Identifying Materials using Radio Frequency

Group Members: Cuong Trinh/ trinhcuonglouis@yahoo.com

Chi Huynh/ chihuynh2005@yahoo.com

Khanh Truong/ khtruong89@yahoo.com

Advisor: Ray Kwok

Date: December 07, 2012

San Jose State University

Electrical Engineering

EE198A Senior Design Project

Professor David Parent

Abstract

The idea of our project is to build the application of detecting metal properties with low-cost effective. It is an application of using two parallel antennas to identify materials properties through microwave. One antenna uses for transmitter, and the other uses for receiver. MATLAB program is implemented for controlling the conversion between analog and digital of the signal in and out. This application will use high frequency with range from 2 GHz to 4 GHz for detecting small metalized objects.

Table of Contents

A. Introduction:

Material characterization has been widely used in many applications from industrial, military to civilian life. Because of its various applications, the need to develop the high speed and high frequency circuits and systems becomes important to develop the accurate detection of materials properties. One of the material characterization applications is airport security scan. After the 9-11 issue, the U.S government has paid more attention to the security system and invested many financial supports into developing a more secure homeland network. Based on one of the articles in the *New York Times*, before 9-11 attack, most security system was formerly done by the airlines or private contractors. However, after 9-11, the security system at airport was handed over to the federal employees. Research also shows that the Department of Homeland Security has spent at least $40 billion investing in the airport security system after the attack.

In addition, the airport security scan point is not a good scanning process. During the process, passengers have to take off everything, such as bags, bell, watch, metalized objects, etc. They would put them into the box, which runs through the cabinet X-ray system. The passengers then will have a full-body scan through the backscatter system. Once they are done with the scan, they will wait to get the box back and put everything on again. Because of this troublesome process and the radiation exposure, some passengers refuse to do these scans. As a result, they have to have a full-body pat-downs test, which can lead to the sexual assault, according to "Airport security scans: what would your doctor do?" article in CNN Health. Therefore, passengers force to choose either going through the troublesome process of scanning or the pat-downs test.

Thinking about all those process and the security system, our team decides to develop a scanning system that would allow passenger to go through the check without take off anything but is still able to detect small dangerous metalized objects. Our "identifying materials using radio frequency" will be the application to satisfy these requirements.

As of today, there are many companies that develop application based on radio frequency. One of the big companies is Analogic Corporation, which likely has the same concept as our project. The product is named eXaminer and COBRS systems. This product can scan 3-D color images of the entire bag and its contents for threat detection. However, our application is to scan the entire body for threat detection. Although Analogic Corp. and our application

implement the same concept of identifying material using microwave, our application will scan the entire body without putting the bag in the cabinet X-ray system. There will be save a lot of time and checking process. In addition, our application is a low-cost effective product because it can be considered the combination of the cabinet X-ray system and the backscatter system. Therefore, our project will be a promising application in the future.

B. Specification

There are a few significant parameters that greatly influence the success of our project. The first parameter is reflection coefficient, as known as S11. By obtaining the reflection of signal from the antenna, we can predict the shape of the object. This step requires a lot of hand calculation to get the shape of the object out of S11. Second, transmission coefficient is another important parameter to our project because from this value, we can actually determine the materials of the testing object. Combination of both S11 and S12, reflection and transmission respectively, will be able to extract relative permittivity of the material (ε). Different type of material has a difference value for ε. Therefore, by knowing the relative permittivity, we can identify the material of the object. When we think about the successful of this project, we definitely need to have accuracy values of S11 and S12 measurement to obtain a correct value for relative permittivity. In conclusion, S11, S12, and ε are three significant parameters to this project.

C. Methodology

This project presents many problems. The first problem that we encounter is finding the right antenna. There are many different types of antennas out there. Therefore, this task is really difficult for this project. Each of us has to do a lot of researching for it. At last, we all agree with cantennas because it is simple to build, work with 2.4 GHz, and efficient in finding reflection and transmission coefficient. Even though we are done building the antennas, we have no idea how to use it to measure the parameter we need. That is when our advisor, Dr. Kwok, provides much useful insight information on how to test our antennas, how obtain the value of S11 and S12, and how uses those information to extract the relative permittivity of the test object.

One possible solution is that we can measure the relative permittivity of the air. In this solution, we first connect our antennas to Vector Network Analyzer (VNA) at a fixed distance.

