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Department of Electronic Engineering

FINAL YEAR PROJECT REPORT

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Radio Frequency Identification for Library: Bookshelf

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ABSTRACT

Nowadays, Radio Frequency (RF) was one of the main technologies in the world. This technique applied with tags was very famous and useful methods to do security control, access control or tracking system. In library, barcode was used a long time for check out the book but it could not do a tracking and circulation system to identify the book on the shelf.

In this project, the main purpose was to design a tracking and counting system in library with RFID to reduce the time spending to find and count books. It checks the row of books and court the number of books in the shelf. There were installed four antennas in each row to detect the books. Each antenna was transceiver. They were enabled one by one based on the switching circuit to select the channel scanning the books. After the signal received, it would send to the computer for analysis.

I am mainly focus on design the switching circuit and patch antenna. The switching circuit had two versions. The first one was simple switching circuit and another one was circuit with high isolation. Then I try to simulate the patch antenna using an edge feed method. The antenna could be operated in the radio frequency between 920MHz to 928MHz. I am also design the structure of the bookshelf.

CHAPTER 1: INTRODUCTION

1.1 Hong Kong Library

Nowadays, Hong Kong library was used barcode to maintain the management such as sorting, check-in or check-out. It was useful on do that. However, sometimes we went to library wanting to read a book, we could not find it but the library system was showed that the book was not lent. Actually, nothing the librarian could do because it was so harsh to find out the book from the library if it was not in its original position. Therefore, we tried to build up a system, which was not only could check the position of book automatically, but also did a security system in the future development.

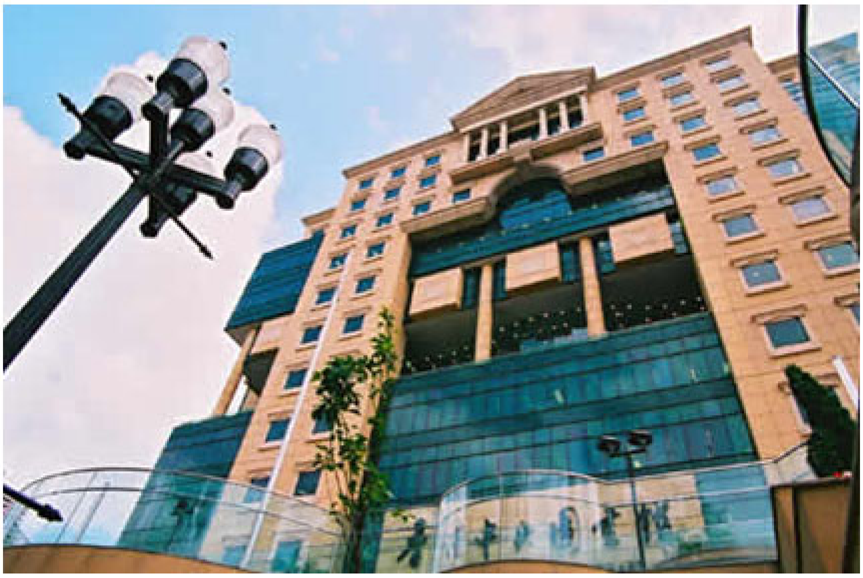

Figure 1.1: Hong Kong Public Library

1.2 Library System Management using RFID

1.2.1 What was barcode?

It used a visual format to represent information such as ID. It produced by a white line and a black line. The width of the line and the separation distance between the lines would be effect the information on the barcode. It was implement Auto ID Data Capture (AIDC) systems widely. It could also read by barcode readers. Therefore, it had a great help for shop or company to manage a large number of items for keeping tracking in store, such as the books or CDs in library.

Figure 1.2a: The book with barcode

Absolutely, there were some benefits on it so it was also applied until now. It identified quickly, such as check-in and check-out. The accurate was high due to the error rating low. It was also business friendly because it was very cheap and common using. However, it also had some disadvantages. It could not change the information after data wrote into. It should read by scanner one by one. The distance between the barcode and the reader should be as short as possible. This was inconvenient method for checking the book or finding a book as long as possible. Therefore, another method was applied. It was Radio Frequency Identification (RFID).

1.2.2 Radio Frequency Identification (RFID)

This technology used a wireless communication to do an automatic identification method. It also used a communication skill to identify the certain target and then reading the relevant data from it. In this method, the distance between the reader and the target was no mechanical or optical contacts. It was widely using in world. For example, a pet was injected IC to their body for identification the behaviour or health state or common application product was Octopus for transportation fees and payment.

Basically, the simple system in RFID should be included three elements. It was a reader, antenna and tag.

Reader: It was used to send the signal to the antenna active the certain tag followed by the instruction. It also controlled the power level and operating frequency.

Antenna: Design the size of the antenna based on the operating frequency and the sharp of it. Actually, it was designed in a certain frequency range, which was LF to MF (125 - 134.2 kHz), HF (13.56 MHz), UHF (868 – 956 MHz) or EHF (2.45 GHz). The function of it was simply as a bridge between the tag and reader for communication. The electrical current was induced by RF signal, which provides a power to power on the IC.

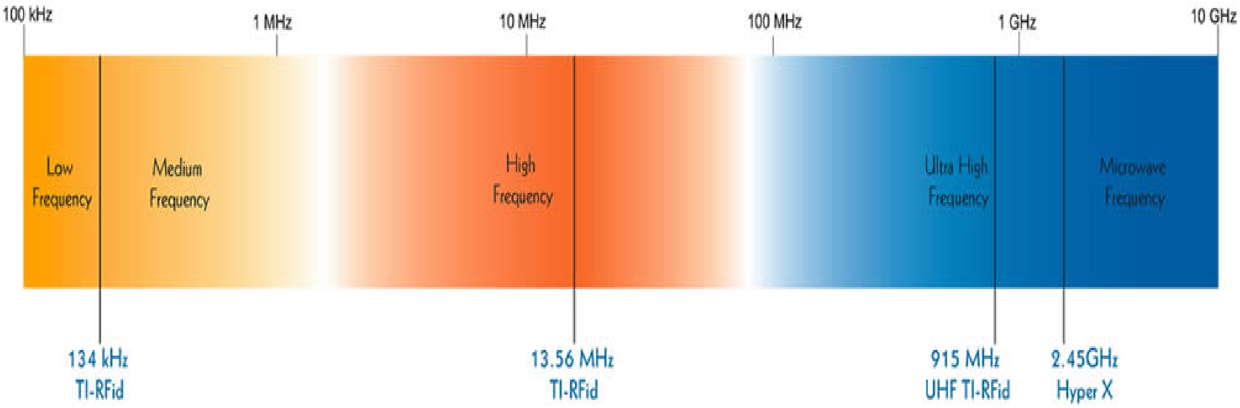

Figure 1.2b: The frequency spectrum of RF

Tag: The size of tag was controlled by the sharp and the frequency of the antenna. It was included silicon chips and antenna, such as the following diagram. It could communicate wirelessly because it had a antenna used

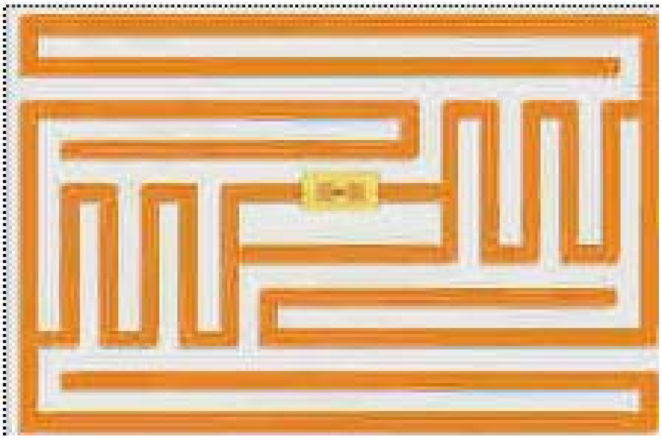

Figure 1.2c: The diagram of tag

for transmitting and receiving signal from the wireless medium. There had two kinds of tags. They were passive tag and active tag.

Passive tag – it was no internal power to transmit the signal and it was non-volatile EEPROM, so the data could be saved in the tag. The size was small, it was suitable to attach with product.

Active tag -- it required a power to turn on the tag, therefore, the size was larger.

1.2.3 The different between barcode and RFID tag

	RFID Tag	Barcode
Capacity	High	Low
Distance of communication	Long	Short
Security	High	Low
Effect by environment	Low	High
Multiple reading	Yes	No

Table 1.2: Comparison between barcode and RFID tag

There was a table to compare with tag and barcode. From this table, we could see that tag had a high capacity than barcode. It could operate in long distance between reader and antenna. It could also read by reader multiple, but barcode could not do that. The security in tag was higher than barcode because it was not easy to copy. It had a less effect by the environment such as the temperature or weather. From the result, we would choose a tag in this project. And the passive tag would be selected because it was no need a power attached to books.

1.2.4 The advantage using RFID for checking the book

After the system was applied in the library, the librarian could save time on finding a book and the human resources could be reduced. If there was no need more staff in library, the cost in human resources was also decreased. For the future benefits, it could be saved a huge of money on operation. And it was easy and convenience for counting, therefore, it was very accuracy and efficient then before method.

CHAPTER 2: THEORY

2.1 Basic theory for switch circuit

In this project, it was using a simple switch circuit to implement. It was called Single-Pole-Single-Throw (SPST) switch. It was operating in a simple on-off circuit. It was controlled by a switch to connect or disconnect the path. The simple circuit was showed below.

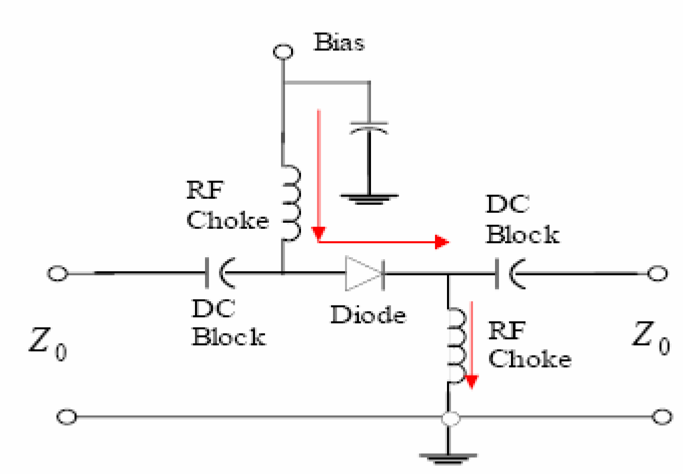

Figure 2.1: Switch circuit

The diode was controlled by the bias. When the voltage was larger than threshold voltage, it would turn on. The signal from left hand side terminal would pass through the capacitors and diode to the right hand side terminal. The inductor in the circuit was used to block the RF signal short to ground.

2.1.1 Switch insertion Loss (IL)

A switch was inserted into a transmission line make the power in receiving port decreased. The ratio in dB of the power received at load after the switch inserted to the power received at the load without insertion. It was called an insertion loss.

$$IL = -10 \log (P_L / P_O) \quad (1)$$

where P_L represent the power transmitted to the load with ideal switch in on state

P_O represent the power transmitted to the load with practical switch in the on device

2.1.2 Switch Isolation

The different between the power transmitted to the load in ideal switch in the on state and the power transmitted to the load in practical switch in the off state.

$$\text{Isolation} = -10 \log (P_L' / P_O) \qquad (2)$$

where P_L' represent the power transmitted to the load with ideal switch in on state

P_O represent the power transmitted to the load with practical switch in the off device

2.2 Mircostrip transmission line

It was a printed circuit construction, which was included a copper or other conductor material on a dielectric substrate. The lower plane was a ground plane, it was used to eliminate the noise effect on the upper transmission line. The properties of the transmission line based on the length and the width of it, but also affected the dielectric constant or the height of the substrate.

