

Material Property of On-metal Magnetic Sheet Attached on NFC/HF-RFID Antenna and Research of Its Proper Pattern and Size On

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Abstract—When a payment system with NFC/HF-RFID is installed in smart-phone, their communication with 13.56MHz is blocked by such metal as battery, coil and PCB. To solve this problem, magnetic sheet with high permeability is set between NFC/HF-RFID antenna and near-by metal. So far thin compound magnetic sheet or thin sintered ferrite has been used.

In order to make thickness of these materials thinner, we propose amorphous magnetic sheet. Besides this amorphous magnetic sheet causes to increase the transmission effect.

I. INTRODUCTION

NFC and HF-RFID system are used in such traffic toll collection system as SUICA and PASMO in Japan, or in such electric money as EDY [1]. This NFC and HF-RFID system have started being installed in mobile phone and smart phone. Its newly developed applications increase recently. This system uses 13.56MHz band and is blocked by metals nearby NFC/HF-RFID antenna of reader/writer or RF tag [2], [3]. The reason is that flowing electric current on NFC/HF-RFID antenna is lowered by anti - flowing electric current generated by these near-by metal. When there is 10mm gap between NFC/HF-RFID antennas and near-by metal, its communication works.

However smartphone must be thin and at the same time NFC/HF-RFID antenna must be thin, too. Thus it is difficult to make 10mm gap in it. Then as usual, thin sheet with high permeability is installed instead of making gap between them. The reasons are described as below; First- to suppress the anti - flowing electric current, Second – to make magnetic flux flow through this magnetic sheet. By the way, as on-metal magnetic sheet, thin compound magnetic sheet or thin sintered ferrite has been used. But thin compound magnetic sheet cannot be thinner. And thin sintered ferrite cost much because it must be covered not to scatter ferrite powder of cut edge. Besides when both sheet are used as square shape, central square part should be cut off. It causes disposal problems. We has found out higher permeability amorphous sheet and developed how to use them to solve these existing problems. We die cut this amorphous sheet into 4 smaller pieces and set them on each sides. In addition there should be some gap between each piece to reduce anti-flowing electric current. As its permeability exceeds to both compound magnetic sheet and

sintered ferrite, this amorphous sheet can be thinner and lighter than them. In this paper, we will report the experimental results of NFC/HF-RFID communication with amorphous sheet when near or on metal.

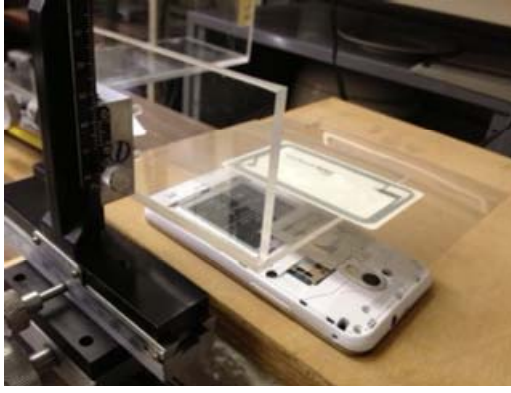
II. TEST MODEL

The system configuration of communication distance measurement system is indicated in Fig.1. We use a smartphones with NFC function and measure the communication distance when magnetic sheet is set between NFC antenna and battery. In this report, the measurement is executed by following two situations; (1) NFC antenna is used as Tx-antenna, (2) NFC antenna is used as Rx-antenna. Frequency of NFC is set to 13.56 MHz. Measurement conditions are indicated in TABLE I. To conjugate match with NFC IC's capacitance, this NFC antenna has large inductance at 13.56 MHz [4]. The amorphous sheet consists of PET cover film, amorphous magnetic sheet and adhesive. Total amount thickness of NFC antenna and amorphous sheet is 0.1 mm.

In the situation of Fig. 1 (1) (hereafter, it is called “read model 1”), the card type passive tag (width X length =50mm X 80mm) according to ISO 14443 [5]-[8] is used. In Fig. 1(2) (hereafter, it is called “read model 2”), NFC antenna communicates with the Reader/Writer antenna in accordance with ISO 14443 as Rx-antenna The communication distance in “read model 1” and “read model 2” is described as d_1 and d_2 , respectively.

TABLE I CONDITIONS OF BOTH TESTS

Frequency	13.56 MHz
Size of NFC antenna	40 × 40 mm
Width of NFC antenna pattern	6 mm
Structure of amorphous sheet	PET cover film, amorphous magnetic sheet and adhesive.
Total thickness of NFC antenna and amorphous sheet	0.1 mm



(1) Read model 1



(2) Read model 2

Fig.1 Communication property evaluation procedure for NFC-Tag. (a) In case of NFC-Tag in free space. (b) In case of NFC-Tag equipped RF device.