The VNA will provide us the value of S11 and S12 of the air. From those values, we could calculate permittivity of air and use it as a reference value. If we obtain the right value of permittivity of air, it will greatly increase our chance in getting a correct value of the test object's permittivity. In order to measure S11 and S12, we have to assume the frequency of antenna is averaged at 2.4 GHz. There are several reasons for using this assumption. This bandwidth of 2.4 GHz is not a required license. It makes the calculation easier in this frequency. Also, the lambda (λ) will be exactly 4.92 inches at this bandwidth. Later on, we will build the receiving circuit, which replaces the VNA, to catches and analyze the transmission and reflection coefficient of the signal.

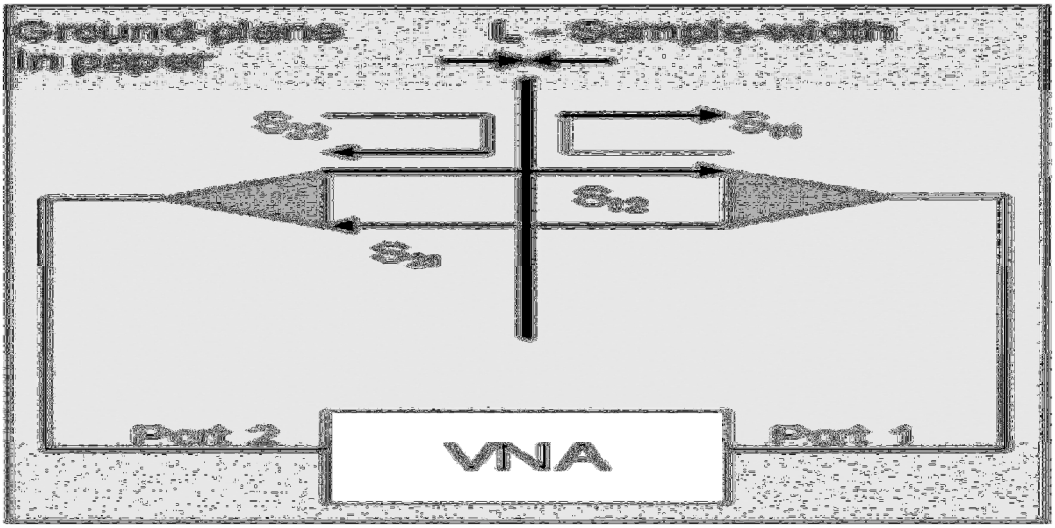


Figure 1: The Connection of Two Antennas to VNA

D. Cantenna Structure

As we mentioned above in methodology section, we will first use the VNA to run several tests for obtaining the data of transmission and reflection coefficient before building the circuit of matching network. We then calculate and compare the variation between the theoretical values and the experimental measurements. To build a cantenna with great transmitting signal, we have to find a smooth body can, which will work better for radiation the signal. The cantenna needs to have one closed end and one opened end in order to send the signal out. Moreover, we have to calculate the right distance from the closed end up to the position of a hole, which uses to connect an N-female connector. The length will be equal one fourth of the guide wavelength. This length will help us to get maximum power transmitted and reflected wave because the

signal that we send and reflect back is acted like a sine wave. Therefore, we must have a right position to get our max signal. Also for the N-female connector, we have to solder a 1.25 inch of 12 gauge cooper wire to reach out to the middle of the can. After all those steps, we will hook it up to VNA and try to accumulate the data.

