

Performance Evaluation of 2.45GHz Chip antenna for Container Security Device(ConTracer)

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Abstract— This paper proposes 2.45GHz antenna of chip type that can be applied to actual container security devices. This antenna configuration has tuning capability when it is applied to practical container security devices. The minimization of the antenna was realized by using a helical and meander structure that has a loop antenna composed of vias and lines on FR-4 PCB of ϵ_r 4.7. The antenna characteristic was analyzed depending on tuning components, the size of supporting dielectric portion and its permittivity by using the commercial software HFSS 3-D EM simulator.

Keywords— 2.45GHz Chip antenna; Helical; Container Security Device(CSD); Active RFID;

I. INTRODUCTION

Active RFID(Radio Frequency Identification) has longer recognition distance compare to passive RFID and easy to apply to metal material which makes it easy to utilize in port and inland logistics transportation management system and container security area.

According to the statistic data[1] from Drewry in 2008, total global container port freight volume is 586,930,000 TEU(Twenty Feet Equivalent Unit). North America port freight volume is 49,670,000 TEU, and the U.S reinforced its logistics security system in omnidirectional way to fundamentally block the terror threat against its country by establishing DHS (Department of Homeland Security) which generalizes safety and security jobs, and series of Maritime Security Act, SAFE Port Act, 9.11 Anti-Terrorism Implementing Recommendation Law. Especially, it signed the law which requires security device, which is recognized by US Customs Office and which can confirm that the container door is not opened during transportation, shall be mounted to all the containers into the country from 2012. In addition to the U.S, EU reinforced logistics security by establishing 'Shipping and Port Facility Security Regulation' which mandates even the International Maritime Organization (IMO) Recommendations of ISPS(International Code for the Security of Ships and of Port Facilities) Code. Also, it continues efforts to reinforce logistics security by legislating the logistics security regulation which is focused

to World Customs Organization's (WCO) SAFE Framework, the business security system, and by establishing and operating import freight search system.

This is current trend of advanced countries around the U.S and Europe that they expand investment for related R&D such as developing electronic seal system, smart container technology and standardization as well as market promotion to reinforce security measures while preventing the obstruction in logistics flow.

The representative electronic security devices for freight container are eSeal(Electronic Seal) with Active RFID technology, and CSD (Container Security Device).

eSeal is mounted to the freight container's door. It senses abnormal opening of the container door and inform it to the reader close-by, and maintain its history.

CSD senses freight loss, theft and intrusion into the container when mounted inside the container. There is no standard for CSD as of now, and U.S DHS issued technology specification which is required by Customs & Border Protection(CBP) [2]. According to this specification, foreign companies such as GE centred Commerce Guard and Savi from the U.S and CIMC from China are progressing R&D activities. But there is no product developed to compete with foreign products up to now in severe competition situation by many other foreign companies.

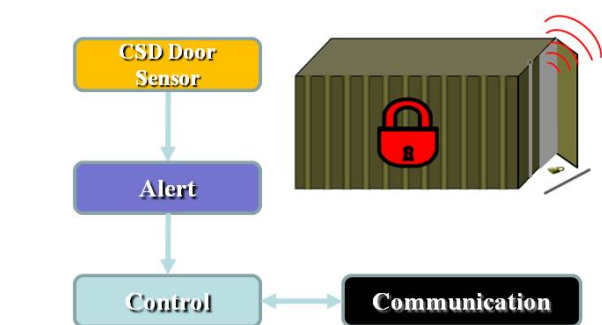


Figure 1. CSD System

Therefore, this research surveyed electronic security device development direction, and compared the CSD device

developed by this research with other company's products which meet DHS CBP requirement specification. [3], [4]. The CSD device developed by this research is named ConTracer. Establish CSD system using the ConTracer, and implemented it to container freight between Korea and China to evaluate the system performance for validating the reliability of this research [5].

This paper is composed as follows. Related Research in Chapter II surveys development trend of electronic security device, compare and analyse container security products. Chapter III explains ConTracer and CSD system using ConTracer. Chapter IV evaluates the performance of demonstration service in domestic/ between Korea and China, and Chapter V gives conclusion.

II. RELATED RESEARCH

This chapter surveys development trend of electronic security device, compare and analyze container security products developed by other companies and ConTracer developed in this research.

