Impedance matching for 13.56 MHz NFC antennas without VNA

Sun Peng, Zhang Zhi-jun, Jin Ming-lu & Wang Kai-yu
School of Electronic Information and Electrical Engineering
Dalian University of Technology
Dalian, China
Email: sunpeng@dlut.edu.cn

ABSTRACT: This paper introduces a method of impedance matching for 13.56 MHz NFC antennas without Vector Network Analyzer (VNA). A LCR meter is used to measure resistance and inductance of antennas instead. A three components match is adopted to realize 50-Ω antenna impedance. Both antenna on board and external antenna are designed with rectangular planar spiral copper. They are tested and compared with each other. The results show that two antennas can work well. External antenna has better performance than one on board.

KEYWORDS: Impedance matching, Near field communication, Antenna, Vector Network Analyzer

1 INTRODUCTION

Antenna plays one important role in wireless communication. A 50-Ω impedance of antenna is needed for maximum power transmission. Antennas of NFC application are usually designed by spiral coil or PCB copper. The antenna needs a impedance matching network. Roland (2008) introduces an auto impedance matching way, however it is complex and a controller is needed. Li (2011) gave a simple impedance match method, performance of antenna is not satisfied. Sekiguchi (2015) focuses on effective pattern of magnetic sheet attached on NFC antenna. Most research about impedance matching of antenna may make use of Vector Network Analyzer (VNA), and not all people can afford to get this device. A method of impedance matching for antennas without VNA is proposed in this paper.

The paper is organized as follows. In section 2, two PCB antennas are prototyped. An impedance matching network is discussion in section 3. A procedure step by step is described in section 4 to achieved a 50-Ω antenna impedance. Antenna on board and external antenna are both tested in section 5. The final conclusion about impedance match for NFC antenna is given in section 6.

2 DESIGN OF ANTENNAS

Two rectangular planar spiral antennas are designed in this paper. The two PCB designs of antenna are both based on FR-4 material, with a material thickness of 1.6mm. The antennas are both 1 layer design (top) with 1 oz (35um) copper.

2.1 *Antenna on board*

Antenna on board is about 1960mil long and 490mil wide. It is designed with 10mil trace width and 10mil trace spacing copper. Antenna on board is composed of 5 complete turns as Figure 1. You should remove JUMPER near J7 terminal, if you want to use an external antenna instead of antenna on board.

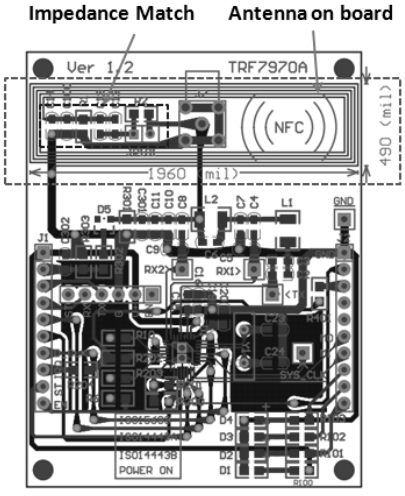

Figure 1. Antenna on board (top).

2.2 *External antenna*

External antenna is about 1640mil long and 1640mil wide. It is designed with 50mil trace width and 50mil trace spacing copper. Antenna is composed of 4 complete turns. The design of external antenna is as Figure 2. It can be connected to the board in Figure 1 through J7 terminal with a SMA cable.

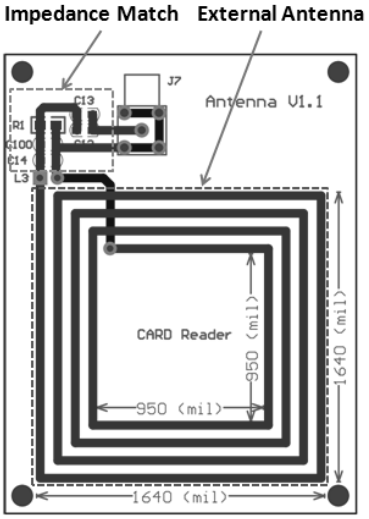

Figure 2. External antenna (bottom).