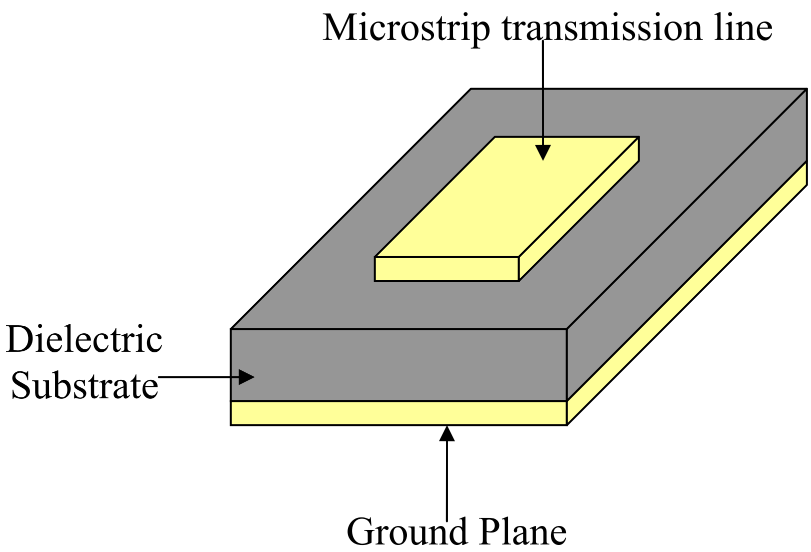

Figure 2.2: The diagram of mircostrip

2.2.1 Characteristic Impedance

It corresponded to the input impedance of a transmission line. When the characteristic impedance was matched to the impedance of load and the source, the maximum power transfer would occur. However, when impedance was not same, most of signal would be reflected to the source. It would lower down the efficient.

$$Z_0 = \frac{\eta_0}{2\pi\sqrt{\varepsilon_{eff}}} \ell_n\left(\frac{8h}{w} + \frac{w}{4h}\right), \qquad \frac{w}{h} < 1; \qquad (3)$$

$$Z_0 = \frac{\eta_0}{\sqrt{\varepsilon_{eff}}}\left[1.393 + \frac{w}{h} + \frac{2}{3}\ell_n\left(\frac{w}{h} + 1.444\right)\right]^{-1}, \qquad \frac{w}{h} > 1. \qquad (4)$$

In calculation, using an effective width and effective dielectric constant would get better result of characteristic impedance.

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\left(1 + \frac{12h}{w}\right)^{-1/2} + 0.04\left(1 - \frac{w}{h}\right)^2\right], \qquad \frac{w}{h} < 1; \qquad (5)$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{w}\right)^{-1/2}, \qquad \frac{w}{h} > 1. \qquad (6)$$

$$w_{eff} = w + 0.44h; \qquad \text{for} \quad w/h > 1. \qquad (7)$$

2.3 Basic theory for patch antenna

Basically, a microstrip patch antenna could use a PCB board to represent. It was included three parts, which was the dielectric substrate between two copper, radiating patch on one side copper and the ground plane on another side copper.

2.3.1 Matching

When the load was connected to something, which was connected with a transmission line and the characteristic impedance was not matched, the length or width of the transmission line changed could make it to match.

$$Z_{\text{matching network}} = (Z_{\text{charteristic impedance}} \times R_L)^{1/2} \quad (8)$$

2.3.2 Return Loss

As same as before mentioned in 2.1.1. Absolutely, the return loss should be less than -10dB.

2.3.3 Gain

It was used to measure the gain in a direction of the antenna. The gain of the antenna was calculation by the ratio of the intensity radiated by it in certain direction with distance divided by the intensity radiated at the same distance by an hypothetical isotropic antenna.

2.3.4 Bandwidth

The bandwidth of antenna was that the range of the frequency could be operation. Actually, it was within -3dB. The following equation showed how to calculate the bandwidth.

$$\frac{f_H - f_L}{f_H + f_L} \times 2 \times 100\% = BW\% \quad (9)$$

2.3.5 Radiation pattern

It was used a graphic to represent the radiation directions. At the resonant frequency, the gain in that direction would be high and it would be called major lobe. Between -3dB, it was the width of the main beam. The other side with low gain was called minor lobes. Different antenna would have different radiation pattern, based on the application method to design the suitable antenna.

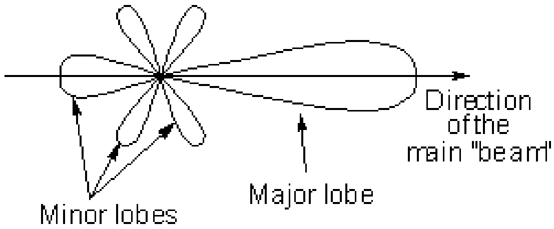

Figure 2.3: Radiation Pattern

CHAPTER 3: BASIC SYSTEM IN LIBRARY

3.1 System Description

This system mainly used in two conditions. The first one was the librarian want to find out a lost book in the library, and the second one was after the opening hours, the librarian should return all of books to their original shelf. From these two conditions, the system would be used.

Before the opening in each day, the library system would check all of the book position through the reader. It makes sure that they were located in their original position. Actually, the database of the position list had already sent to the reader. It was used to compare the different between the database and the data read from antenna. After the reader scanned all of books on their bookshelf, the data would be back to the reader to do a comparison. Roughly, the position of a book would check by an antenna through the reader to select the port. A part of book was scanned by one of the antennas. After reader read the data, it would compare with the present position and original position. If it were not match, the reader would send the message to the computer through the network, and alerted the librarian to collect all of the books.

Because it had a function to check the position of book, helping the customer find the lost book in the library was easy and convenient. As same as before, when a book was putting on wrong bookshelf, there was a warning message sent from reader to remind librarian.

3.2 Structure

In this system, it was constructed by five elements, which was computer, reader, switch circuit, antenna and tag with book. In a bookshelf, there were four layers and each layer had 4 antennas inside.

Computer: It was used to send an instruction through TCP/IP to the all of reader and instructed them to do something the user want.

Reader: It followed by the instructor from computer to control the center frequency of the signal or RF power level. It would be a static state if the computer did not send any instruction. However, when it received, it would follow by the instruction to send a signal to different antenna. Oppositely, it would also receive the signal from antenna and then sent back the signal to computer for analysis through TCP/IP.

Switch: It was a bridge between reader and antenna. It was used to select the different antenna connected to the reader and the channels, and the three control pins controlled the output ports.

Antenna: It was a mircostrip patch antenna. It was operating in 900M to 925M Hz. It was used to get the data from tag or active it.

Tag: It was attached with the book. It was not only recognized the position of book, but also got the information with the attached item.

3.3 The operation flow in the system

Firstly, the computer would set all of parameters in RCW program and sent an instruction to the reader. When the reader got the instruction, all parameters in reader were set and then started to order switch circuit. It would control three control pins in switch circuit to select which channel was used. When the channel was connected, the signal with 900M to 925MHz from reader sent to antenna to active the passive tag. The tag was induced by magnetic field and got an induced power. Therefore, it was based on the reader signal enable transmit and receive signal. After the tags were replied, the data would send back to the reader and compare with the database, make sure it had a correct position. If it was wrong position, the reader through TCP/IP transmits the signal to computer and alert a librarian collect the book.

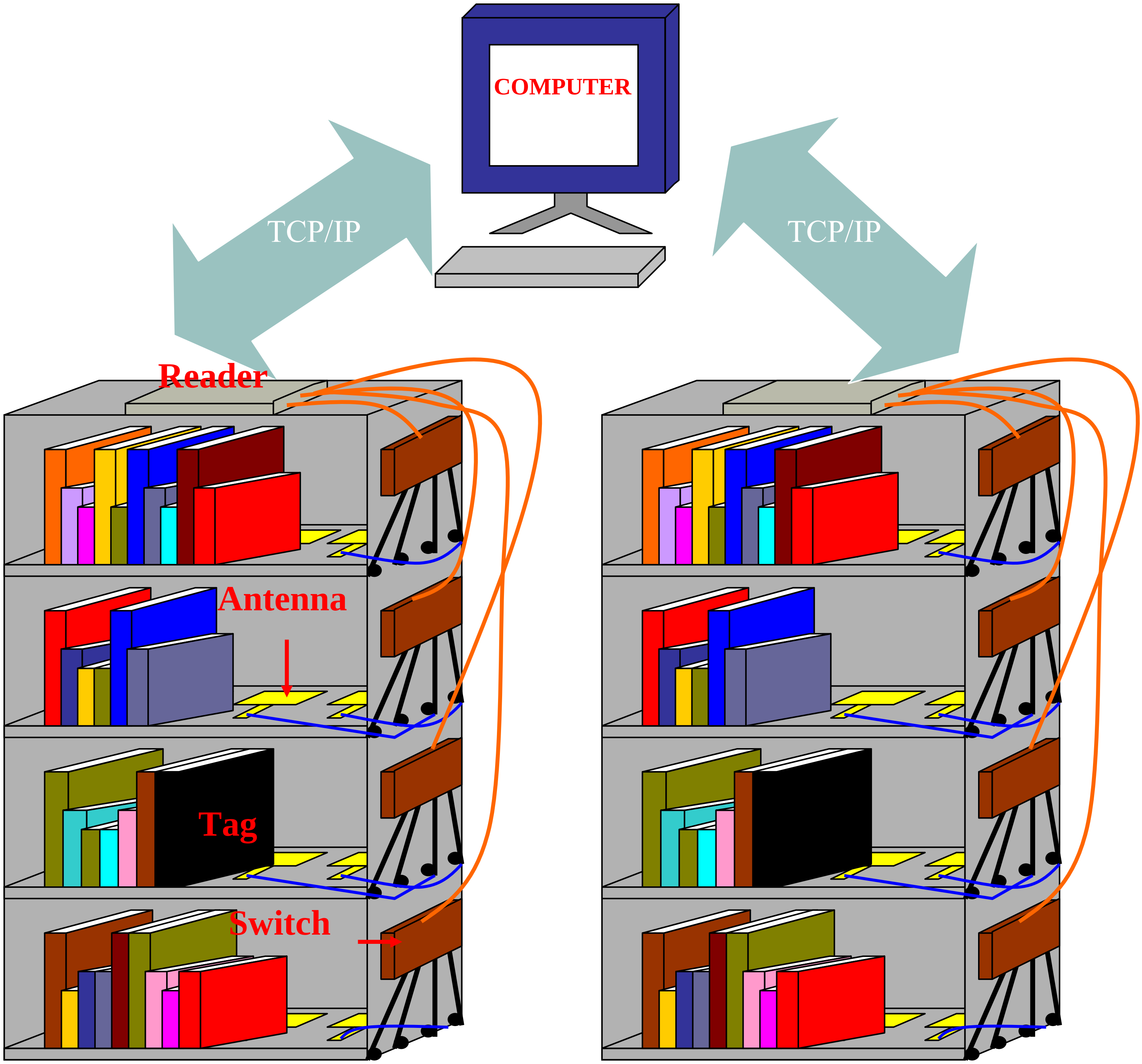

Figure 3.3: Structure diagram about the whole system

CHAPTER 4: SWITCH CIRCUIT

4.1 Description

It was a switch circuit. It was built up by three elements, which was inductor, capacitor and PIN diode. The purpose of the switch was used to select the four antennas in a layer. It was one input port and four output ports and it was controlled by voltage sources. Based on different voltage sources combination could control different port enabled. This circuit seemed as a bridge between reader and antenna so the power loss was a main consideration in this circuit. It would totally affect the performance of the system. The loss caused by the value of inductor. If the value of it were large enough, the loss would be reduced because the inductor impedance for high frequency was very high. Absolutely, the impedance ration between the inductor and capacitor were also importance. If the ration was more than 20, meaning the impedance of inductor was 20 times the impedance of capacitor, the loss could be improved as large as possible.

