**System Design Document:**

RF Direction of Arrival System

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# 1 Introduction

## 1.1 Purpose and Scope

The purpose of the System Design Document is to describe the system requirements, system architecture, human-machine interfaces, detailed design, and external interfaces.

## 1.2 Project Executive Summary

This section provides a descriptive overview of the DoA system from a management perspective.

### 1.2.1 System Overview

The goal of the Radio Frequency (RF) Direction of Arrival System is to design an affordable system that detects the directions of arrival of an RF propagating wave, in the ISM band, with the intention of eventually being used in a classroom setting.

### 1.2.2 Design Constraints

The project is limited to two major factors, budget and components. The total cost of components shall not exceed $1,500. For the project, the components will be purchased from online vendors if possible. The goal is to avoid constructing components as much as possible so that the project can be recreated by someone else.

### 1.2.3 Future Contingencies

## 1.3 Document Organization

The System Design Document is constructed to provide an overall concept of the system design.

## 1.4 Project References

## 1.5 Glossary

**ADS –** Advanced Design System

**AP-S** – Antennas and Propagation Society

**CT** – Continuous Time

**DoA** – Direction of Arrival

**ERAU** – Embry Riddle Aeronautical University

**IEEE** – Institute of Electrical and Electronics Engineers

**ISM** – Industrial, Scientific, and Medical

**LNA** – Low-Noise Amplifier

**RF** – Radio Frequency

**SDR** – Software Defined Radio

**SPDT** – Single Pole Double Throw

**SP4T** – Single Pole Four Throw

# 2 System Architecture

This section provides an overview of the hardware and software architecture.

## 2.1 System Hardware Architecture

The DoA detection system consists of multiple hardware components. The following components will be utilized to connect the system as a whole.

APAMBJ-135 Antenna – 8 antennas arranged in an octagon shape to build the overall antenna.

SKY13351-278LF RF Switch – SPDT switch used to send the signal to the SDR.

PE4244A-Z RF Switch – SP4T switch used to send signal to SPDT switch.

HackRF One – SDR that receives the 5.8GHz signal.

HMC311LP3ETR RF Amplifier – Amplifier used amplify the desired signal after filtering.

RFBPF1608060K98Q1C RF Band Pass Filter – Filter used to limit bandwidth of output signal to limit interference.

Raspberry Pi – Computer used to determine the direction of signal using frequency modulation.

PIM370 Display – Extension of RaspberryPi that will display the direction result of DoA system.

Figure 1 displays the overall architecture of the hardware components. The antenna array detects the signal which is then sent through the switching array. Then the signal is passed through a bandpass filter and amplifier before it is sent to the HackRF One. The Raspberry Pi will then receive the signal from the HackRF One to be processed. Once the signal is processed, the result will be displayed on the display screen.

Figure 2 demonstrates the design of the 8 antennas that make up the whole antenna system. The antennas will be mounted onto a copper plate with copper deflectors to assist in refining the signal to be detected by one antenna. Figure 3 exhibits the physical design of the antenna array.

Diagram

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Figure 1. – Block Diagram of System Overview

Shape, polygon

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Figure. 2 – Basic Antenna Array and Positioning