One or more traditional bolt barrier "Seal" of plastic or metal "Seal" has been used as door hasp mechanism has been used since the early period of container freight logistics. With development of IT technology and emphasized importance of container security since 2000, eSeal is developed which is mounted to the container door and senses abnormal opening of container door using active RFID technology.

But eSeal is mounted outside container door, has disadvantage that it is fragile and is not reusable.

CSD development became serious according to the CSD requirement document published by US DHS in 2007 which is mounted inside container to detect illegal opening of container door, and can be reused. Currently, ACSD(Advanced Container Security Device) is under developing which is advanced version of CSD, and enables container inside monitoring and illegal immigrants monitoring as well as illegal door opening. Future evolution will be intelligent container with embedded ACSD instead of mounting it to the container.

Device characteristics of ST-675 from Savi and CSD from GE Security are developed current container security device. These two devices can be utilized in container security related area such as CSI and SAFE Port Act, C-TPAT, 10+2 Regulation of U.S DHS. The Savi ST-675 is an active RFID container security tag with intrusion and environmental sensors.

The ST-675's sensor arm detects the open/closed state of the shipping container door, and the intrusion light sensor monitors the amount of light entering the container.

These intrusion sensors detect potential theft or tampering. The temperature, humidity and shock sensors monitor environmental conditions to prevent spoilage and damage to goods. The ST-675's unique C-clamp door-mount design places the sensitive RFID components inside the shipping container.

Only the low profile, external antenna casing is on the outside of the container, which significantly reduces the risk of tag damage during the loading, unloading and transportation of shipping containers.

The CommerceGuard CSD is built to be affordable and engineered to be secure and trustworthy. It is located inside the container for protection from tamper attempts, from being dislodged or knocked off, and from the harsh maritime environment.

Data communications are coded with AES 128-bit encryption technology, the same technology that secures international banking transactions. The CSD communicates at the 2.4GHz frequency, globally available without special governmental licensing. It is reusable, with a long battery life, allowing the cost of hardware to be amortized over several years.

III. CONTRACER INTRODUCTION

ConTracer which is developed by this research is developed to comply with U.S DHS's CSD. It uses frequency of 2.4GHz. 2.4GHz adapts O-QPSK modulation. It has less than 3.6mW output with more than 100m recognition distance between reader and tag. It is mounted between container wall and door using magnet, senses container door opening using micro-switch. It is equipped with temperature, humidity and shock sensor to detect the container status during transportation and provide history. ConTracer is mounted inside the container, has less risk of damage, reusable and has long recognition distance of more than 120m.

3.1 Introduction of ConTracer

Figure 2 shows each part of ConTracer components developed in this research. It is composed of reed-sensor to detect container door, Main Board Mounting for temperature, humidity and shock sensor, and 2.4GHz RF Module Mounting.



Figure 2. ConTracer Mounting Location

ConTracer developed in this research is designed and manufactured to fit to all Dry containers which complies with DHS requirements and ISO 668[6] Standard. As seen in Figure 3, it is mounted in the gap between container wall and door at

proper height using fixing magnet. Figure 4 shows door status sensing method based on DHS RFI.

3.2 Design chip antenna for performance improvement

The 2.45GHz chip antenna has been designed and analysed by Ansoft HFSS. Figure 3 shows the geometry of the designed chip antenna. The designed antenna including main board has dimensions of 65mm ×35mm and the dielectric substrate of FR-4 (thickness: 0.6mm, er = 4.7) is used. Top and bottom ground planes are connected via hole and the signal is excited into the chip antenna through CPWG feeding.

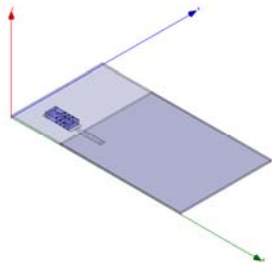


Figure 3. Geometry of 2.45GHz Chip antenna



Figure 4. Measured 2.45GHz Chip ANT in anechoic chamber

Figure 4 show the antenna was measured using Anritsu Vector Network analyser in an anechoic chamber. And measured return loss of the designed antenna shown in Figure 5.