4.2 Circuit Explanation:

For the switch circuit, there were two versions. They were simple switch circuit and switch with high isolation circuit. They were also used to design the switch circuit, but with different performance between them.

4.2.1 Simple switch circuit

The following diagram was the simple switch circuit schematic.

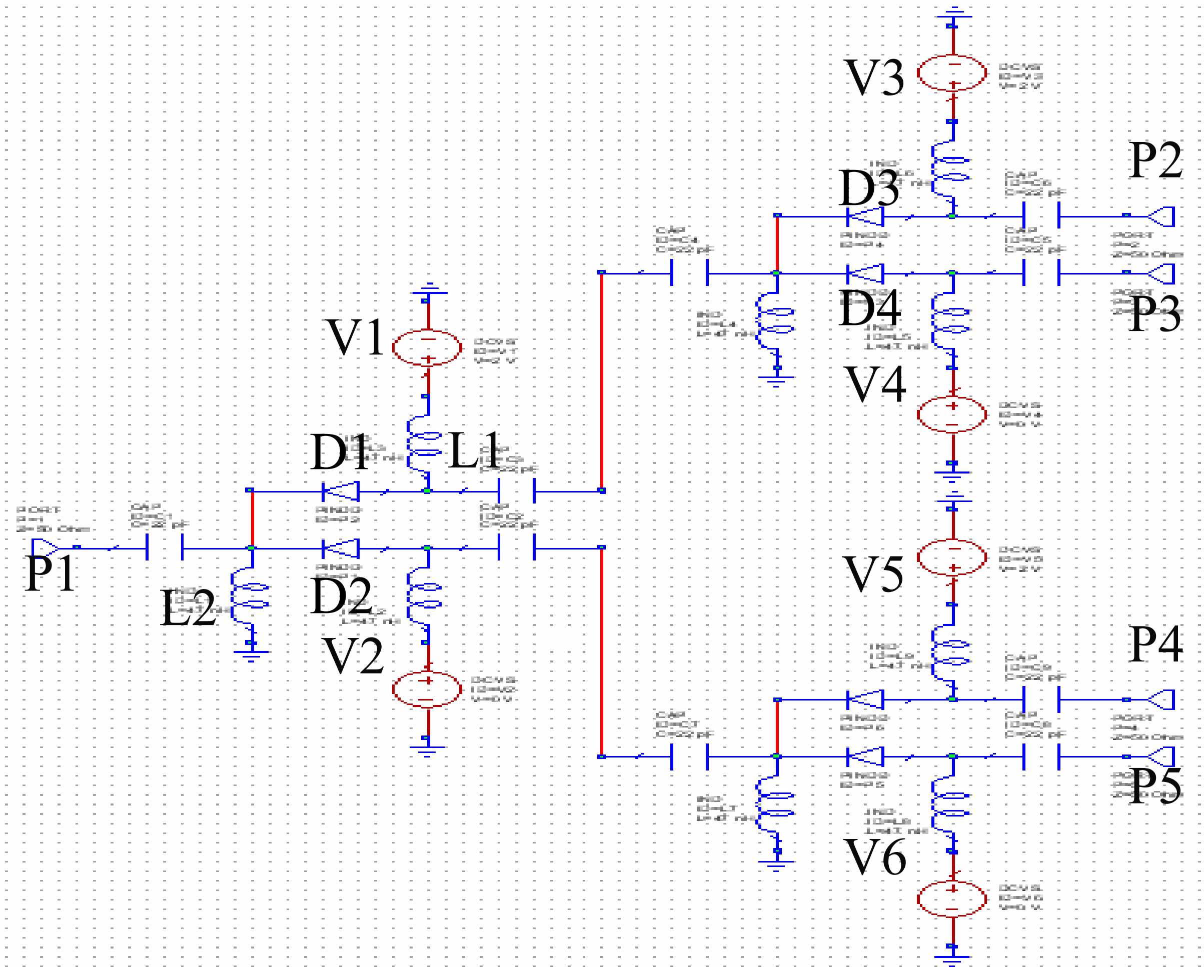

Figure 4.2a: Simple Switch Circuit Schematic

In this circuit, the value of inductor and capacitor and the model of diode were 47nH and 100nH, 22pF and common cathode PIN diode respectively. There was Port 1 to Port 5. Port 1 was input port, which was connected to the reader. The rest of ports were connected to different antennas in a layer. The antennas connections were controlled by six voltage sources, V1 to V6. Different voltage applied on voltage sources would had a different channel selected. The voltage source supplied a low frequency voltage, therefore, the signal could pass through the inductor. However, the capacitor would block the signal pass through, unless it was a high frequency signal.

When the voltage sources turned on the diode, the high frequency signal from P1 could pass through to output ports. Moreover, the inductor would prevent the high frequency signal short to ground, that make the output port get large signal reading.

4.2.2 Example for showed the connection between Port 1 to Port 2

When V2 was connected to ground, it had not enough voltage to turn on D2 diode. Therefore, in port 4 and port 5 was not able to use. Now, if V1 was applied +1V, the inductor would be a short circuit and the capacitor would be an open circuit. The low frequency signal passed through the L1 inductor, turned on D1 PIN diode, passed through L2 inductor and shorted to the ground. At that time, just only considered port 2 and port 3. As same as before, V4 was 0V. D4 diode was turned off and D3 diode was turn on when V4 was applied a high voltage. Therefore, port 2 was selected. The signal could be flown from port1 to port2. It was because the signal could be transmit from reader to antenna or from antenna sent back signal to reader, so that from port 2 to port 1 was also available. This was a table to show how to connect different port.

V1	V2	V3	V4	V5	V6	Switch Port
1	0	1	0	X	X	P2
1	0	0	1	X	X	P3
0	1	X	X	1	0	P4
0	1	X	X	0	1	P5

Table 4.2a: The table of simple switch circuit for selection port

In simulation, the result was

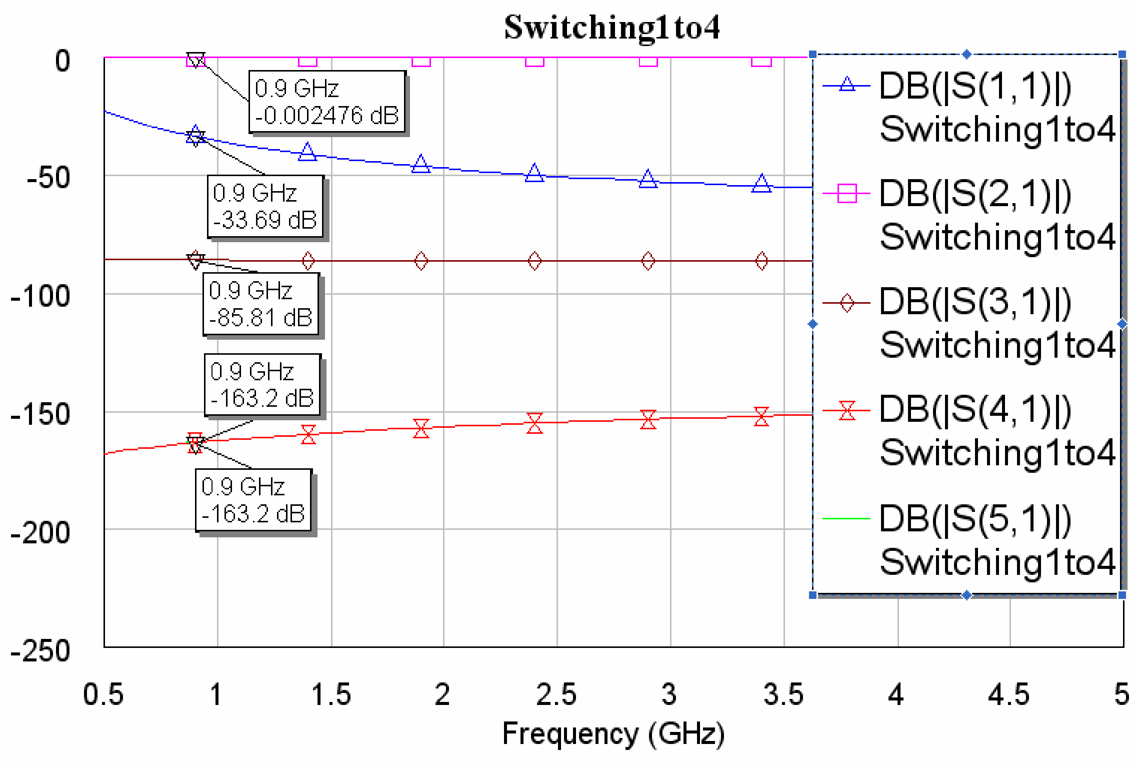

Figure 4.2b: The performance of simple switch circuit in simulation

In practice, the value of inductor and capacitor were different to a simulation result. They were 47nH, 100nH and 22pF replaced by 330nH and 30pF respectively. The common cathode of PIN diode was the same as the simulation element.

When 0dBm with 900MHz was supplied to the input port, the output port was read about -1.03dBm and the near port, P3, was read about -28.45dBm. Thwas was an acceptable result, only 1dBm loss.

There was other measured result showed on port 2 about changing the value of capacitor:

C (F)	L (nH)	Input voltage(dBm)	Output voltage(dBm)
1p	330	0	-11.44
10p	330	0	-2.61
22p	330	0	-1.33
30p	330	0	-1.03
47p	330	0	-1.05
82p	330	0	-1.1
220p	330	0	-1.05
1n	330	0	-1.33
10p	330	1	-1.61
30p	330	1	-0.03
47p	330	1	-0.05

Table 4.2b: The output signal with different value of capacitor

From the result, we found that if the input voltage increased, the output signal was also increased. However, changing the value of capacitor between 22pF to 1nF had not a big different in output reading. The result in simulation and measured were some different.

In simulation, there was showed that the forward gain, S21, was -0.002476dB, but the reading in measured value was 0.78886 in 33pF used.

The input signal was

$$0dBm = 10\log\left(Vin / 0.001\right)$$
$$Vin = 10^{(0/10)} x0.001$$
$$Vin = 0.001$$

The output signal was read

$$-1.03dBm = 10\log\left(Vout / 0.001\right)$$
$$Vout = 10^{(-1.03/10)} x0.001$$
$$Vout = 788.86x10^{-6}$$

The forward gain in measured, S_{21} = Vout / Vin

= 0.78886

The value used in simulation and practice was less different, but the forward gain in the result had big different. Therefore, the simulation just only used to get the reference value. The actual value should be measured and test in the circuit.

4.2.3 Lumped element replaced by microstrip

Because the lumped element, inductor, in simple switch circuit was replaced by microstrip line, we could try using Microwave Office to do a simulation to find the best result. This was a schematic of mircostrip switch circuit.