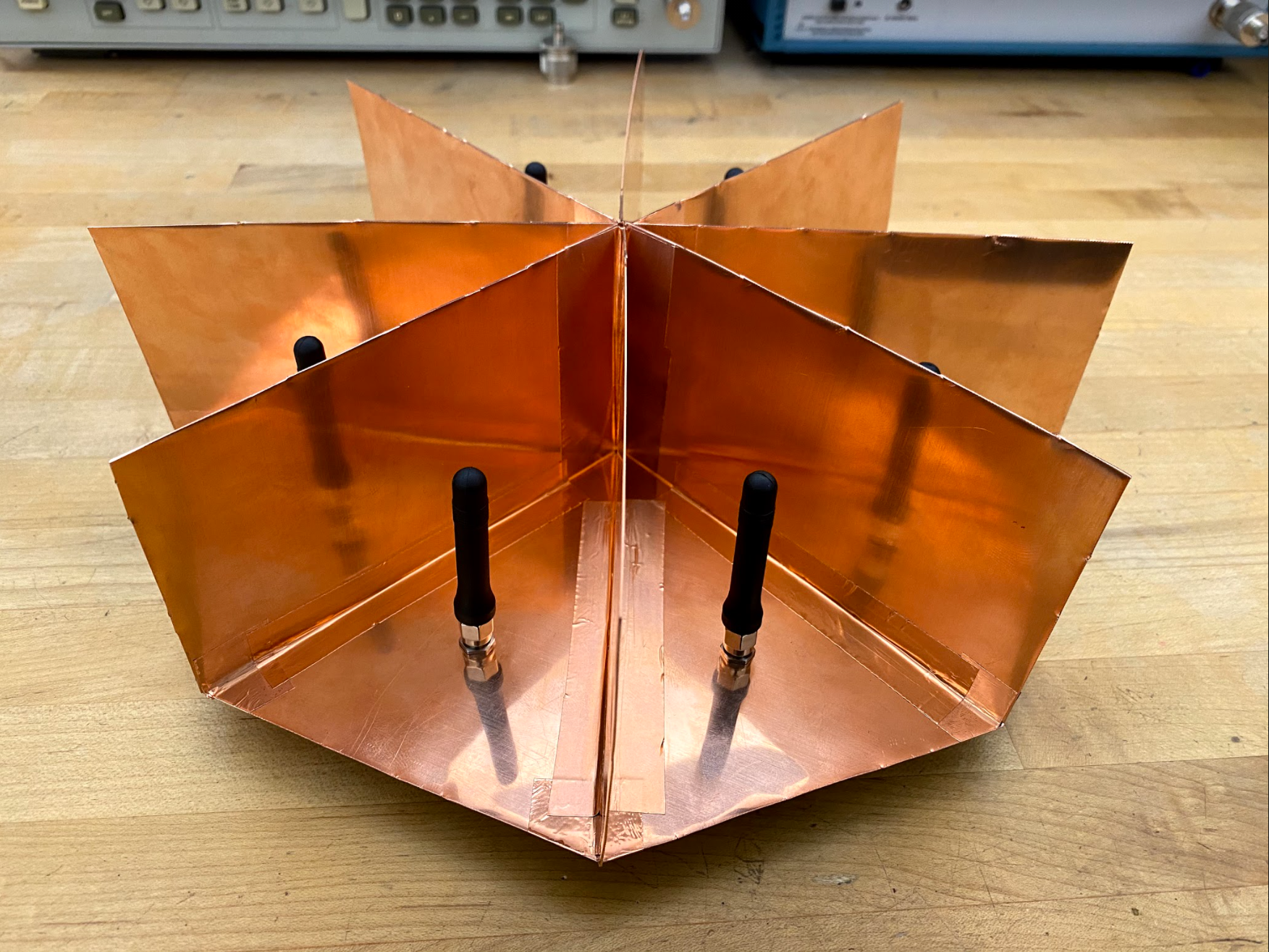


Figure 3 – Antenna Array mounted on copper base.

## 2.2 System Software Architecture

## 2.3 Internal Communications Architecture

# 3 HUMAN-MACHINE INTERFACE

## 3.1 Inputs

The only inputs that the user will have to provide to the system are turning the system on or off. There will be a switch that allows the user to do so.

## 3.2 Outputs

The only output of the system will be the direction that the generated 5.8GHz signal is coming from.

# 4 DETAILED DESIGN

This section contains the detailed designs for the signal of interest, hardware components, and software components of the system.

## 4.1 Signal of Interest

The signal of interest for this project is in the ISM band range. This range is between 5.7-5.9 GHz. The signal will be generated in a lab environment using a signal generator.

## 4.2 Hardware Detailed Design

The system design of the hardware components consists of the antenna array, PCB for switching, external power, and the HackRF One. The specific components used are as follows, eight Abracon APAMBJ-135 antennas, Skyworks SKY13351-378LF SPDT switch, two Peregrine PE42442 SP4T switches, a Raspberry Pi, a Walsin Technology Corporation Band Pass Filter, Analog Devices RF Amplifier, and a HackRF One SDR. The antennas will be mounted on a copper base with copper deflectors attached to corner off each antenna as previously seen in Figure 3. Each antenna is connected to the two SP4T switches on the PCB board using coaxial cables. From the SP4T switches, the logic control pins connect to the Raspberry Pi. The SP4T switches also connect to the one SPDT switch on the PCB board through coaxial cables. Figures 4 and 5 display the basic design of the switches on each PCB board.

