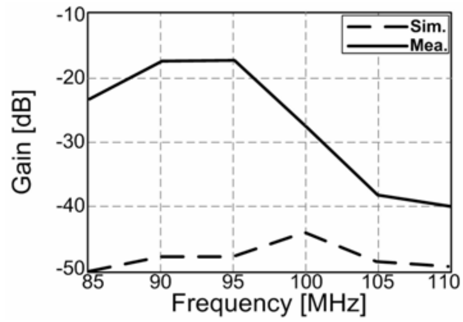


Fig. 15 Measured gain of proposed antenna.

IV. Conclusion

In this paper, the internal FM radio antenna for mobile terminal is presented. The antenna is matched by R, L chip elements, backside patch and stubs. We confirm that the operating frequency, bandwidth, and gain is satisfied the standard specification of FM radio antenna. Resonance frequency is decided by R and L chip element, and backside patch. Bandwidth is controlled by stub on the backside patch. Two stubs decrease size of the antenna, and final resonance frequency and bandwidth is controlled by total antenna length. The return loss is -22 dB, the bandwidth is 89 ~ 111 MHz below -10 dB, the impedance is 50 – j7 Ω, and the radiation pattern is omni-directional at 100 MHz, and gain is about -17 ~ -40 dB from the measurement results. The proposed antenna with novel design has advantage for internal FM radio antenna.

References

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