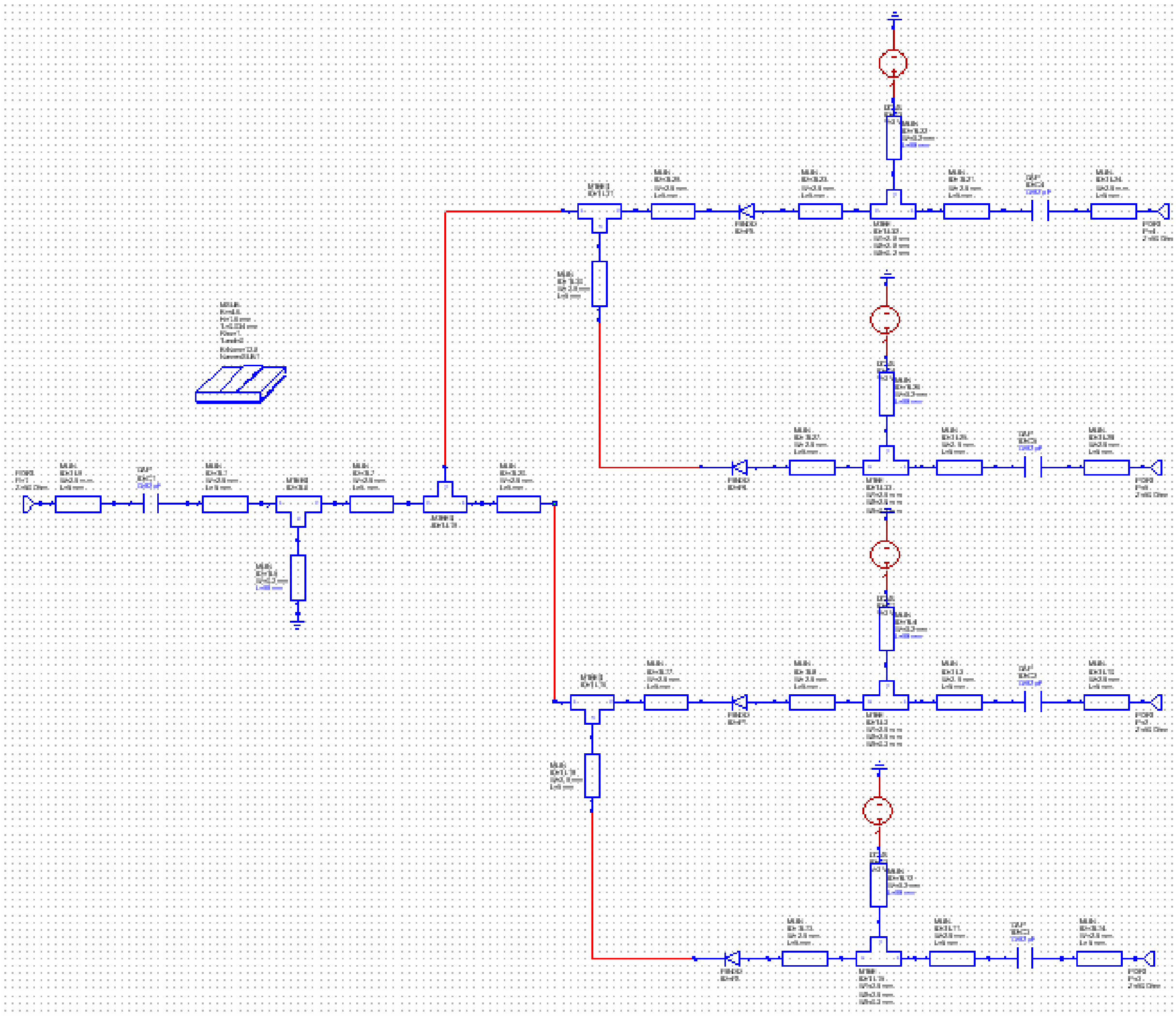

Figure 4.2c: Mircostrip switch circuit in schematic

From the simulation, we found that the width and the length of microstrip line were 0.2mm and 50mm to replace inductor. It could be better to represent the lumped element.

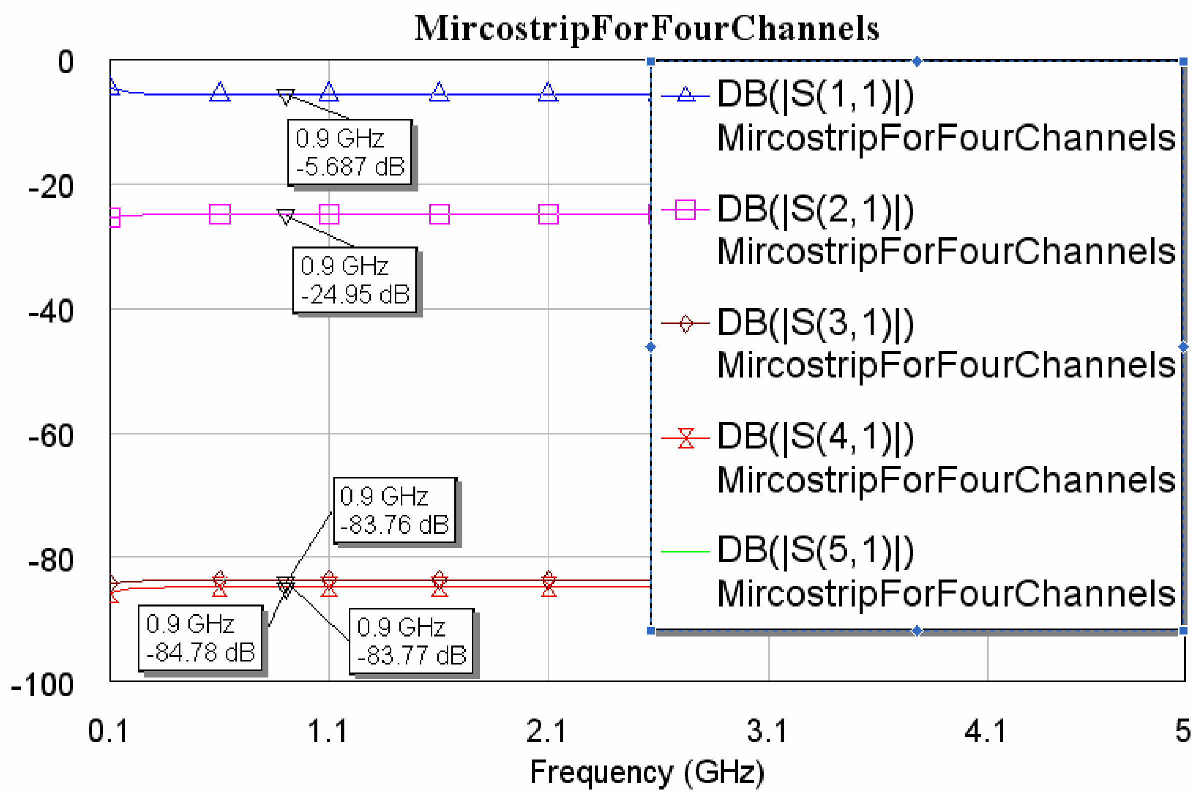

Figure 4.2d: The performance of mircostrip switch circuit in simulation

Compared with the forward gain and return loss in lumped element and microstrip, it was observed that the result in microstrip was worst. Using lumped element could get better result.

This was the layout of the simple switch circuit using microstrip representation. The thin line represented inductor.

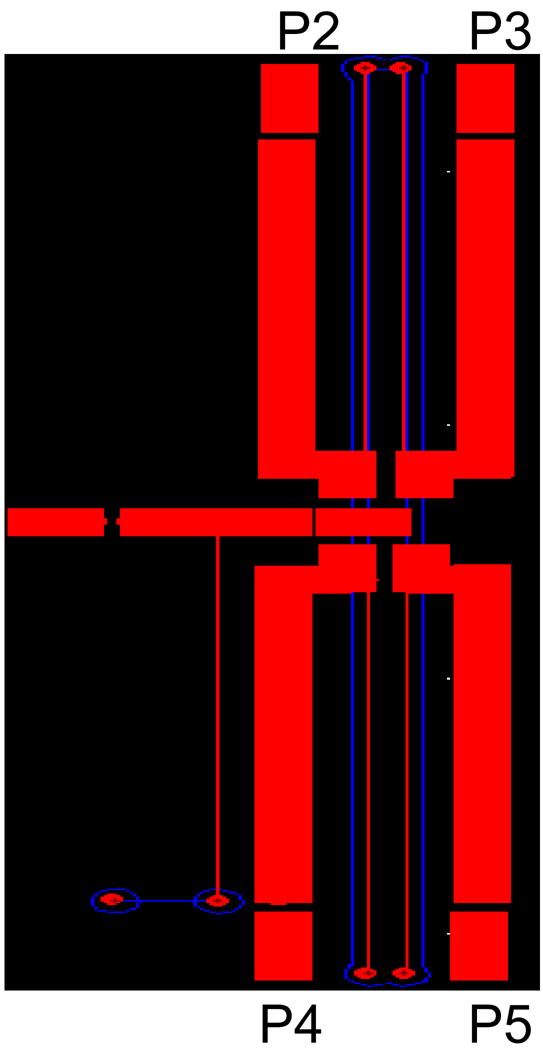

Figure 4.2e: The layout diagram of microstrip switch circuit

The distance between Port 2 and Port 3 or Port 4 to Port 5 was very close. Some problem would occur, which was coupling. The signal coupled to near port when two ports were closer. From this reason, we wanted to try to short the unselecting port to the ground. It makes the coupling signal read in output port elimination effectively. Therefore, there was a new version used. It was called switch with high isolation circuit.

4.2.4 Switch with high isolation

The circuit was simply same with the before circuit. However, it had a main advantage in this circuit was that it could improve the coupling problem. It shorted the ac signal to ground when the unpredicted signal was coupling to the unselecting port.

