Electrically Small Antenna for a Handy Terminal

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1. Introduction

Recently, the remote keyless entry system is conveniently employed in private cars [1]. In the future system, expanding the communication range of a handy terminal is requested. This system uses the 315MHz band. Therefore, the handy terminal antenna must be achieved in a very small size less than 0.05 wavelengths. On the other hand, high antenna gain is requested in the handy use for the long communication distance. For these purposes, a normal-mode helical antenna (NMHA) is thought suitable. High antenna gains of NMHA were ensured in the case of metal plate proximity [2],[3]. However, effects of human hand were not clarified.

In this paper, first of all, design methods of a NMHA for efficient radiations are clarified. In a very small antenna, because the input resistance is very small less than a few ohms, antenna impedance matching to a feed cable becomes very important. Therefore, an impedance matching method by the off-set feed configuration is clarified. In order to ensure the design adequateness, calculated results are compared with measured results. Finally, affects of a human hand to the designed antenna are investigated in electrical characteristics such as input impedances and radiation patterns.

2. Fundamental design of a small antenna

As a promising candidate of the handy terminal antenna, the normal-mode helical antenna (NMHA) shown in Fig.1 is selected. The cross sectional shape is formed rectangular to achieve low profile. This antenna has two radiation sources such as magnetic current (I_m) and electric current (I_e) sources shown by solid and dotted arrows, respectively. At the hand side of the NMHA, a small metal plate is attached in order to suppress the input impedance change by a hand. This metal plate decreases the electrical current performance and increase the magnetic current performance. The antenna is fed at the center position. Because the wavelength at 315 MHz is nearly 1 m, the NMHA size is about 0.05 wavelengths. Important design subjects to achieve efficient radiations in this small antenna are the self resonance condition and reduction of ohmic loss of antenna wire. By the self resonance condition, antenna input impedance is adjusted to the pure resistance. So, the poured power to the antenna is efficiently converted to the radiation power. However, in the small antenna less than 0.05 wavelengths, the input resistance is very small less than 1 Ω. Therefore, the ohmic resistance of the NMHA wire becomes comparable to the radiation resistance. The effective way to reduce the ohmic resistance is to broaden the wire diameters. In this case, wire diameter of 2 mm is employed.

In Fig.2, the self resonance conditions are shown. Solid lines indicate self resonant structures. For given N, relations of L and W are determined to achieve the zero reactance in antenna input impedance. ⊙ mark indicate the structure of Fig.1. In large W values, because cross sectional areas of the NMHA increase, radiations from magnetic sources increase. Broken lines indicate antenna gains. Antenna gains almost depend on L values. Radiation patterns of Fig.1 are shown in Fig.3. E_{Im} and E_{Ie} denote radiation fields from the magnetic and electric currents, respectively. Here, E_{Ie} becomes larger than E_{Im} about 3.5 dB. From the fact that E_{Im} and E_{Ie} are almost the same, a circular polarization is radiated. Antenna gains in Fig.2 are that of circular polarization. Now, antenna structure and radiation characteristics become clear.

In order to ensure realization, antenna input impedance measurements are conducted. The fabricated antenna is shown in Fig.4. For a coaxial cable, a sperrtopf balun is equipped. Measured and calculated input impedances are shown in Fig.5. Based on good agreements of measured and calculated results, design accuracies are ensured. In calculation, the radiation resistance (R_r) and the ohmic resistance (R_l) are distinguished. The ohmic resistance is reduces efficiently.

3. Impedance matching

The simplest impedance transformer method is the off-center feed [4] shown in Fig.6. When the feed point is moved toward the end of the antenna, high antenna impedances are easily achieved. Measured and calculated input impedances are shown in Fig.7. The feed point is located near the end of the antenna. Without any change of antenna sizes, self resonances are achieves at 315 MHz. Step up ratio (r) of input resistance becomes r = 50/0.65 = 77. Excellent impedance matching can be achieved. The high input resistance of measurement corresponds to the measured R_{in} in Fig.5. Next, radiation characteristics are studied as shown in Fig.8. By comparing Fig.8 with Fig.3, it is concluded that the off-set feed does not degrade the radiation characteristics.