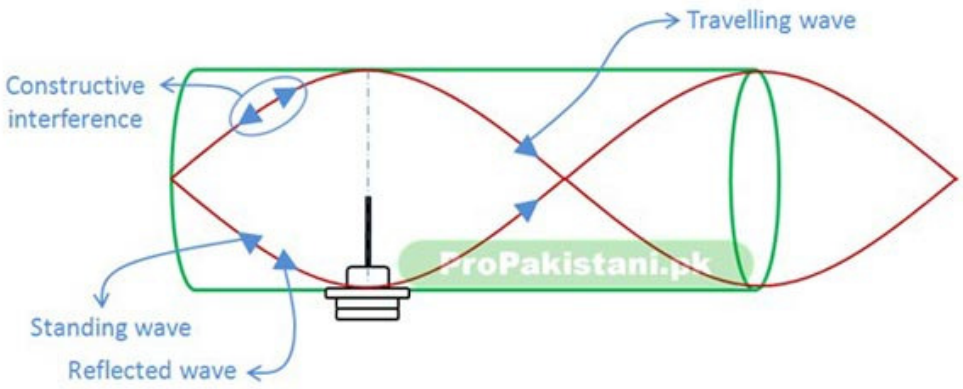


Figure 2: The Structure of Sine Wave in Cantenna

E. Circuit Components and Cost

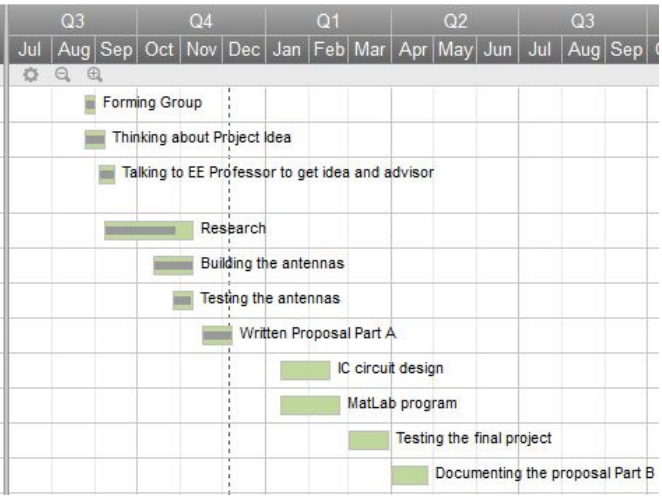
Going into the components of our product, we need a receiving circuit for analyzing and matching the coming signal, so we will need several Op-Amps, capacitors, resistors, and a board to solder our circuit. Also, we need to buy the pigtail wire to connect from the antenna to the modulator. We will need 2 pigtail wires because we have two antennas. One is transmitting the signal, and other one is receiving the signal. Moreover, we need the modulator and frequency control, so we can send the signal with the frequency that we need.

About the cost of our product, the EE department lab can provided us the resistors, Op-Amps, capacitors, and the soldering board. However, we have to spend the money to buy the modulator, frequency control, N-female connector, and pigtail wires. As we did researches, the most expensive one is the modulator; each modulator is about 40 dollars. And for the pigtail wire, it costs about 10 dollars for each one. Overall, we will need to spend approximately $100 for our product.

F. Time Management

Table 1: Timeline for the Project

	Task Name	Start Date	End Date
1	Forming Group	08/24/12	08/31/12
2	Thinking about Project Idea	08/24/12	09/07/12
3	Talking to EE Professor to get idea and advisor	09/03/12	09/14/12
4	Research	09/07/12	11/09/12
5	Building the antennas	10/12/12	11/09/12
6	Testing the antennas	10/26/12	11/09/12
7	Written Proposal Part A	11/16/12	12/07/12
8	IC circuit design	01/11/13	02/15/13
9	MatLab program	01/11/13	02/22/13
10	Testing the final project	03/01/13	03/29/13
11	Documenting the proposal Part B	04/01/13	04/26/13



Base on the schedule, we will start building IC circuit design and writing MATLAB code for our application starting January 1, 2013. According to the schedule, we will try to manage and complete our project before March 3, 2013 in order to test our product. The hardest challenge of the project is how to detect the materials in front of our cantennas. We will need to try to run many tests as possible in order to have the right concepts of materials.

G. Responsibility among Team Members

As we mentioned, this is a difficult project, so each member has a lot of responsibility toward the project design. There are a lot of arguments, and we have to make sure that everyone in the team agrees to the one single final decision before moving to the next task. The purpose we spend time on argument is that we want everyone to agree to the best solution. Since we don't have a summer time, it's essential that each member will complete the assigned tasks on time. We all agree to meet the advisor and gather together every two weeks to update information on the project.

H. Preliminary Work

We tried to run some tests with our antennas and VNA to see how the reflection and transmission coefficient change with the different materials. From this information S11 and S21, we can calculate the values that we need to determine the material in between. However, in the next semester, we will have our circuit and hook it up to our laptop to see the result without VNA.