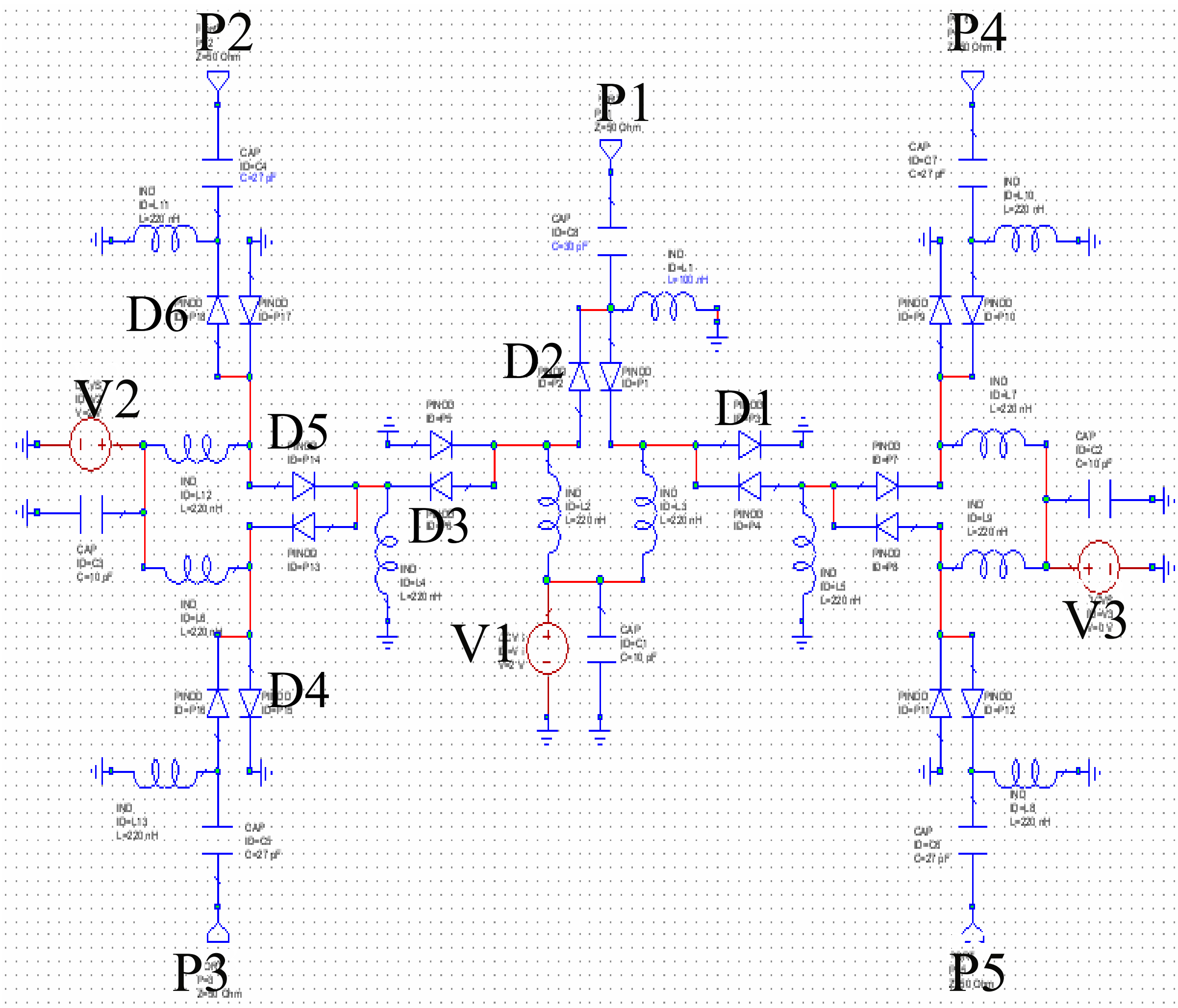

Figure 4.2f: The schematic of switch with high isolation

This was a circuit with high isolation. At V1, a positive voltage was applied. The signal would turn on D1 diode. For ac signal, it seemed short to the ground when the signal flew to D1 diode. Therefore, even if some ac signal was coupling to port 4 or port 5, it also shorted to ground, reducing the signal reading in port 4 and port 5. V1 also turned on other diode, such as D2 and D3. Now, the left hand side port was considered. When V2 was applied positive voltage, D4 diode was turned on and shorted ac signal to ground. The near ports totally decreased the coupling effect. The rest of two diode, D5 and D6 diode, were also turned on by V2, therefore, the port 2 and port 1 was built up a channel. The path was available now.

The large effect on forward gain was the inductor connected with the input port. Therefore, turning the inductor value could get the best result. The following diagram showed a simulation result.

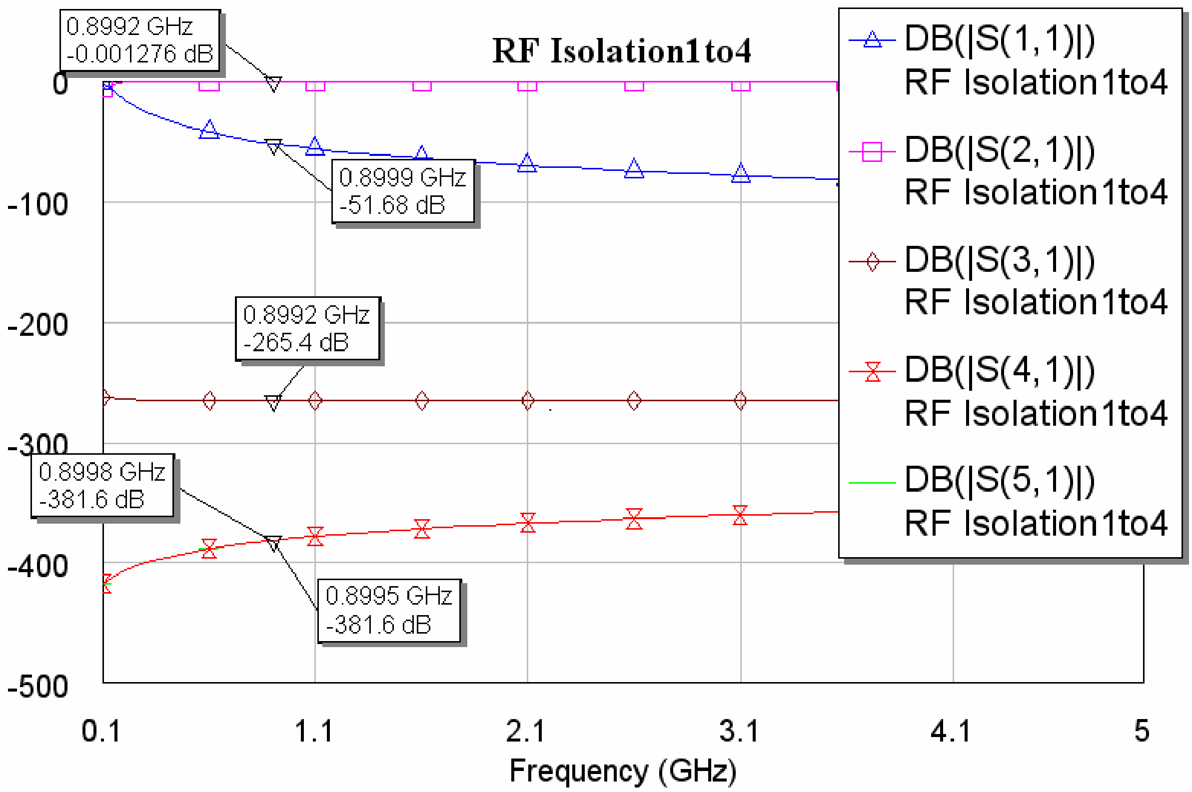

Figure 4.2g: The performance of switch with high isolation in simulation

And, this was a channel selection table.

V1	V2	V3	Output Port
+1	+1	X	P2
+1	-1	X	P3
-1	X	-1	P4
-1	X	+1	P5

X – Don't care terms

Table 4.2c: For selection port in switch with high isolation

In my experiment, when the input port was applied 0dBm signal with 900MHz, the output port read -0.94dBm and the near port read -47dBm. Compare with simple switch circuit, the signal read in near port was improved about 20dBm.

This was a product diagram. The upper port was connected to reader, and the port in left hand and right hand were connected to antennas. Three white wires were control pins.

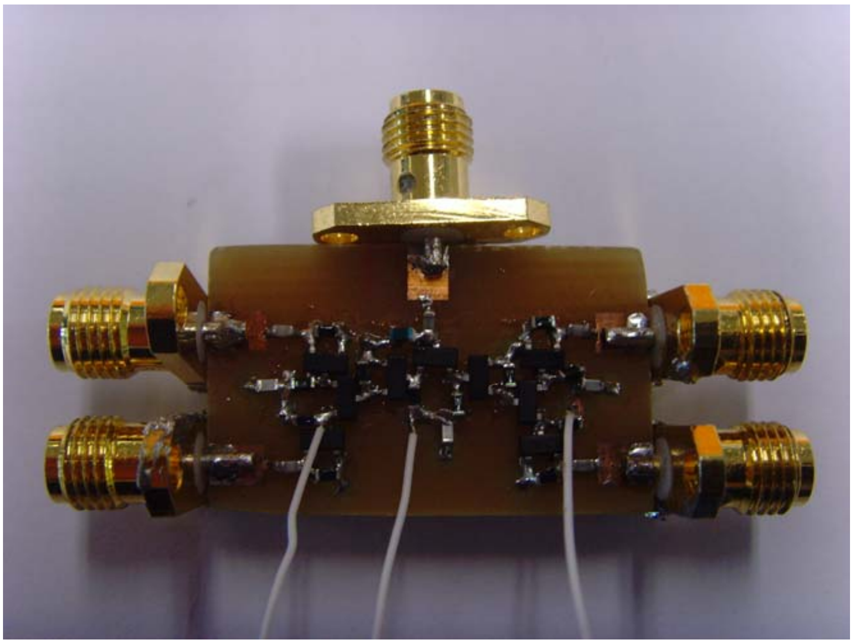

Figure 4.2h: The diagram of switch with high isolation product

CHAPTER 5: PATCH ANTENNA

5.1 Antenna Description

In the bookshelf, there were four antennas inside each layer. The antenna was used to active the tag to get some data from it such as ID code, or location. The size of the antenna would be designed to square sharp.

In this project, there were two methods used to design the antenna. The first one was same as the following diagram:

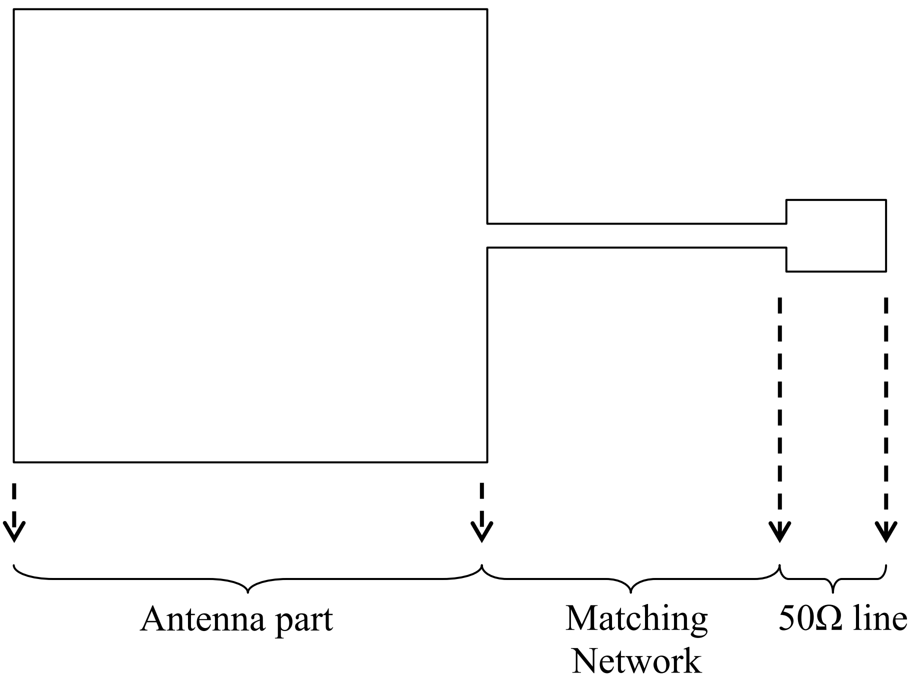

Figure 5.1a: Diagram of designing antenna in method 1

It was adding a matching network between the antenna part and 50Ω line to do a match.