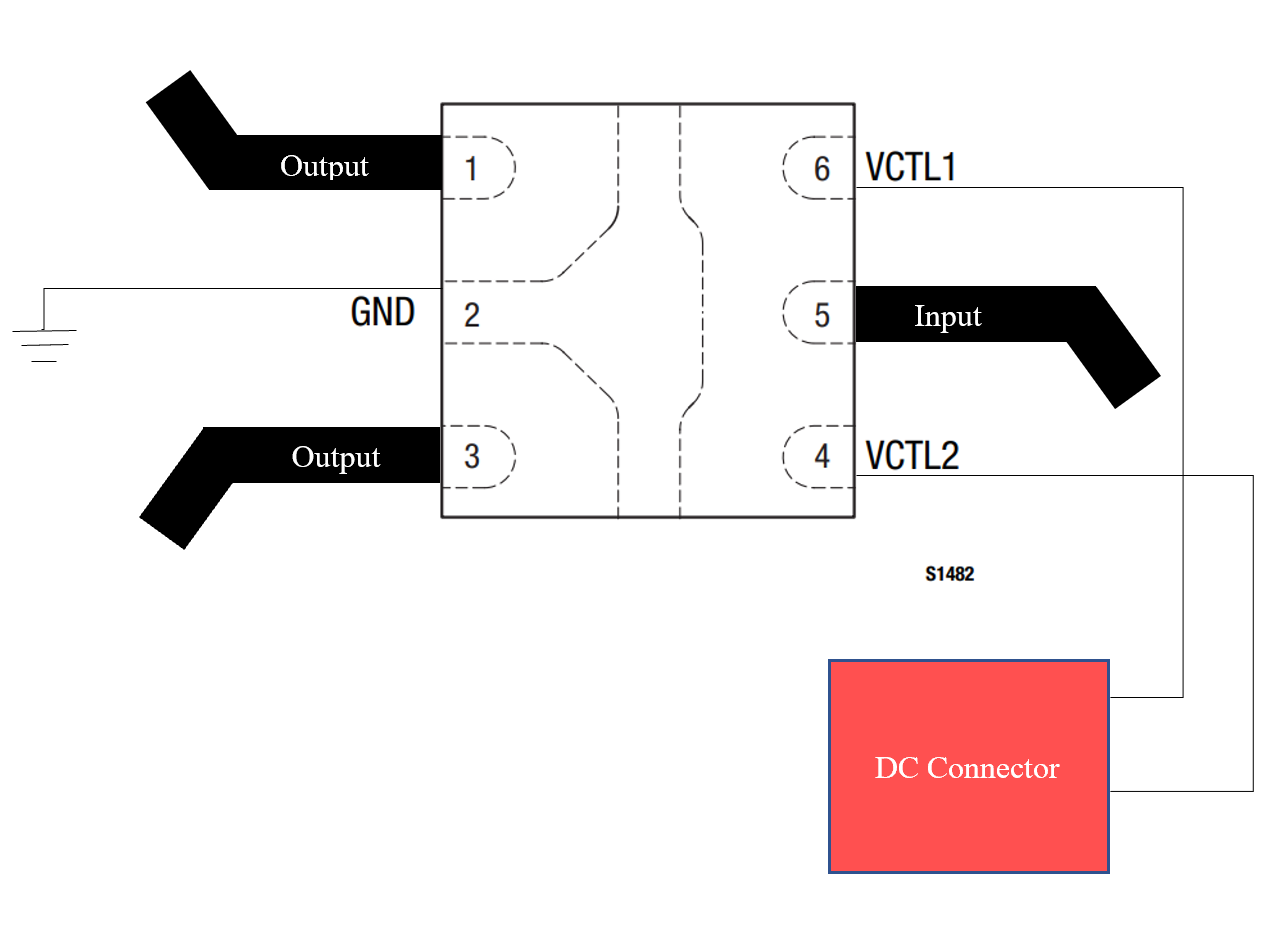


Figure 4 – SPDT switch PCB design.