Here was some picture that we tried to test out the materials in between two antennas with the VNA in the communication lab EE238:

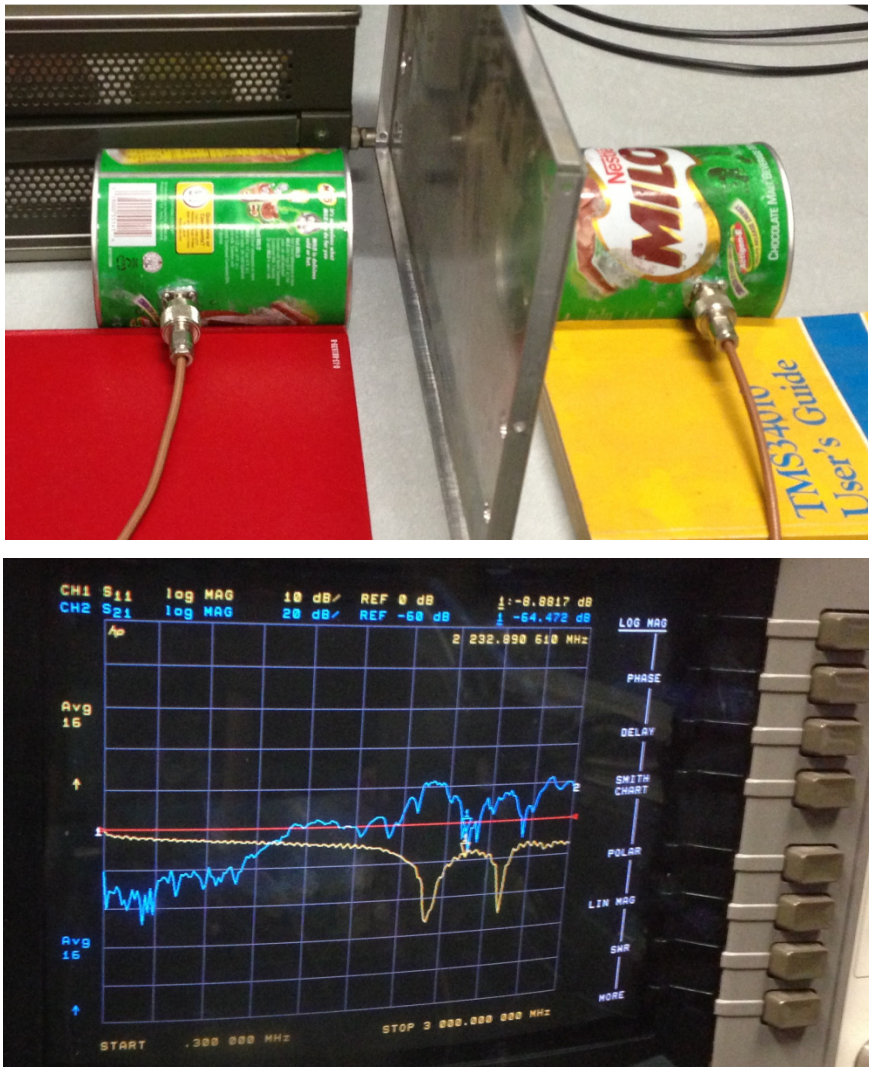


Figure 3: A test with Aluminum material in between two antennas

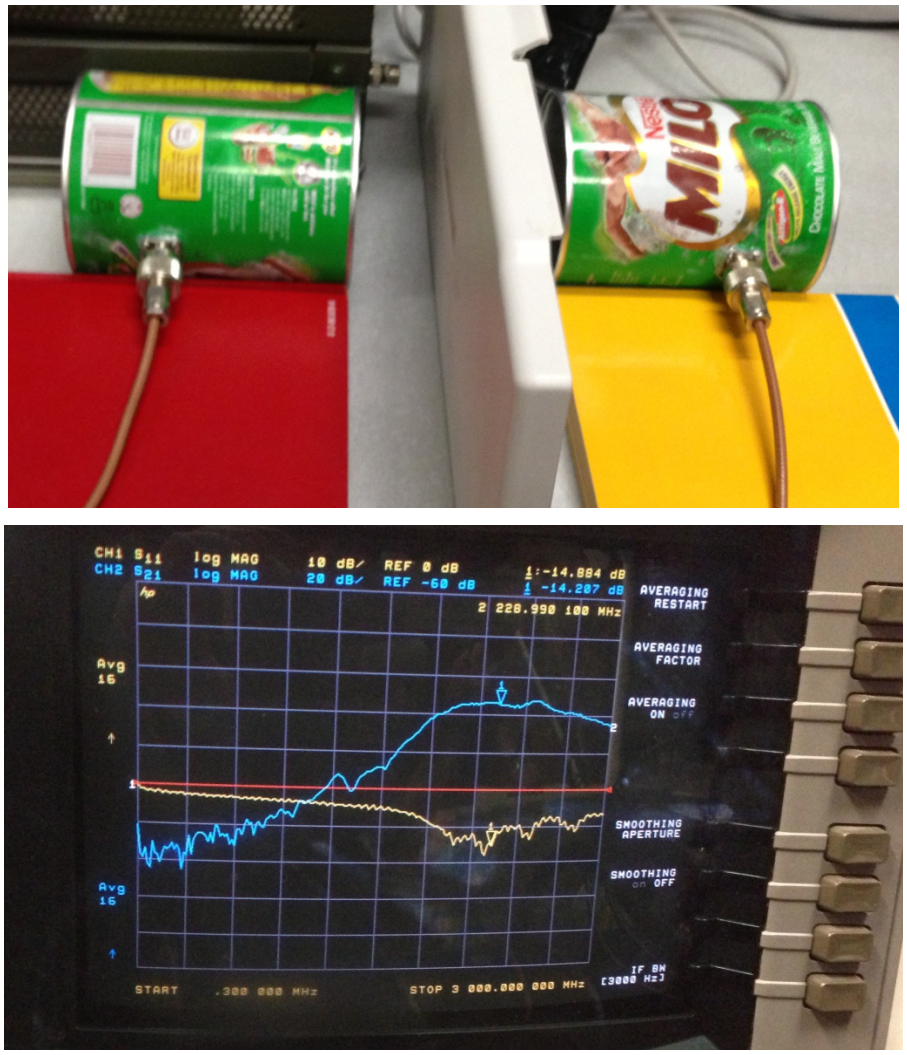


Figure 4: A test with the plastic material in between two antennas

I. The Various Skill Sets

In order to succeed in this project, a minimum knowledge requirement in several courses has to be had. Our team had learned about EE161: Digital Communication Systems. We would apply the knowledge of modulation A/D and D/A into our project. In EE124: Microelectronic Design II, we learned about MOSFET, amplifiers and their application. In EE172: Microwave, we learned how to wave propagation in the air and how to construct and test a simple antenna. In EE153: Introduction to Digital Signal Processing, we learned about MATLAB program and the shapes and behaviors of signals in frequency domain. Using this knowledge, we will be able to write a simple MATLAB code to generate and analyze the transmission and reflection of the signals.

J. Conclusion

Overall, “Identifying material using RF” is an interesting project. The success of this application can bring us not only the good grade in our senior design course but also the promising career later on. Security system has become the top priority in the U.S. The government and private sectors would provide a lot of fund and jobs to develop any project related to security system. There are many companies developing and updating application with