4. Affects of a hand

This antenna is usually held in a hand. As a fundamental case, the configuration of Fig.9 is considered. The antenna is placed on a palm of a hand with a spacing of 10 mm. In this case, the antenna width (W) of 0.5 mm is reduced in order to tune the input impedance. Excellent impedance matching is achieved. The simulation condition of this model is shown in Table 1. In calculation, the method of moment scheme of a commercial simulator FEKO is employed. The hand is modeled by a dielectric material of $\varepsilon r = 38.8$ and $\tan\delta = 0.51$. In order to calculate the dielectric material, the surface equivalence principles that convert the electromagnetic behaviours to the surface currents is used. Mesh size is 0.005 wavelengths. The calculation loads are rather small.

Radiation characteristics are shown in Fig.11. Antenna gain of −2.12 dBi is achieved in the magnetic current source (I_m). The antenna gain in the electric current source (I_e) is reduced to −9.11 dBi. Therefore, it is made clear that sufficient antenna gain can be achieved in the handy terminal.

5. Conclusions

A very small normal-mode helical antenna (NMHA) was designed for a handy terminal. The important technical results are as follows:

1. The self resonance conditions and antenna gains of a NMHA with a small conducting plate were clarified.
2. Effects of the off-center feed for impedance matching were clarified.
3. Antenna gain of −2.12 dBi of a handy condition was shown.

References

[1] Y.Hamada, M.Numoto and M.Tsurunaga, “Virtual Testing Technique for Remote Keyless Entry Receiving Performance”, Mazda Technical Report, No.27, pp.119-124, 2009

[2] W. G. Hong, N. Michishita and Y. Yamada, “Low-profile Normal-Mode Helical Antenna for Use in Proximity to Metal”, ACES Journal, Vol. 25, No.3, pp.190-198, March 2010.

[3] N. Q. Dinh, N. Michishita, Y. Yamada and K. Nakatani, “Electrical Characteristics of a Very Small Normal Mode Helical Antenna Mounted on a Wheel in the TPMS Application”, IEEE AP-S’09, Session 426, No.4, June 2009.

[4] John L. Volakis, “Antenna Engineering Handbook, Fourth Edition”, McGraw-Hill Companies, pp.4-16 to 4-19, 2007.