3 TOPOLOGY OF IMPEDANCE MATCHING

For an optimized system, the impedance seen into the antenna should match the characteristic impedance (system impedance). There are an infinite number of impedance match networks, this paper focuses on a 50-Ω match. We use a three components match.

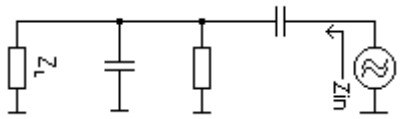

Figure 3. Topology of impedance matching.

In Figure 3, Z_L is impedance of original antenna. Z_{in} is impedance after matching, which is about 50-Ω. The Q-factor of antenna is related with this shunt resistor. The impedance is moved along the constant conductance circle with a shunt capacitor and along the constant resistance circle with a series capacitor.

4 PROCEDURE OF IMPEDANCE MATCH

4.1 *Antenna impedance*

The first step in impedance matching is to measure impedance of unmatched antenna at 13.56MHz. For accurate impedance measurement, a Vector Network Analyzer must be used. The VNA measures both amplitude and phase, so it will display complex impedance values. That is simple if you have a vector network analyzer with you. However we measure resistor and inductance of antenna by LCR meter respectively in this paper. Then the impedance of antenna at 13.56 MHz is calculated.

Table 1. Impedance of antennas at 13.56MHz.

	Resistance	Inductance	Impedance
Antenna on board	1.66Ω	1.67uH	1.66+j142.28
External antenna	0.51Ω	1.03uH	0.51+j87.76

4.2 *Q-factor*

A three component match has the added advantage of allowing the circuit Q to be a chosen value. Suppose that the required operating bandwidth is chosen at 2 MHz, we have:

$$Q = \frac{F_0}{BW} \tag{1}$$

where F_0 *is 13.56* MHz, *BW* is *2*MHz.

According equation 1, we get $Q = 6.78$. The value of Q is usually less than 20 in NFC applications.

4.3 *Impedance matching network*

The approximate parallel resistor value (R_P) needed is determined as follows:

$$R_P = Q \cdot X_L \tag{2}$$

Where X_L is the same as the calculated reactance value from Table 1.

For antenna on board,
$R_P = 6.78 \times 142.28 \doteq 965\Omega$, the one closed to nominal value is 1kΩ.

For external antenna,
$R_P = 6.78 \times 87.76 \doteq 595\Omega$, the one closed to nominal value is 620Ω.

The value of impedance matching network for antenna on board and external antenna is as Table 2.

Table 2. Impedance matching network.

	Shunt Capacitor	Shunt Resistance	Series Capacitor
Antenna on board	30pF	1k	56pF
External antenna	68pF+1pF*	620	68pF+3pF*

* Two capacitors are connected in parallel to obtain a un-nominal value of capacitance.

4.4 *Smith chart*

Smith chart is an important graphical aid that helps calculating antenna tuning circuits. In this paper, the shunt capacitor and series capacitor are both calculated by smith chart.

For antenna on board, we get TP4(51.123 + j1.680) Ω from start point DP1(1.66+j142.28)Ω after impedance matching.