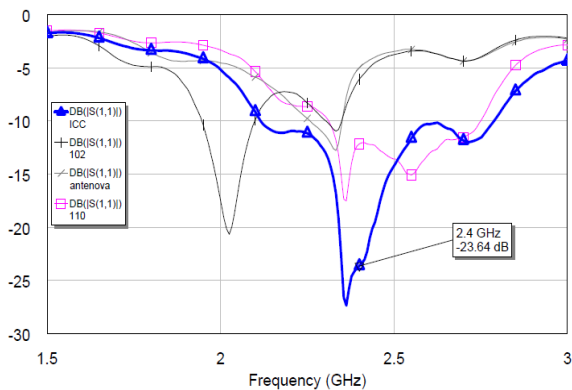


Figure 5. The Result of Measuring Antenna Reflection coefficient

3.3 Performance Evaluation of 2.45GHz RF module

In order to test RF module with antenna, we analyses the signal strength of the RF power received from the tag. Figure 6 and Figure 7 show measured RF output power for the 2.45GHz antenna board based on RF module.

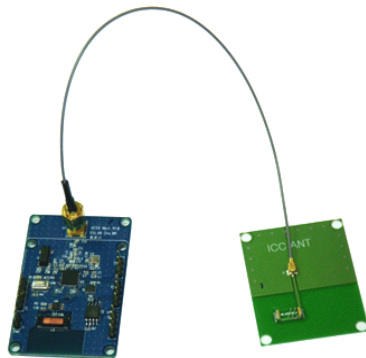


Figure 6. Fabricated RF module with 2.45GHz antenna board

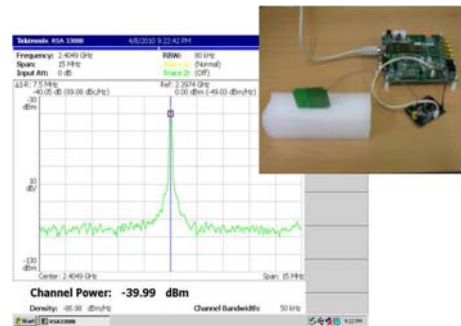


Figure 7. The results of measuring continuous power signals

One of the advantages of RFID technology is that tags can be read from a distance of several hundred meters using radio waves. Figure 8 show results of measured the distance.

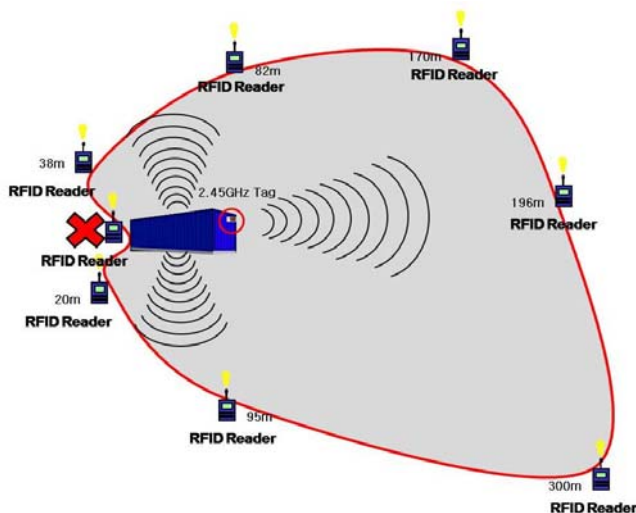


Figure 8. The results of measuring at field test

IV. CONCLUSIONS

This paper introduced the development stages of container security device, and investigated container security devices whose design and manufacturing are based on Active RFID. It also introduced ConTracer which is developed in this research and complies with CSD requirements published by the U.S Department of Homeland Security(DHS). ConTracer is mounted at the gap between container wall and door using magnet. It detects door opening using reed sensor, equipped with temperature/ humidity/ shock sensors to detect transportation status of container and provide its history.

For performance improvement ConTracer, In this paper the small chip antenna is suggested to miniaturize the container security device and to have a good performance. Physical size can be shortened by using both the printed circuit technology and the meandered antenna structure. In result, those methods enable the antenna to be embedded in the device so that those lead to good space efficiency. Moreover, the chip type helical antenna has several design parameters that make the optimum condition to maximize bandwidth at 2.45GHz. In this antenna, the return losses (s11) in 2.45GHz are measured -22.34 dB. The antenna that is proposed in this paper can be embedded in container security device because it has a small size of 9mm height, 4mm width and 1 mm thickness, and it was designed to be applied to many applications such as container security device.

Future projects would be ConTracer mounting location to solve recognition instability problem when the container is filled with steel freight, DCP interlocking problem for data transmission to server, RF performance environment interference of ConTracer in steel structure which were found from the international demonstration service results. Also, we will take performance evaluation through domestic and international demonstration service between Korea and China.

ACKNOWLEDGMENT

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