The characteristic and dimension of magnetic sheet used for this measurement are listed in Tabel II. There are three kinds of magnetism sheet used for the measurement. That is compound magnetic sheet, sintered ferrite and amorphous sheet. 3 types of sheet size and shape are indicated in Fig.2

- (1) Patch type : square shape covers whole antenna.
 - (2) Loop type : square without central part covers only antenna lining pattern.
 - (3) Strip type : Loop type to be got rid of each corner sheet.
- When strip type magnetism sheet is used, the same length strips are put on each sides of the antenna. The length of these pieces is all the same. Its length is indicated as below; l_g [mm]

TABLE II TYPES OF MAGNETIC SHEET

Composition	Thickness [μm]	Permeability μ' (Real part)	Permeability μ'' (Imaginary part)
Compound magnetic sheet	200	50	1.5
Sintered ferrite	100	100	1
Amorphous sheet	20	250	400

A correlation between the input impedance and the communication distance when the NFC antenna is attached to a metallic object is described in the following chapter. The variation of input impedance and the communication distance when magnetic sheet is inserted between the NFC antenna and a metallic object is also described in next chapter.

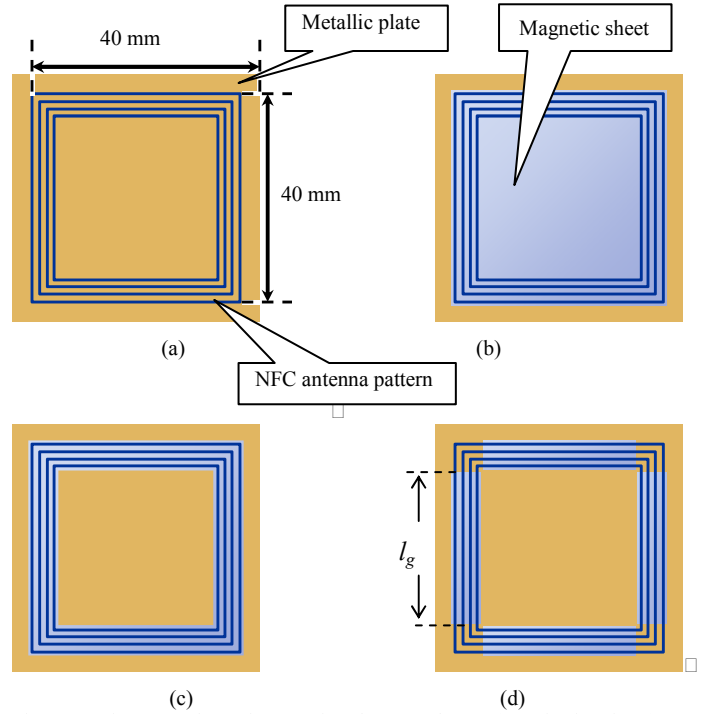


Fig.2 Location procedure of magnetic substance sheet. (a) Basic situation (not magnetic substance sheet loadings). (b) Magnetic substance patch loadings case. (c) Loop-shape magnetic substance sheet loadings case. (d) Magnetic substance strip loadings case.

III. IMPEDANCE MATCHING AND COMMUNICATION DISTANCE

A. Impedance Matcing

The permeability ($=\mu$) of magnetic sheet led from the impedance measurement result with a coaxial waveguide is shown by the expression (1).

$$\mu = \frac{Z_S - Z_0}{j\omega\mu_0} \cdot \frac{2\pi}{h \ln \frac{c}{b}} + 1 \quad (1)$$

where,

Z_0 : Intrinsic impedance of coaxial waveguide

Z_S : Input impedance of coaxial waveguide when magnetic substance sheet is inserted

h : Thickness of magnetic substance sheet

c : Internal conductor's radius of coaxial waveguide.

b : External conductor's radius of coaxial waveguide.