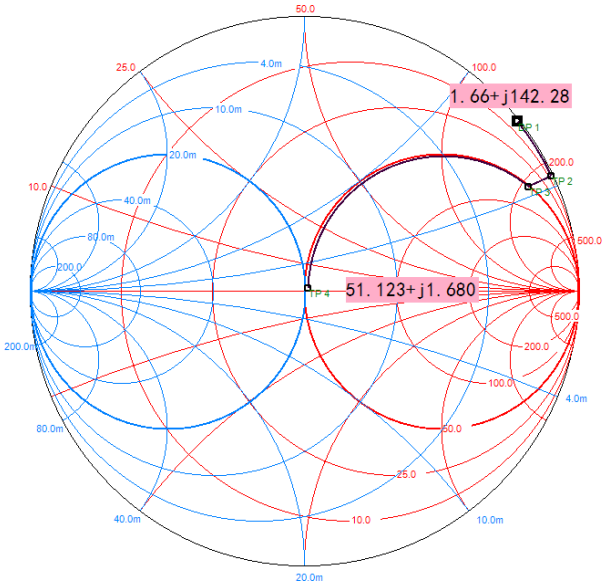

Figure 4. Impedance matching of antenna on board

For external antenna, we get TP4(50.514 + j0.617)Ω from start point DP1(0.51+j87.76)Ω after impedance matching. The VSWR of antenna is 1.02.

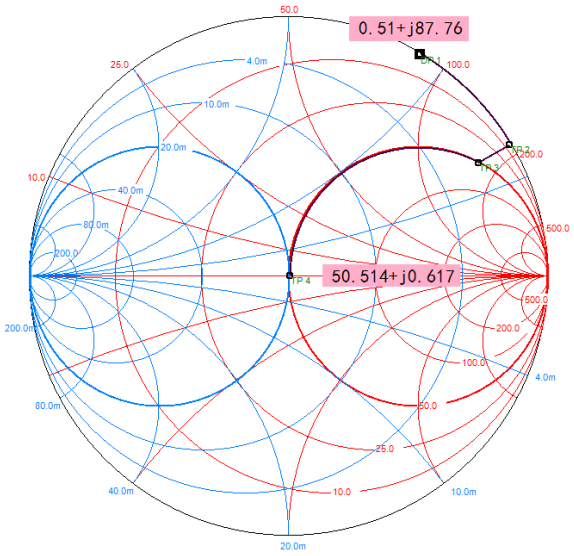

Figure 5. Impedance matching of external antenna.

From Figures 4-5, the target points are very closed to characteristic impedance. The VSWRs of antenna on board and external antenna are 1.04 and 1.02.

5 EXPERIMENT RESULTS

A performance test of antenna is in progress in this paper. There are 2 kind of standard size cards, 8 different antennas on board, 4 external antennas with 0.6 meter cable and 2 external antennas with 1.2 meter cable. The long distance stands for better performance.

5.1 *Experiment with antenna on board*

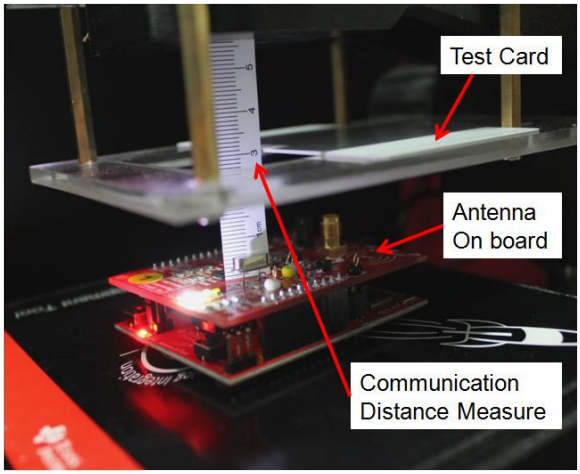

Figure 6. Performance test of antenna on board

Table 3. Experiment results with antenna on board.

	Card No.1	Card No.2
#1	3.0cm	4.4cm
#2	3.2cm	4.4cm
#3	3.0cm	4.3cm
#4	3.2cm	4.4cm
#5	3.1cm	4.4cm
#6	3.0cm	4.4cm
#7	3.0cm	4.4cm
#8	3.0cm	4.3cm

In experiment, maximum communication distance of antenna on board is 4.4cm for standard card No.2.