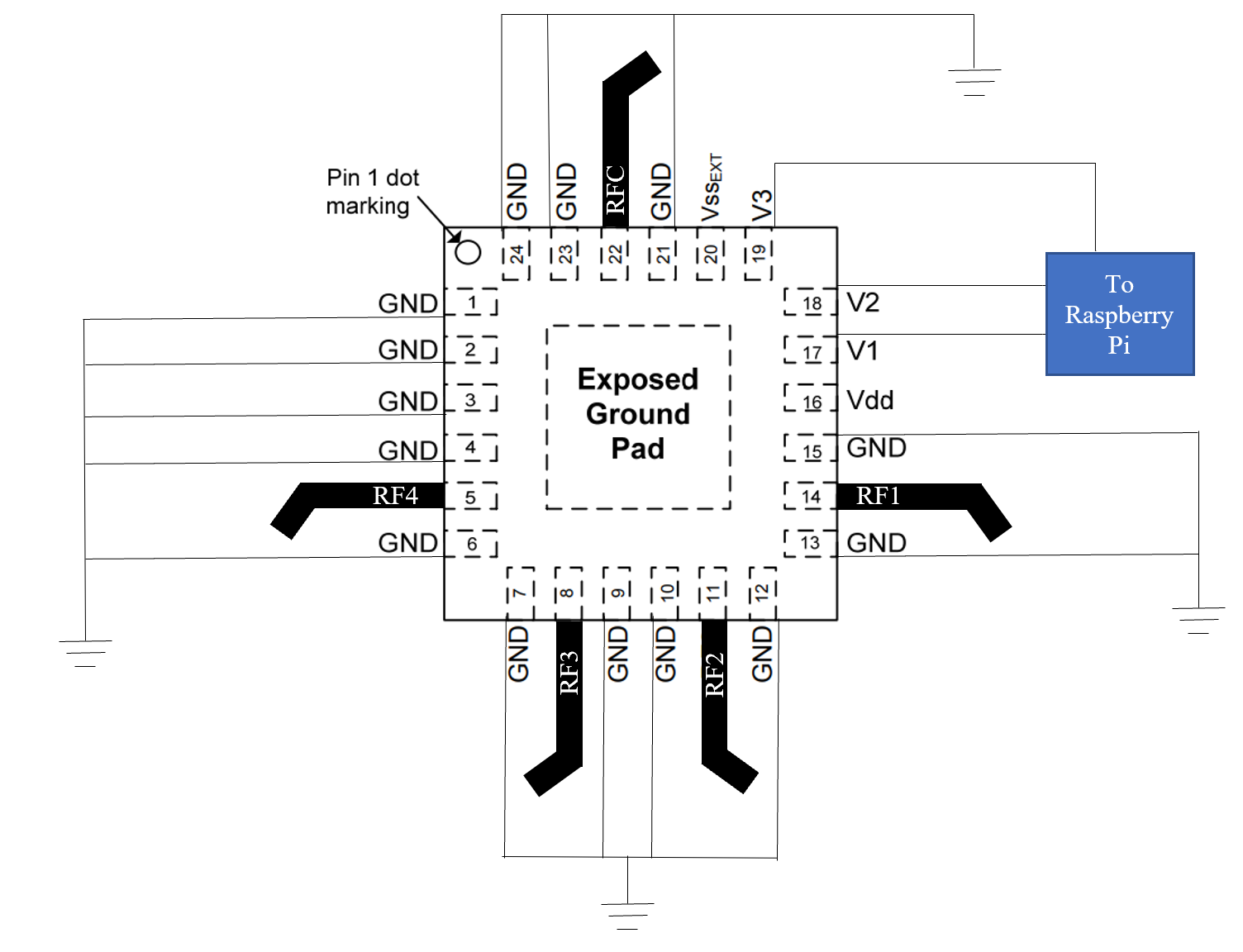


Figure 5 – SP4T switch PCB design.

Before developing the physical PCB boards for the switching array, the design was implemented using the ADS software. Simulations were performed to identify the S-Parameters of the PCB layout and their behavior. The center frequency used for these simulations will be 5.8GHz. Figure 6 displays the ADS schematic of the SPDT switch. Transmission lines are used to connect the SPDT to the SP4T switches and the Raspberry Pi. Figure 7 displays the ADS schematic for the SP4T switches. In this figure, there is only one SP4T switch. The second SP4T switch will mirror the design of the one displayed in the figure. Transmission lines are used to connect the two SP4T switches to the antenna array and the SPDT switch.