The second one was:

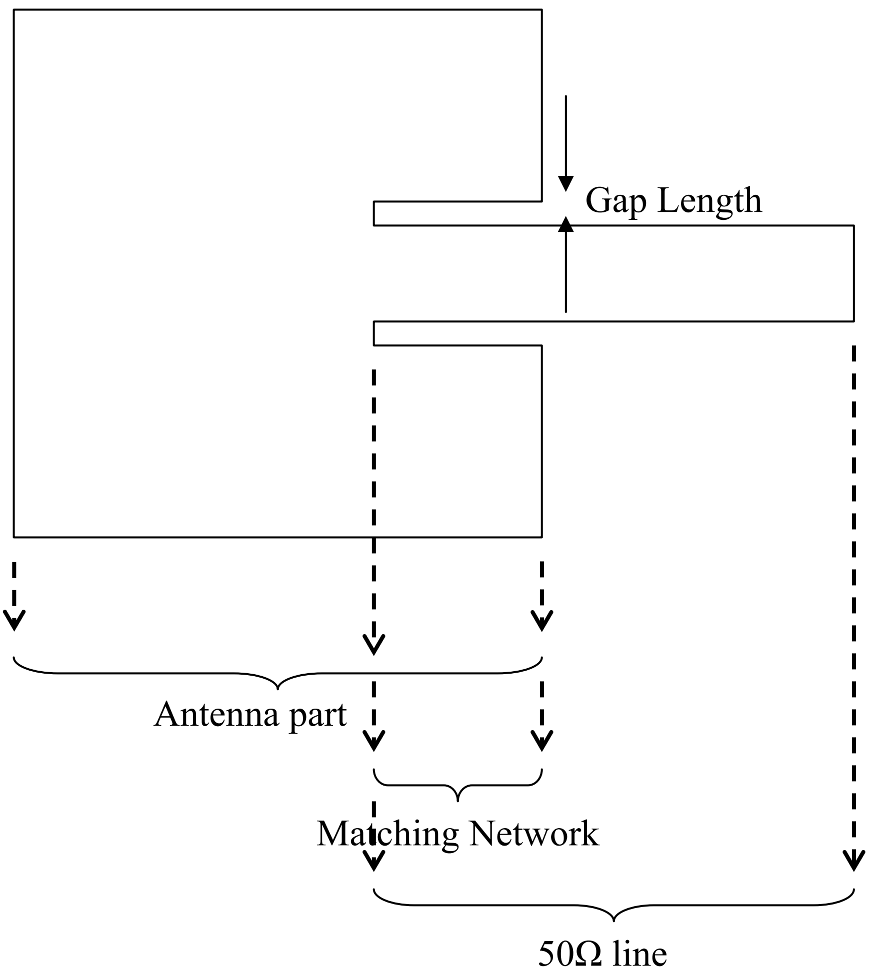

Figure 5.1b: Diagram of designing antenna in method 2

The matching network was not same as before one. The 50Ω line was inserted into the antenna part. When the insertion position was correct, the return loss in resonant frequency would be the lowest.

5.2 Patch Antenna in method 1

Firstly, the antenna part should be designed. In this project, using IE3D simulates the antenna. However, before do that, it should be calculated the size of the antenna. Therefore, using a program from Microwave Office calculated the size of the antenna.

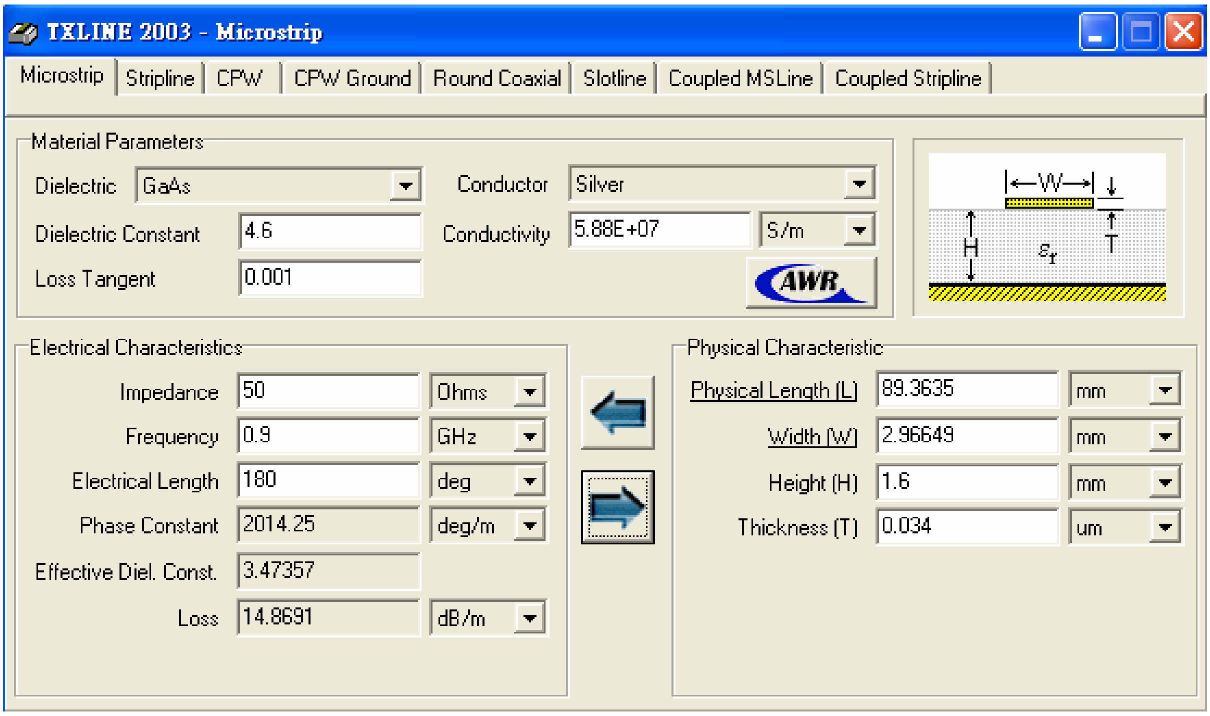

Figure 5.2a: Calculation the width and length by Microwave Office

5.2.1 Antenna Part:

From the program, we could see that the length of the antenna was 90mm and the width of it was also 90mm. Actually, the calculation should not correct so 90mm was a reference for trying the different size of the antenna.

Based on the result, we find that if the size of the antenna was decreased, the resonant frequency would move from low frequency to high frequency.

In dB and Phase of S-Parameters, S11 in resonant frequency showed in this graph was not accurate.

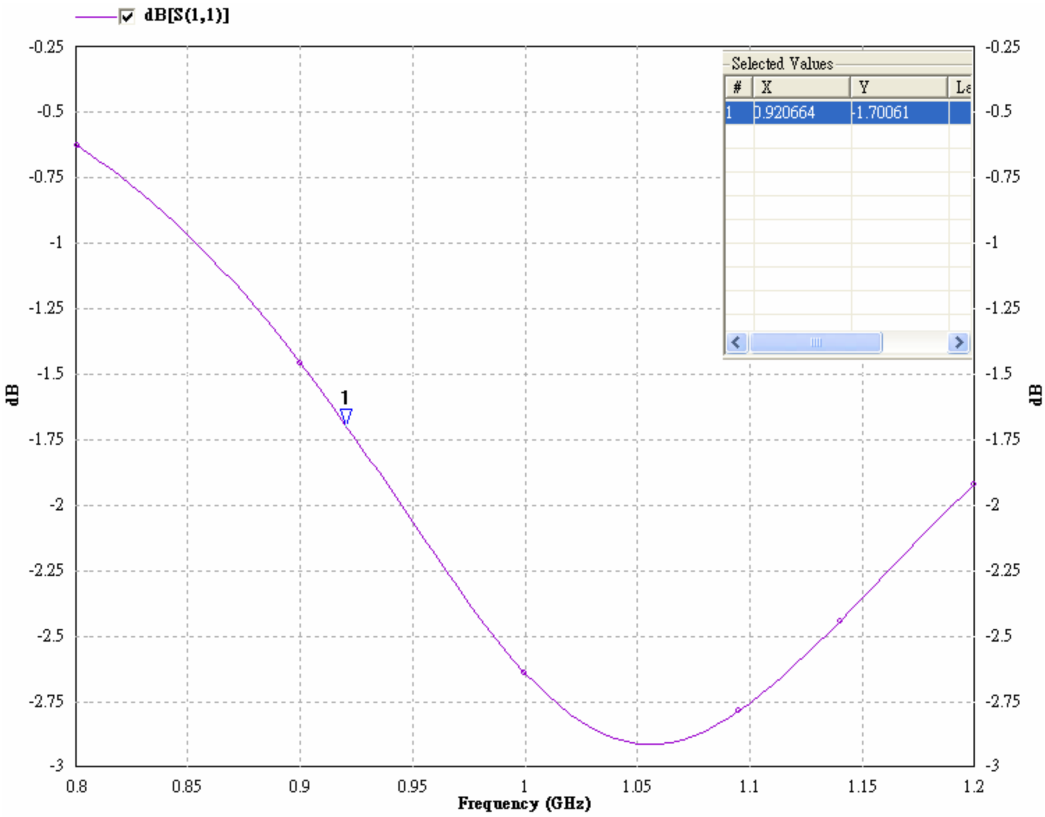

Figure 5.2b: Antenna performance showed in dB and Phase of S-Parameters

Therefore, we could see another diagram to check the resonant frequency. It was Real and Imaginary Parts of Z-Parameters. Checking frequency at zero impedance in the imaginary part, if the frequency matched to 920M to 925MHz, the size was suitable to our target.

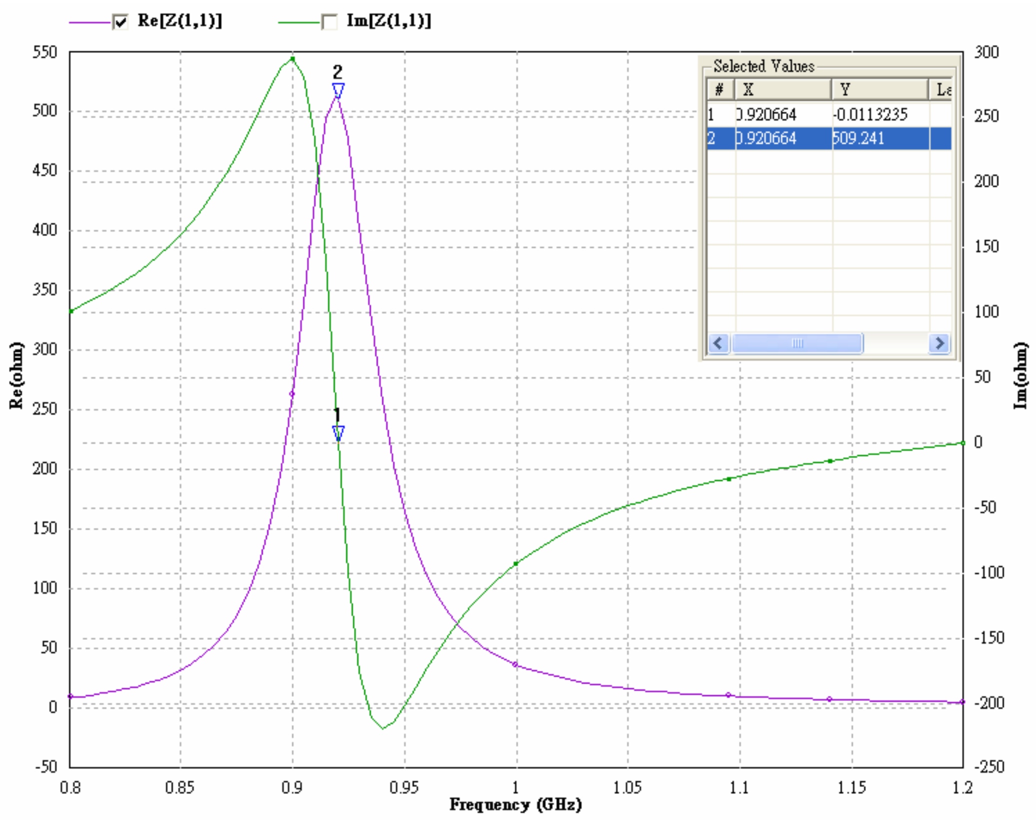

Figure 5.2c: Antenna performance showed in real and imaginary parts of z-parameters

5.2.2 Matching Network

Now, the antenna part was done. Then we should do matching to improve the return loss less than -10dB.