On the other hand, ' Z_S ' is shown by using R_S (=equivalent resistance of magnetic sheet) and L_S (equivalent inductance of magnetic sheet) like expression (2).

$$Z_S = R_S + j\omega L_S \quad (2)$$

Moreover, μ is separated to real part ($=\mu'$) and imaginary part ($=\mu''$) as shown in the expression (3).

$$\mu = \mu' + j\mu'' \quad (3)$$

Therefore, L_s and R_s are given as a function of μ' or μ'' like the expression (4) and (5).

$$L_s = \frac{(\mu' - 1)}{\gamma} \quad (4)$$

$$R_s = Z_0 - \frac{\omega}{\gamma} \mu'' \quad (5)$$

Fig. 3 shows L_s and R_s as the function of permeability based on actual measurement data. As results, it is guessed that the permeability control of magnetic sheet is indispensable to the impedance matching of the NFC antenna. However, the permeability control by the composition of the magnetic substance is not so easy. Accordingly, it is attempted to control the impedance of the NFC antenna by intermittently attaching magnetic sheet. TABLE III shows the input impedance measurement result of the NFC antenna when procedure for magnetic sheet loading is changed.

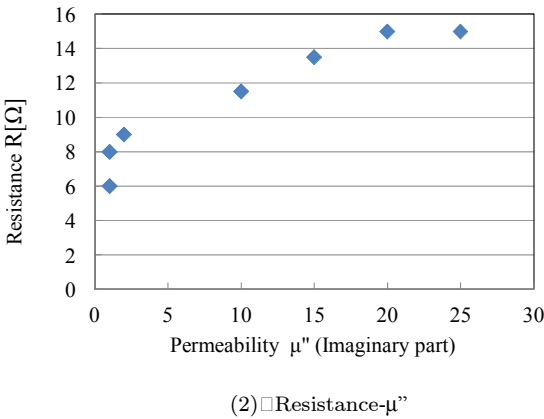
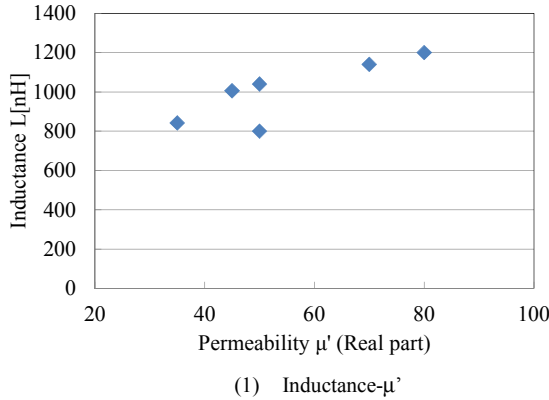


Fig 3. Relation with impedance and permeability.

The result of verifying the influence that the impedance matching for the NFC antenna gives to the communication distance is shown in the next paragraph.

TABLE III TEST RESULT OF IMPEDUNCE

Loading material	Type	Resistance [Ω]	Inductance L [nH]
Cf. Antenna in free space	-	6.0	1220
Without magnetic sheet	-	5.8	200
Compound magnetic sheet	Patch	12.6	912
Compound magnetic sheet	Loop	11.2	872
Compound magnetic sheet	Strip	9.4	768
Sintered ferrite	Patch	10.4	1634
Sintered ferrite	Loop	7.0	988
Sintered ferrite	Strip	6.0	840
Amorphous sheet	Patch	60	1800
Amorphous sheet	Loop	42	1480
Amorphous sheet	Strip	16	1100

B. Communication distance

Fig. 4 shows the comparison measurement results of the NFC communication distance about three magnetic sheet insertion procedures between the antenna and metallic object. The comparison measurement results by two types read model are also shown in Fig. 4.

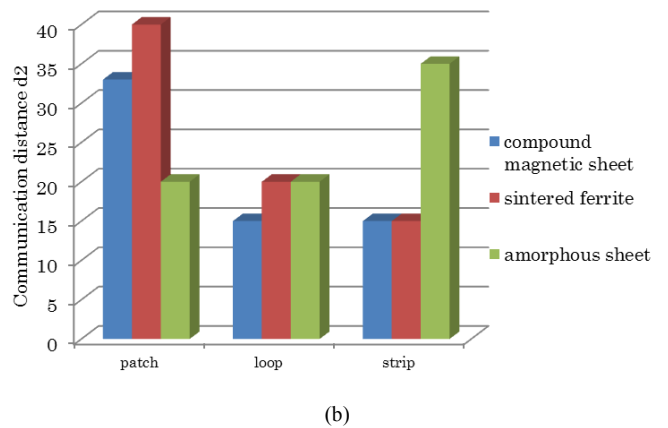
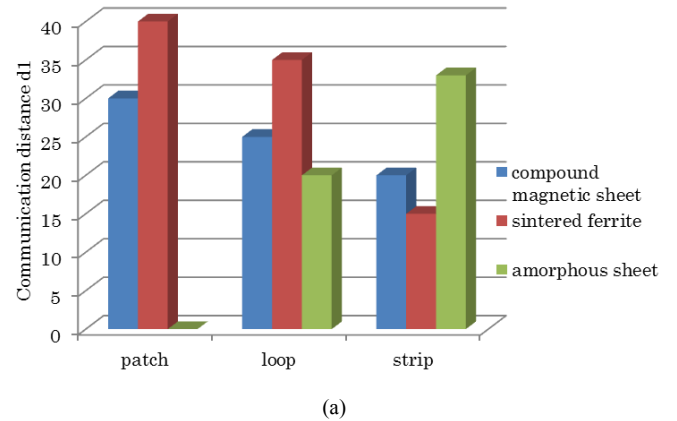