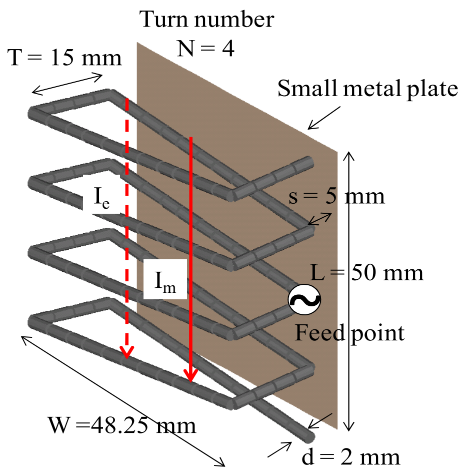

Fig. 1 Configuration of a NMHA

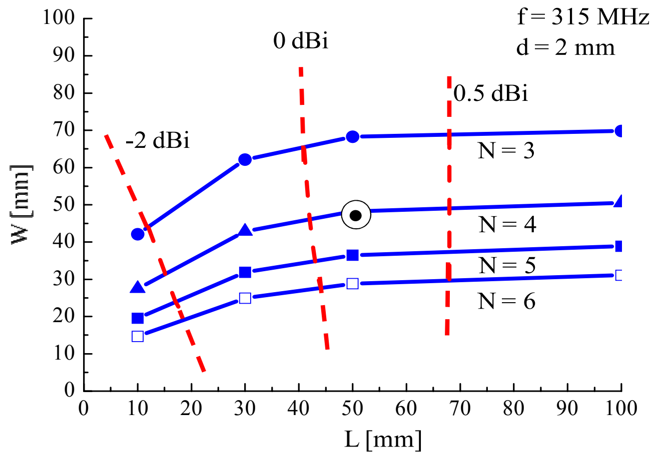

Fig. 2 Self resonance conditions

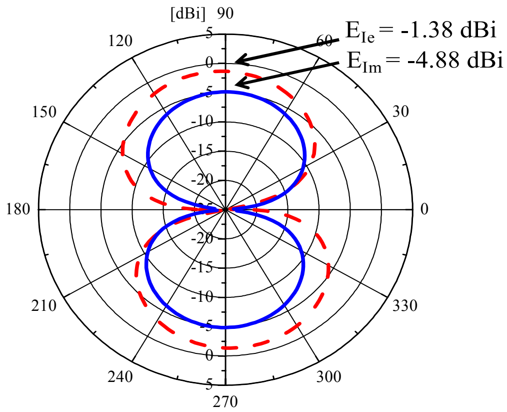

Fig.3 Radiation pattern

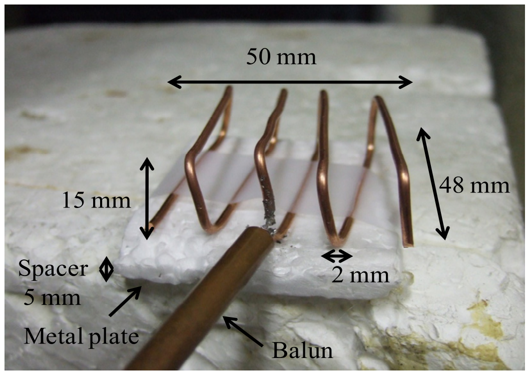

Fig.4 Measurement configuration

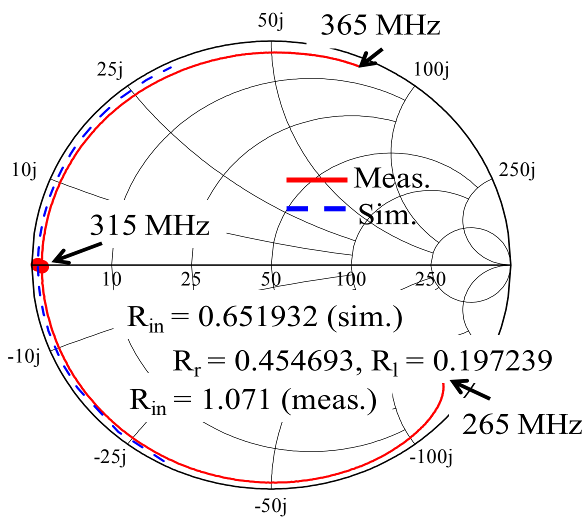

Fig. 5 Input impedance

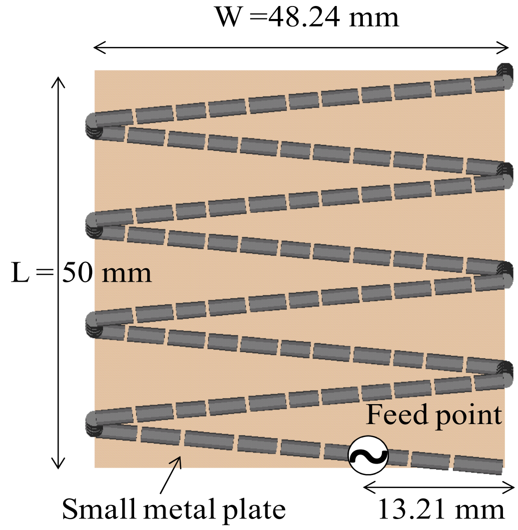

Fig. 6 Configuration of a off-center feed

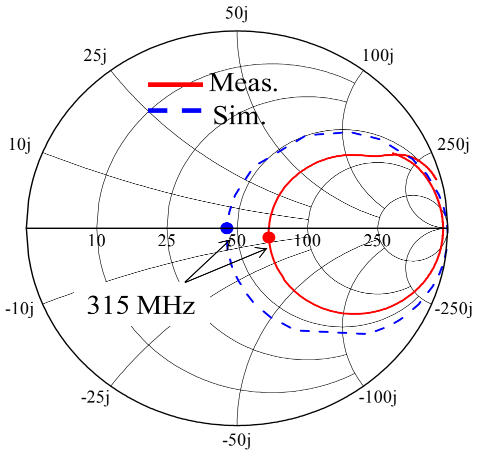

Fig. 7 Input impedance