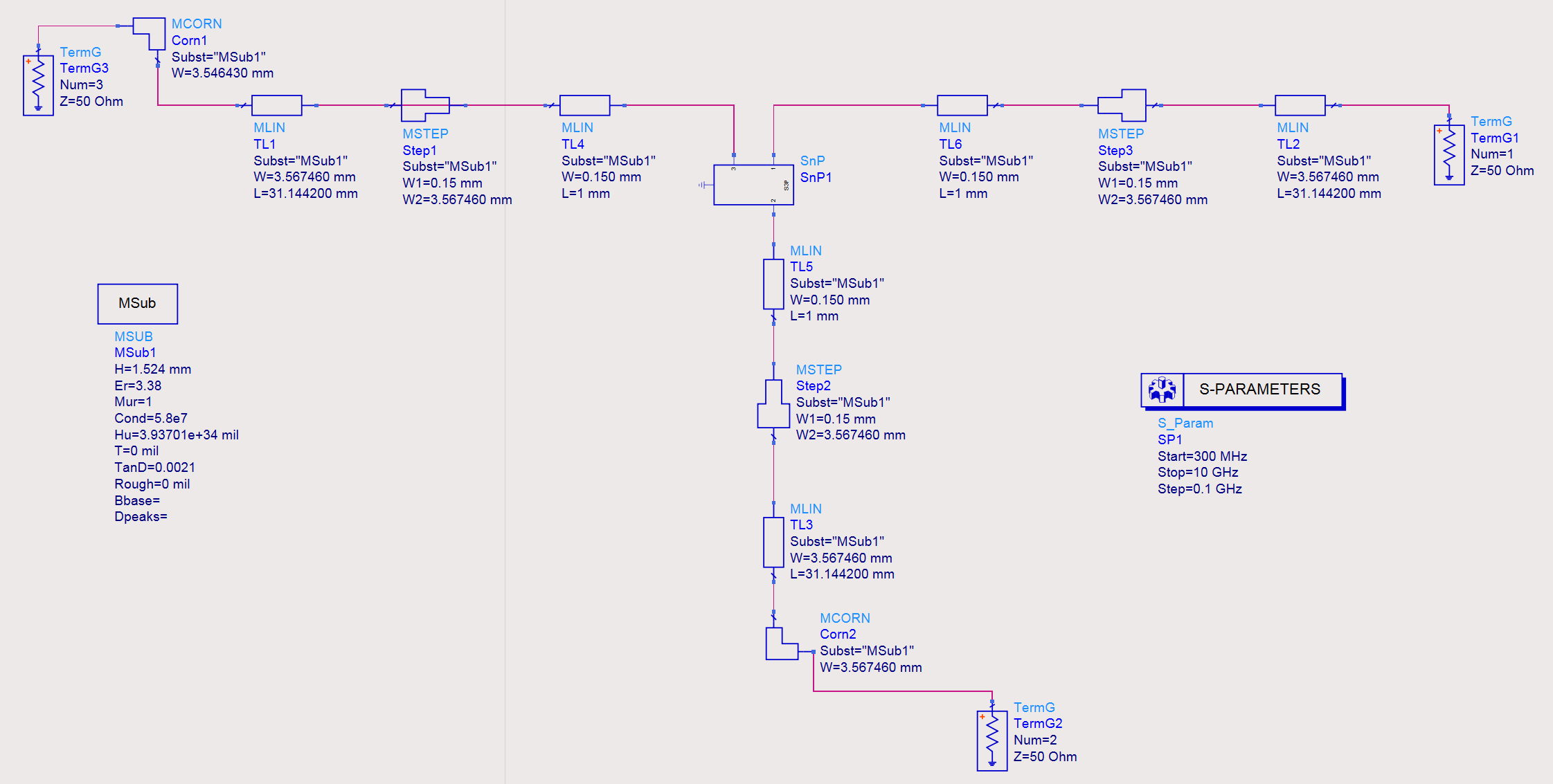


Figure 6 – ADS schematic for SPDT switch.