In the Real and Imaginary Parts of Z-Parameters, read the real impedance value in the resonant frequency. Absolutely, the impedance value was much larger than 50 Ω, therefore, the return loss was very large. Now, base on the equation (8) to calculate the impedance of the matching network.

$$Z_{\text{matching network}} = (Z_{\text{charteristic impedance}} \times R_L)^{1/2}$$

$$= (50 \times 510)^{1/2}$$

$$=160$$

The result was putting into Microwave Office to calculate the length and width of the matching network.

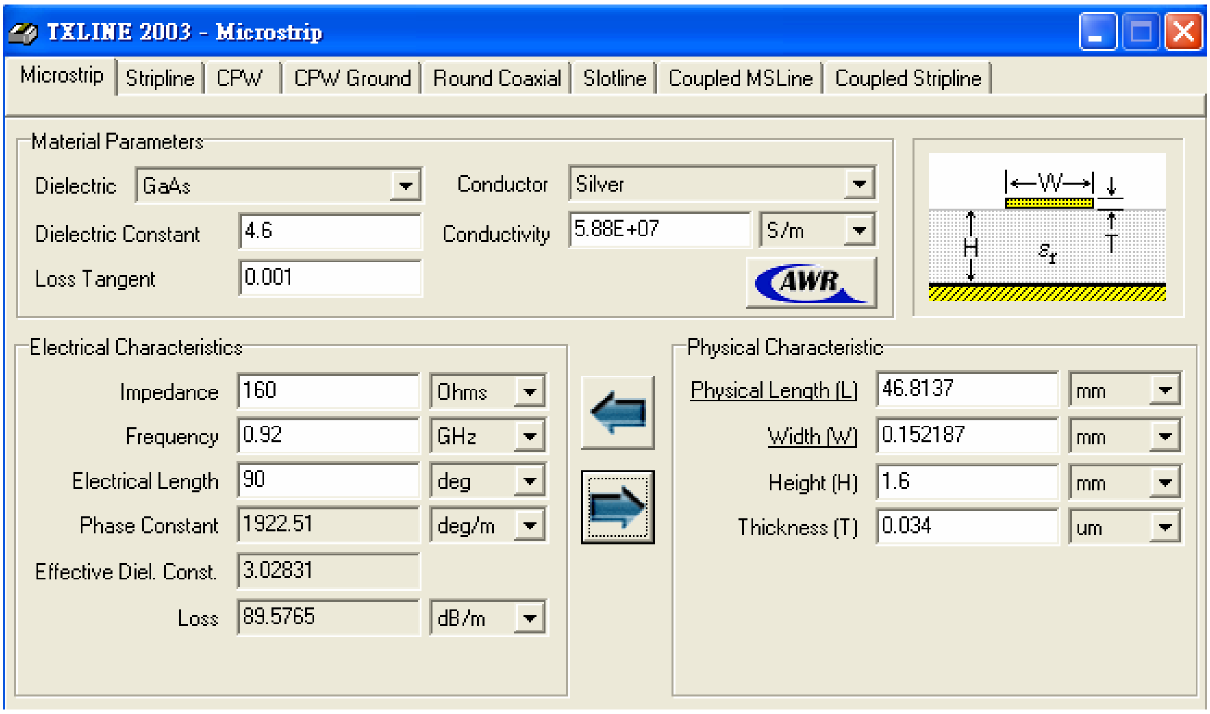

Figure 5.2d: Calculation the width and length of matching network by Microwave Office

The width and the length calculated from Microwave Office were found 0.152187mm and 46.8137mm. Therefore, I finally chose the value of the width and length were 0.2mm and 47mm respectively. Assuming the width was not changed, we found that 0.2mm and 37mm were the best result. It was because the resonant frequency between 920M to 925MHz, the best of S11 was -23.1836. The following table showed the result in different length of the matching network.

Length (mm)	Resonant Frequency (MHz)	S11 (dB)
30	922	-8.842
33	919	-9.41607
34	930	-24.2322
35	930	-24.1237
35.5	925	-19.1202
36	925	-20.449
37	925	-23.1836
38	920	-17.3557
40	920	-22.9014
44	920	-16.2641
46	920	-12.7216
49	900	-14.2431

Table 5.2: The effect in different length of matching network

5.2.3 50Ω line

It was same as the before calculation method to solve the width of 50Ω. The width was 2.9662 mm so choosing the width was 3mm. The length of it was changed just only a little bit effect on the resonant frequency so longer or shorter line was no problem. However, the length must be larger than or equal to the width of the line.

The following diagram was simulated by IE3D. The probe feed point was at the end of the 50Ω line.

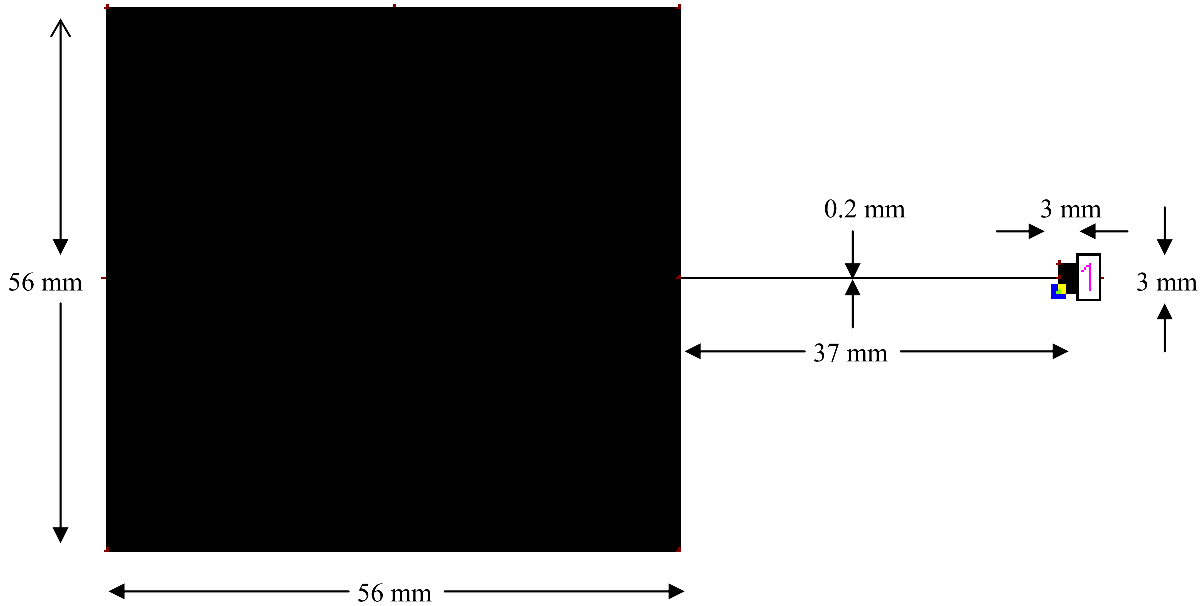

Figure 5.2e: The simulated antenna

From the result, we found that the return loss, radiation pattern and the gain at resonant frequency were -23.1874dB, 113 degree and 2.45347 dBi respectively. Now, the following would show the graph of return loss, radiation pattern and gain.

