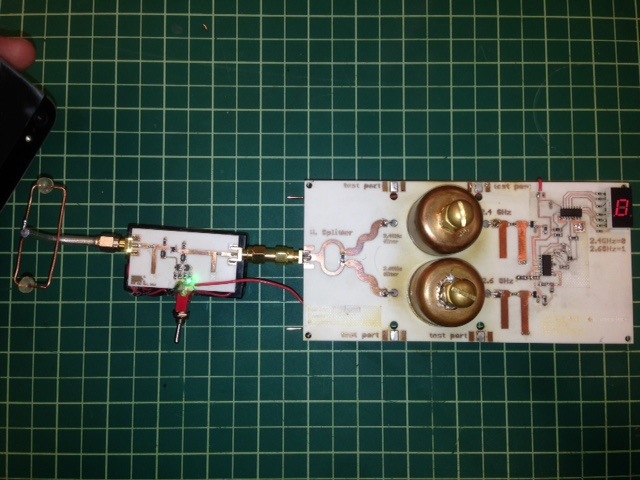
**2.4-2.6GHz FSK Receiver**

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**Abstract**

Frequency Shift Keying is currently used in many applications such as wirelessly transmitting binary data. Using high frequency sinusoids, a transmitter shifts between two frequencies which are later interpreted a logic ‘1’ or ‘0’. A 2.4 – 2.6GHz FSK receiver was designed, simulated in ADS and built using the rapid prototyping equipment in the Lab for Interconnected Devices at Portland State University. The receiver included a LNA on the front end, a Wilkinson power divider, resonant cavity filters and diode detectors. Later a 7-segment display and appropriate logic was used to interpret the data and display what the binary value is.

**Requirements**

* Operate at 2.4 and 2.6 GHz
* Reliably distinguish between 2.4GHz and 2.6GHz signals
* Amplifier with at least 10dB gain and S11 < -10dB.
* 3dB power divider
* 2.4 and 2.6GHz Bandpass filters
* Diode detector to output DC when signal is received.

**LNA**

The LNA is the front end of the receiver. Its purpose is to amplify very weak signals with out adding much noise to the system. This is done through various input and output matching techniques. Initially, a packaged LNA (PSA-5043+) was going to be used, however after several iterations the measured performance did not meet specs, and instead an LNA (shown in figure X) designed for a previous project was used. The alternate LNA has a gain of about 13dB at 2.4GHz and about 11dB at 2.6GHz and S11 around -10dB at 2.4GHz. This was decided to be sufficient to be used in the final receiver.

**Wilkinson Splitter**

A simple Wilkinson power divider, designed for 2.5GHz was implemented. The design was simulated in ADS, and the layout was done in Eagle CAD (shown in figure XX). The measurement of the splitter showed that it the center frequency was indeed at 2.5GHz and the output on each channel had a loss of 3dB when properly terminated with 50ohms. S11 was measured to be approximately -15dB.

**Filters**

There were two different types of filters that were investigated in this project. First, a lumped element filter, using a combination of microstrip capacitors, and SMD components was designed in ADS. Second, a resonant cavity type filter was used.