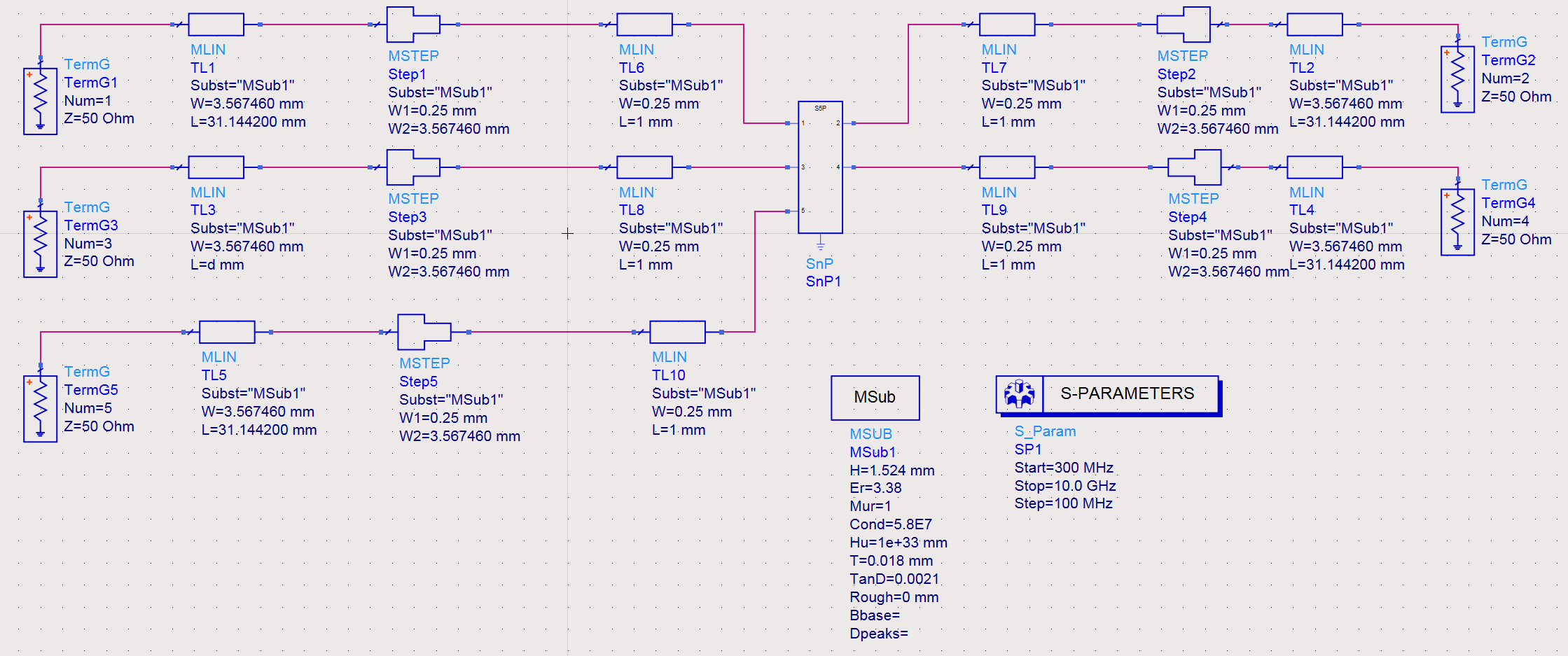


Figure 7 – ADS schematic for the two SP4T switches.

## 4.3 Software Detailed Design

### 4.3.1 Base Station Subsystem

### 4.3.2 Communication Subsystem

### 4.3.3 Demodulation Subsystem

### 4.3.4 Telemetry Subsection

## 4.4 Internal Communications Detailed Design

# 5 EXTERNAL INTERFACES

This section describes the interfaces between the DoA system and any external systems or subsystems.

## 5.1 Interface Architecture

The primary external system that the DoA system will interact with will be the signal generator. The DoA antenna must be able to detect the generated 5.8GHz signal from the signal generator.

## 5.2 Interface Detailed Design

# 6 SYSTEM INTEGRITY CONTROLS

The designed system will be used to detect signals in the 5.7-5.9GHz range.