Fig.4 Communication distance transition for location procedure of magnetic substance sheet. (a) In case of read model 1. (b) In case of read model 2.

In these results, length of the strip type magnetic sheet is fixed to $l_g=25\text{mm}$. About compound magnetic sheet and sintered ferrite, as the size of sheet is bigger, so its communication distance becomes longer. On the other hand, as the size of

amorphous sheet is bigger, so its communication distance becomes shorter. The Table II indicates that amorphous sheet has higher permeability compound magnetic sheet and sintered ferrite and at the same time has higher loss property. Therefore when amorphous sheet used, the size must be as small as possible to minimize the resistance. However this causes decrease of inductance. The shape and size of amorphous sheet to obtain the desire resistance and inductance is important task. TABLE IV shows test result of communication distance test and impedance of strip type when l_g is changed. Furthermore, the relation with sheet size and impedance of amorphous sheet is summarized in the Fig.5. From the viewpoint of the antenna input reactance reduction, it predicted that the communication distance expand when the amorphous sheet inserted antenna's inductance approaches the inductance in free space ($L=1220$ [nH]). In this figure, it is shown that the resistance mismatch quantity is an important parameter for the communication distance besides the remaining reactance. When magnetic sheet size is set to $l_g=25$, the communication distance becomes 30 - 50% longer at the loop type pattern.

TABLE V TEST RESULT OF IMPEDANCE AND COMMUNICATION DISTANCE ABOUT STRIP TYPE

l_g [mm]	R [Ω]	L [nH]	d_1 [mm]	d_2 [mm]
20	15	840	18	18
23	16	910	24	21
25	22	1160	33	35
27	26	1200	27	31
30	30	1500	24	30

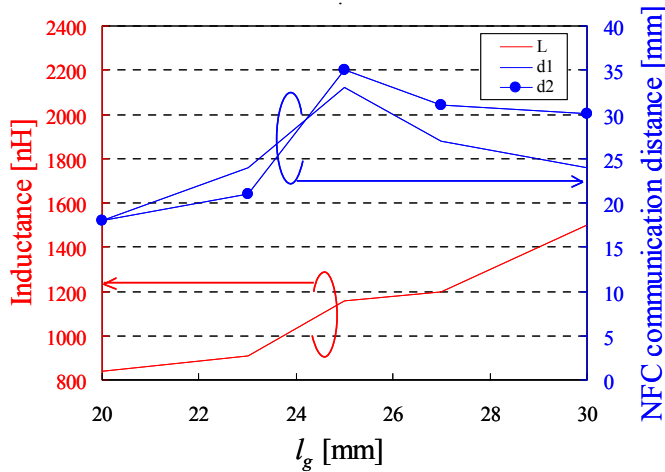


Fig.5. Relation with inductance and communication distance about strip type .

IV. CONCLUSION

In this report, impedance matching and communication distance of NFC system was mainly measured with respecting for the permeability and shape of on-metal magnetic sheet. It was confirmed that the amorphous sheet, even if it had not

been used because of its higher permeability at 13.56 MHz, was applicable for NFC antenna with near-by metal by shaping different size of this sheet. The distance of it is as long as theirs of existing compound sheet and sintered ferrite. The longer the communication distance is the wider the size of these 2 sheets are. As their imaginary part of permeability is very low, the resistance is hardly be changed. On the other hand amorphous sheet with higher permeability indicates higher loss property. Therefore it is necessary that with downsizing sheet and suppressing its resistance intrinsic impedance of sheet match to the preferable impedance of this sheet. Before this amorphous sheet is used, it is inevitable to evaluate the impedance of this sheet. Finally, this amorphous sheet is useful for downsizing and cost down for smartphone because even smaller size and thinner thickness is applicable for NFC/HF-RFID on-metal communication. From now on, we will get more data of test and simulation at the same time to optimize the amorphous sheet size and thickness according to NFC/HF-RFID antenna of smartphone.

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