5.2 *Experiment with external antenna*

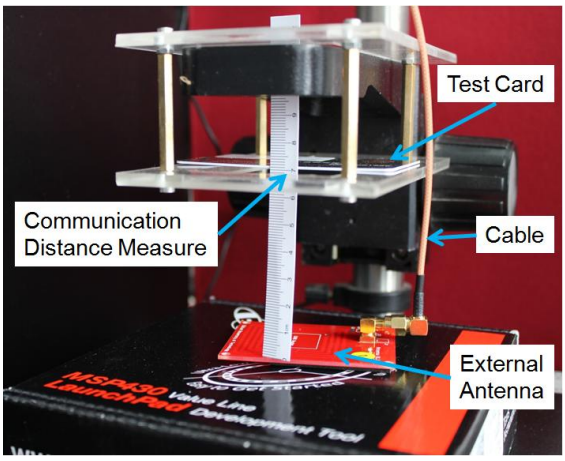

Figure 7. Performance test of external antenna.

Table 4. Experiment results of external antenna with 0.6m cable.

	Card No.1	Card No.2
#1	5.15cm	7.10cm
#2	5.10cm	7.10cm
#3	5.10cm	7.10cm
#4	5.10cm	7.10cm

Table 5. Experiment results of external antenna with 1.2m cable.

	Card No.1	Card No.2
#1	4.40cm	6.65cm
#2	4.60cm	6.70cm

In experiment, maximum communication distance of external antenna with 0.6 meter cable is 7.1cm for standard card No.2.

6 CONCLUSION

External antenna we designed in this paper can work in the distance of 7.1cm. Distance of near field communication is limited less than 10cm for the reason of security. Antenna has outstanding performance if distance is about 6~8cm. The method of impedance matching without VNA is accepted for NFC application. Smith chart is an important graphical aid that helps calculating antenna tuning circuits. We can also draw a conclusion that size of antenna is more important than inductance of antenna for the card with standard size.

ACKNOWLEDGEMENT

This work is supported by “the Fundamental Research Funds for the Central Universities”. We would also like to thank Xie Sheng-xiang from Texas Instruments Semiconductor Technologies (Shang hai) Co., Ltd. for his technical assistance.

REFERENCES

Chung, M.A. 2015. A dual-mode antenna for wireless charging and Near Field Communication. 2015 IEEE International Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting: 1288-1289.

Couraud, B. 2015. A low cost impedance measurement method for integrated circuits. 2015 IEEE 16th International Conference on Communication Technology (ICCT): 13-16.

Dieng M. 2014. Study of adaptive tuning strategies for Near Field Communication (NFC) transmitter module. 2014 19th International Mixed-Signals, Sensors and Systems Test Workshop (IMS3TW):1-6.

Huang C.F. 2014. Design of antennas and circuit for integrating RFID and wireless charging systems. The 8th European Conference on Antennas and Propagation (EuCAP 2014): 1580-1581.

Li L. 2011. NFC Antenna Research and A Simple Impedance Matching Method. 2011 International Conference on Electronic and Mechanical Engineering and Information Technology (EMEIT): 3968-3972.

Mourad O. 2014. System modeling of the RFID contactless inductive coupling using 13.56 MHz loop antennas. The 8th European Conference on Antennas and Propagation (EuCAP 2014): 2034-2038.

Roland M. 2008. Automatic Impedance Matching for 13.56 MHz NFC Antennas. 6th International Symposium on Communication Systems, Networks and Digital Signal Processing, 2008: 288-291.

Sekiguchi T. 2015. Study on effective pattern of magnetic sheet attached on NFC antenna. 2015 IEEE International Symposium on Radio-Frequency Integration Technology (RFIT): 208-210.

Wang M.S. 2014. Equivalent circuit analysis of inductively coupled NFC antennas. 2014 IEEE Antennas and Propagation Society International Symposium (APSURSI): 1540-1541.

Yehya, A.N. 2016. Modeling and design of NFC RFID backbone using a Computer Aided Design tool. 2016 Sixth International Conference on Digital Information Processing and Communications (ICDIPC): 162-167.