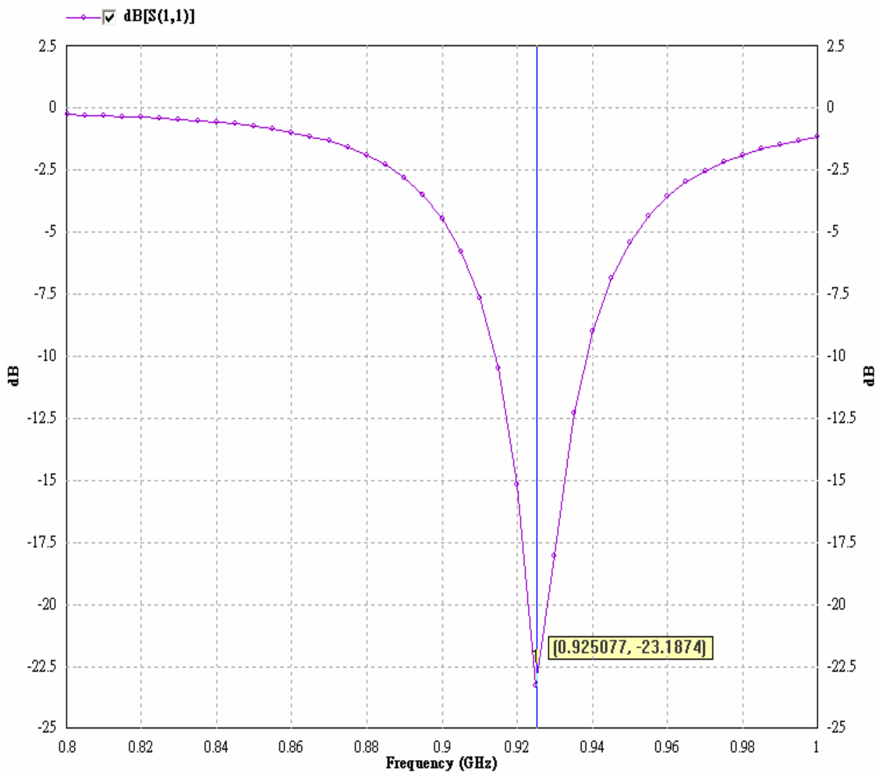

Figure 5.2f: Return loss at resonant frequency in simulation

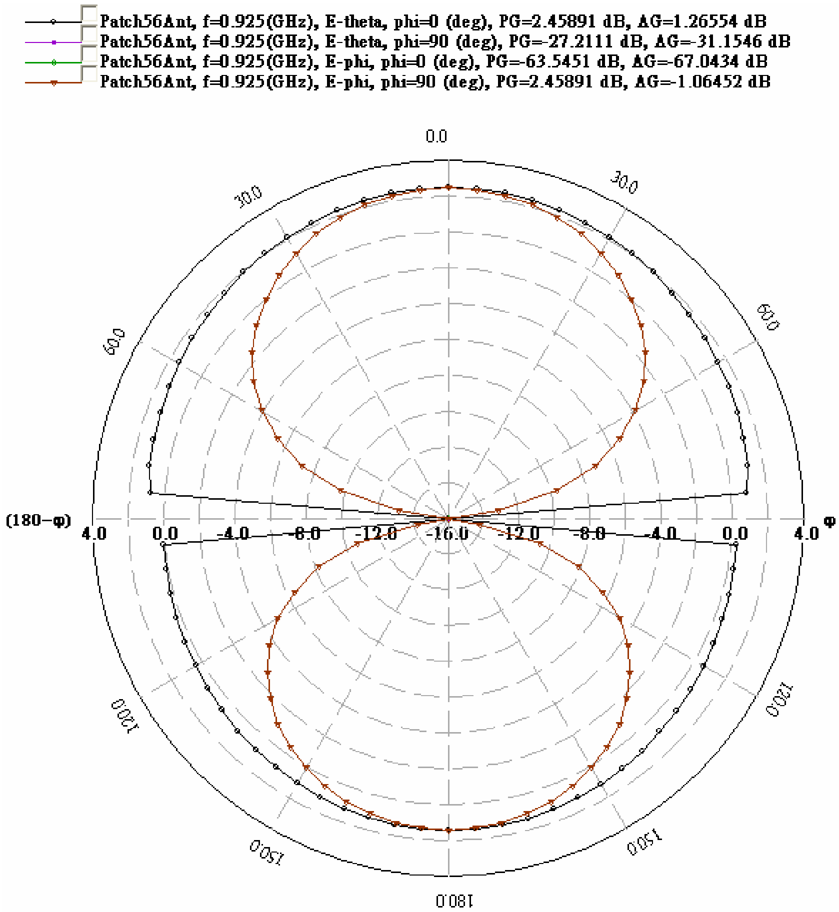

Figure 5.2g: The radiation pattern of patch antenna in simulation

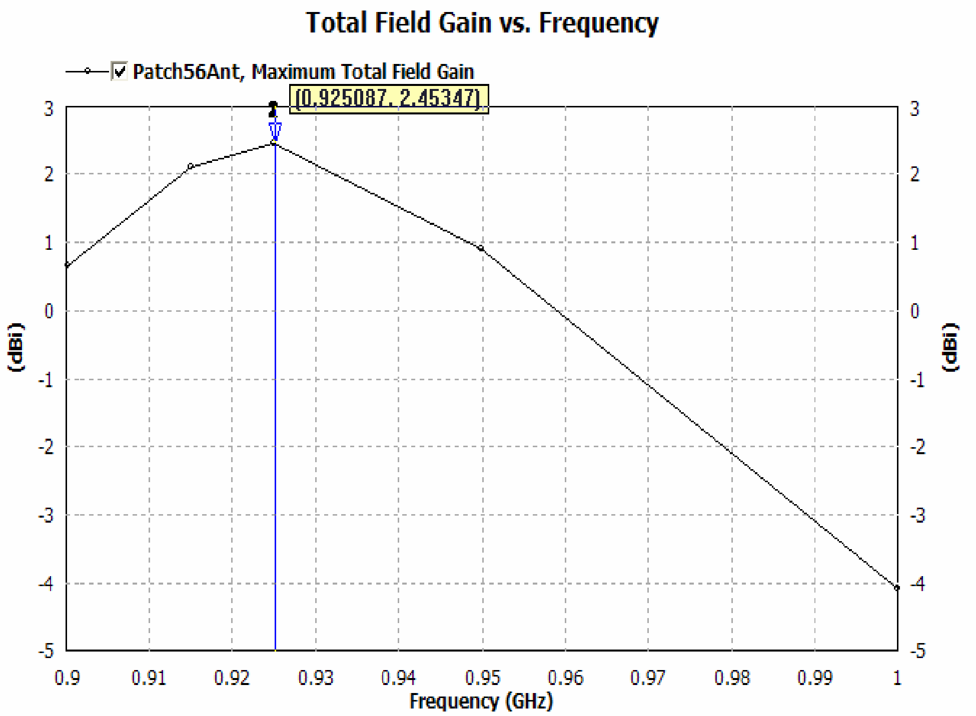

Figure 5.2h: Gain vs Frequency in simulation

5.3 Patch Antenna in method 2

In this method, the antenna could not design to our expectation return loss.

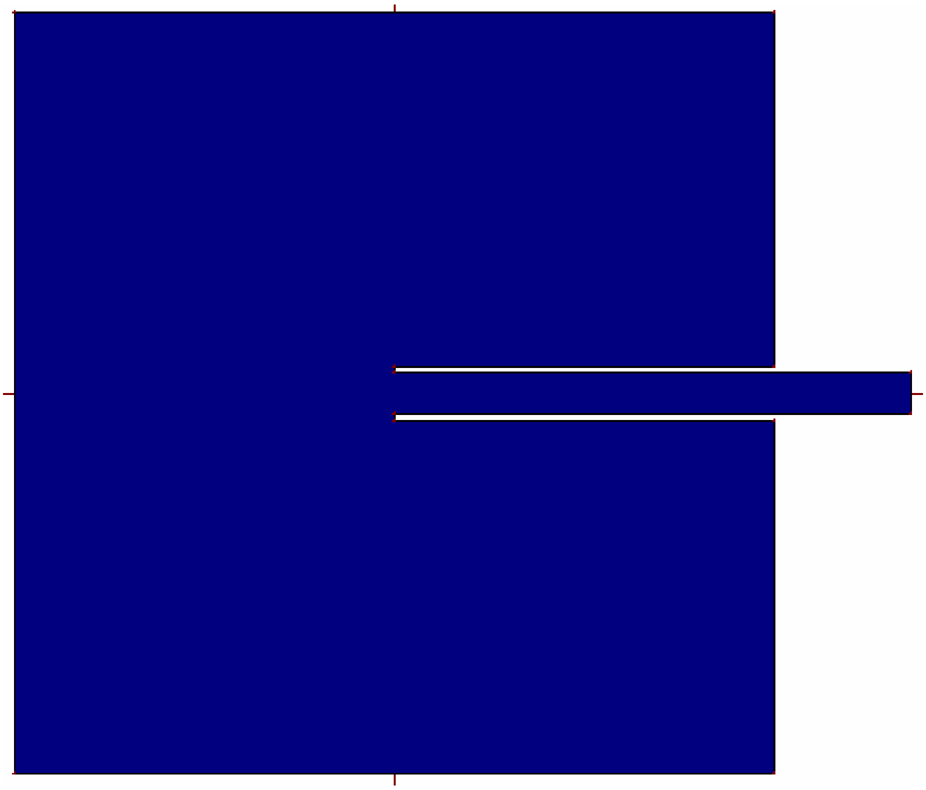

Figure 5.3: The simulation result in method 2 by IE3D

From the table, we could see that the gap length increased, the return loss was slightly increased. Therefore, it could not be simulated to the desired result.

W & L	Resonant Freq.	dB	Gap length Added
90	0.80031	-3.31879	
90	0.849845	-2.92619	5
90	0.8669969	-2.7036	7
90	0.880495	-2.44964	10
90	0.915789	-2.16754	14
90	0.93	-1.5	15
56	0.760062	-1.07302	0
56	0.821362	-1.32477	5
56	0.868731	-1.69007	10
56	0.916099	-2.20112	20
56	0.941213	-2.7123	22

Table 5.3: Simulation result when gap length increased

CHAPTER 6: DISCUSSION

Before the start of the switch circuit, the value of inductor and capacitor were one of the problem, the value of them used to make it operating in proper performance. It is because the circuit is operating in 900MHz, the bandwidth should be considered. However, in the circuit, the main consideration is the loss rather than the bandwidth. Because it is a high pass frequency, it can operate in different frequency. It just pays attention in power loss. Therefore, selection the value of inductor is the main purpose of the circuit.

After the circuit is produced, checking the circuit proper or not is also spent most of time on it. When the voltage sources supply a high voltage to switch circuit, it will be short circuit. However, checking the positive pin and negative pin show that two pins are not shorted. After I do a experiment, I discovered that when the supply voltage is too large, more than the threshold voltage of PIN diode, it will make the short circuit condition occur. That is a one of the problem I discovered in switch circuit.

In switch circuit, something should be mentioned, which is how to check the connection about capacitor, inductor and diode. For capacitor, if it is operating proper, checking the impedance of it is infinite. However, if it has already broken, the impedance will be checked to be zero. The performance of inductor is inversely to capacitor. When the impedance is zero, it represent that it is work appropriate, however, if the impedance is infinite, it is broken. As the PIN diode be concerned, checking the pin diode work is easy. Connecting the voltage source to diode and apply a voltage to it. If there is a voltage dropped in the diode and it is as same as the voltage supplied. This representation they are connected.

Increasing the forward gain in the circuit is very difficult. It is because change the value of inductor to be larger, the performance of it is just a slightly change. It is not efficient. Therefore, the model of PIN diode is very important in the circuit. If the impedance of diode is low, the power consumption will be decreased and the loss can be improved.

In the switch with high isolation, the performance is better than simple switch circuit. However, the production cost is very expensive. Therefore, I suggest try to find another circuit with same function or selection another type of IC, which is cheap than this one.

The source is one of the bad designs in switch with high isolation circuit. It is because it is using a positive and negative voltage to turn on the ports or short the ac signal to ground. However, supplying a negative voltage to the circuit not only enhance the cost, buying a IC to convert positive to negative voltage, but also make the circuit to be more complicate. Therefore, if the coupling problem can be omitted, simple switch circuit is good in our system.

In the antenna, the size of it is large about 10cm length and 8cm width. If we can use another material to do it, the size can be reduced. It is because the width and length will be changed by the dielectric constant and the height of the substrate.

Through this training, I learn some skills, for example, how to simulate a circuit by microwave office, use IE3D to simulate an antenna or construct a layer by PowerPCB. However, the simulation result in Microwave Office is not accuracy.

There is a big different between the simulation result and the measured result. Therefore, doing simulation by this software is not only inaccuracy, but also affect the performance of the circuit.

When the whole system is constructed, it can do some further development. In my opinion, I suggest to build up a system, which can check the whole library, anyplace will also be checked, not only the book on the shelf. It is because many people put a book anyplace. If someone put it on desk or chair, it cannot find. If it is developed, it is efficient than this project but also build up a security system in the library, prevent the book be stolen.

CHAPTER 7: CONCLUSION

In my conclusion, the simple switch circuit had a small return loss and high forward gain. The circuit was simple just used a number of lumped element to build up a switching circuit. Using some voltage sources to turn on or off the pin diode to control the channel. However, when the lumped element, inductor, was replaced by the microstrip, the performance of the circuit in simulation was totally distortion. Not only the gain was less than before one mostly, but also a high return loss affected the efficient. The coupling problem was one of the bad reasons on the microstrip circuit. Therefore, the new version, switch with high isolation circuit, would be built up. The performance of it simply better than the before version, and the return loss was improved about 20dBm. That was the big advantage in this circuit. However, the cost of this circuit was very expensive. It was because one surface mount inductor needs four dollars per each and the IC, series PIN diode, need around seventeen dollars per each. The production cost in a circuit was expensive than other circuits design. But the performance of this circuit could get the best result. Therefore, it should be selected also.

In the antenna, there were two methods to design it. About these two methods, we found that the first one was easy design than method 2. It could follow by the instruction, such as showed in chapter 6, to design the antenna the user wanted. The procedure was simple so design it was no need spent most of time on it. However, the second method had no instructions followed, and from my result, the resonant frequency was difficult to find. Even if it was found, the return loss was also large. It could not be applied on our system. Therefore, the first method to design the antenna would be better.

COMPONENT LIST

For antenna

PCB board	1
SMA Terminal	1

For switching circuit

Simple switch circuit

Name	Value	Quantity
Capacitor	30p	9
Inductor	330n	9
IC(common cathode)		3
PCB board		1
SMA Terminal		5

Simple switch using microstrip

Name	Value	Quantity
Capacitor	30p	5
IC(common diode)		2
PCB board		1
SMA Terminal		5

Switch with high isolation

Name	Value	Quantity
Capacitor	30pF	5
	10pF	3
Inductor	330nH	12
	100nH	1
IC(series)		9
PCB board		1
SMA Terminal		5

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GLOSSARY

High Pass Filter (HPF)

Radio Frequency Identification (RFID)

Single-Pole-Single-Throw (SPST)