the cabinet X-ray system and backscatter system. However, we believe that our application is unique since it is a combination of both systems. That’s why we are excited in our project design. Although we run into many obstacles, we are able to build two cantennas and have them tested. Our project is interesting but not easy to construct. It requires a lot of time and effort to gather information. Each member in the team has to have some basic knowledge of EE161, EE124, EE172, and EE153 in order to participate in the project. By scheduling ahead, we already know what we will do in the following semester. We are enthusiastic and cannot wait to see our precious application on the market someday in the future.

K. Reference

1. Hasar, U.C., "Permittivity Measurement of Thin Dielectric Materials from Reflection-Only Measurements using One-Port Vector Network Analyzers," *Progress In Electromagnetics Research, PIER 95, 365-380, 2009.*
2. Alcorn, J (2012, August 12). *Airport Security*. Retrieved December 01, 2012, from The New York Times website: http://topics.nytimes.com/top/reference/timestopics/subjects/a/airport_security/index.html
3. Cohen, E (2011, March 31). *Airport Security Scans: what would your doctor do?* Retrieved November 30, 2012, from CNN Health website: http://www.cnn.com/2011/HEALTH/03/31/ep.airport.scanners/index.html
4. Richards, Jodi. *(2008, November 2). TSA Pilot Prompts a Hands-Off Approach at DFW Checkpoints*. Retrieved November 2, 2012, from Analogic website: http://www.analogic.com/Collateral/Documents/English-US/AI%20DWF%20Article.pdf