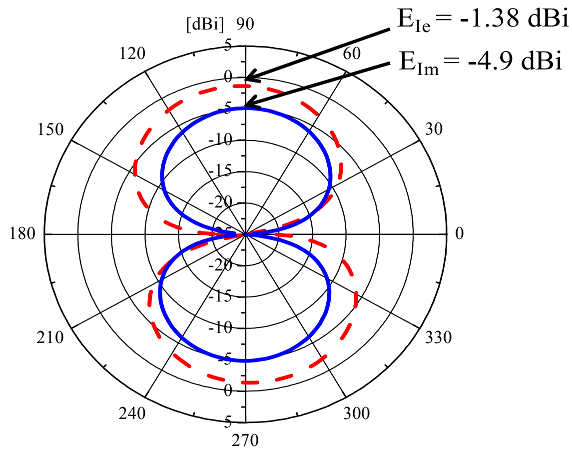

Fig. 8 Radiation patterns

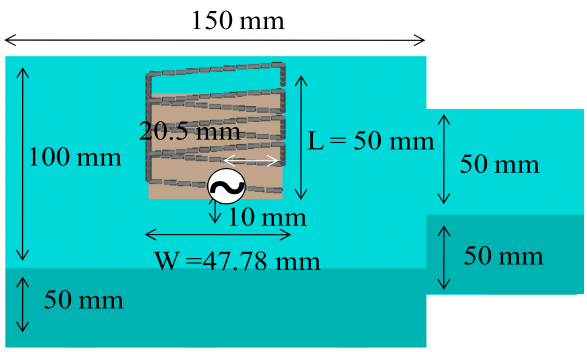

Fig. 9 Antenna placement on a hand

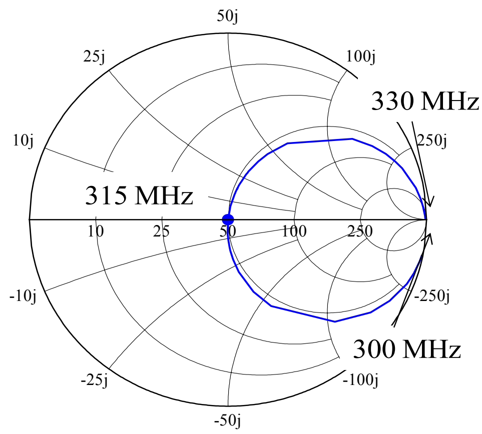

Fig. 10 Impedance characteristics

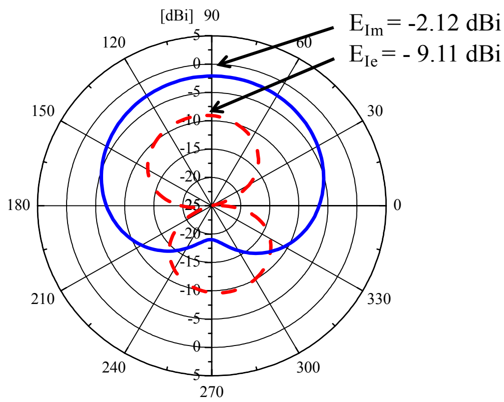

Fig. 11 Radiation patterns

Table 1 Simulation conditions

PC		CPU 2.80 GHz, 16 GB RAM
EM solver		FEKO
Frequency		315 MHz
Hand	ε_r	38.8
	$\tan\delta$	0.51
	Simulation method	Surface equivalence principle (SEP)
	Mesh size	λ/200
Memory		562 MByte
Time		224 seconds