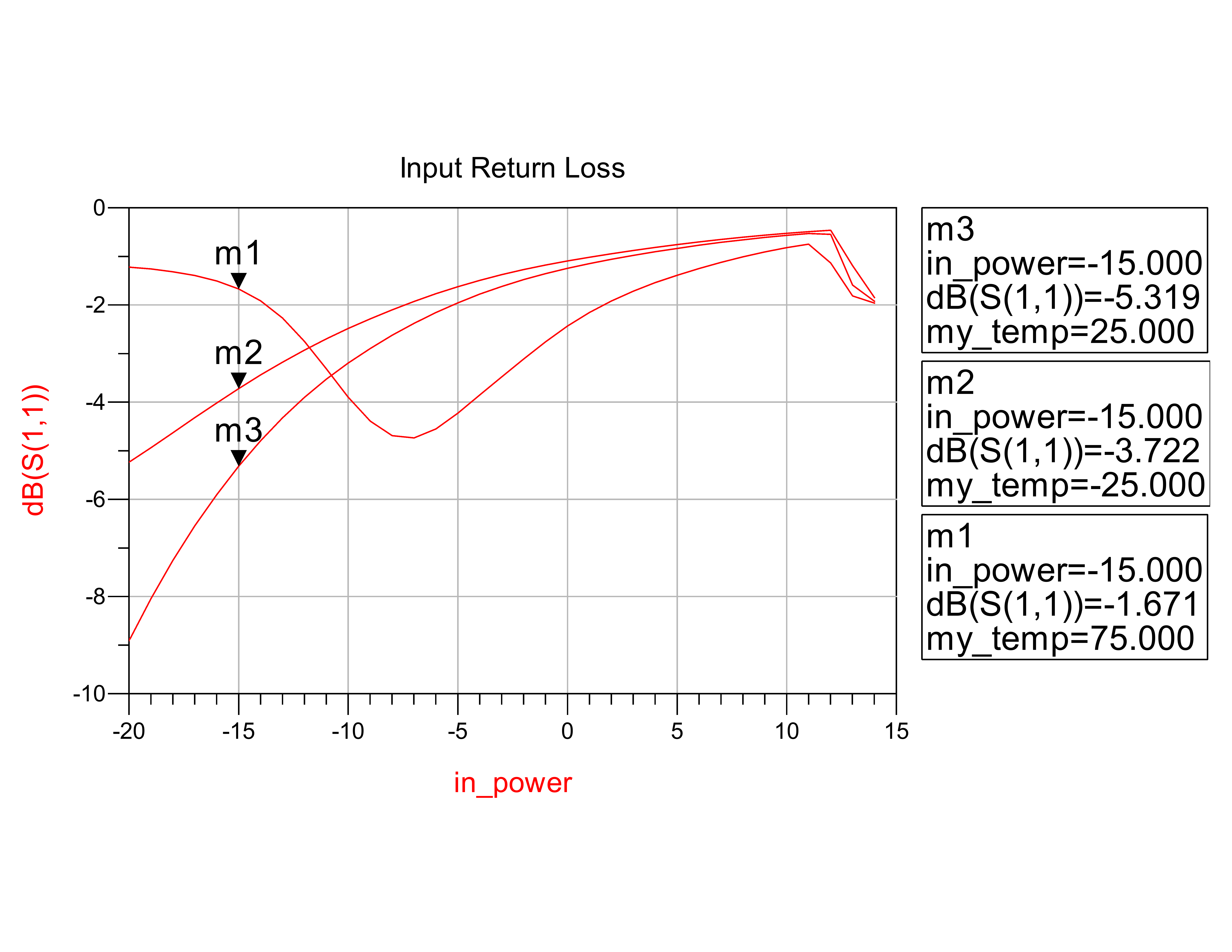
**Pipe Cap Filters**

The resonant cavity filters were chosen because they offer a very high Q, which will allow the receiver to easily distinguish between 2.4GHz and 2.6GHz. Shown below is an equivalent circuit for the resonant cavity. To construct the cavity filter a one-inch copper pipe cap was used as a cavity. The volume of the pipe cap happens to be just right for the frequency range of interest. To tune the filter, a #4-40 brass screw was used to vary the inductance and capacitance of the cavity to just the right frequency. The insertion loss of the cavity filters is around 1dB, and a bandwidth of approximately 15MHz was achieved. S11 was also decent at around -15dB.

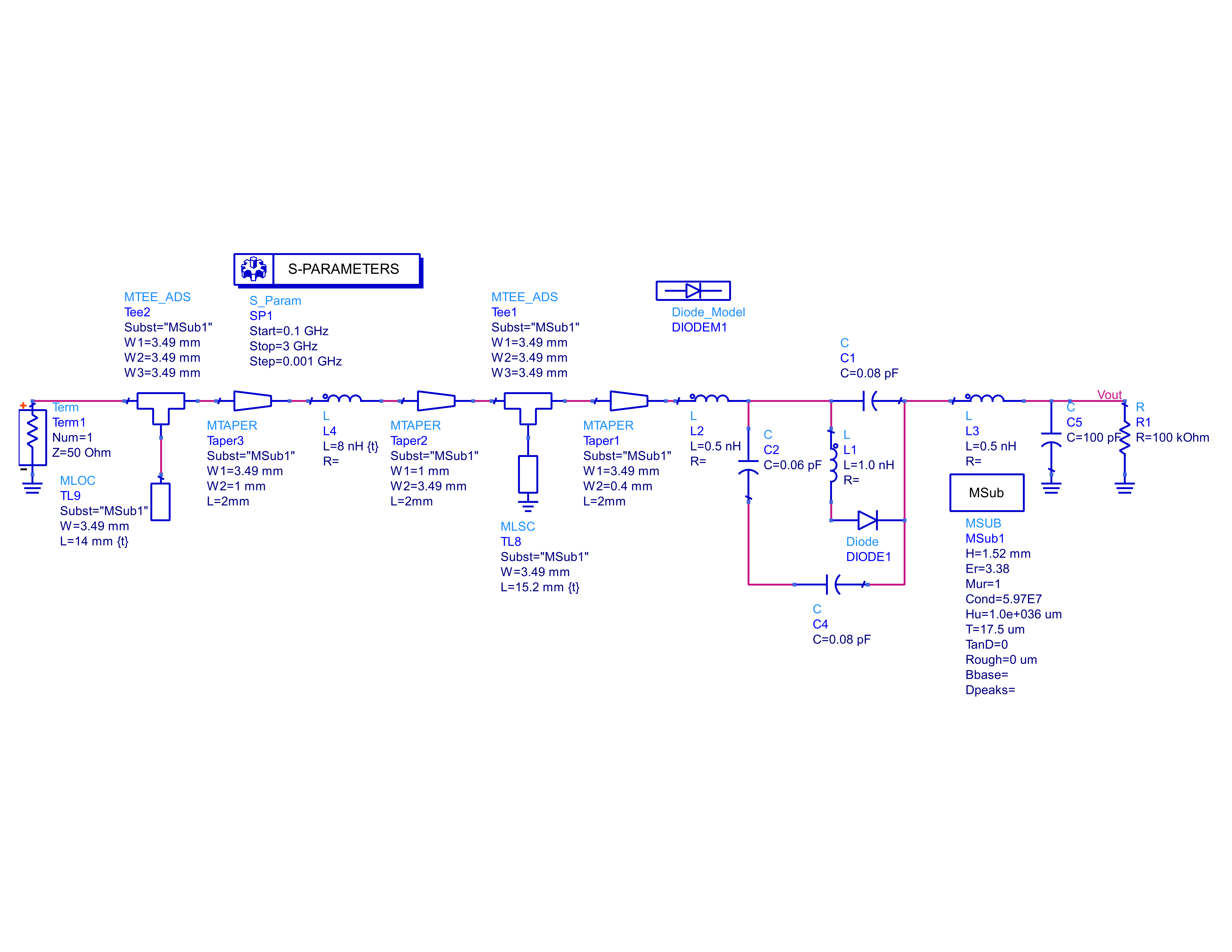
**Lumped Element**

**Diode Detectors**

We begin by creating an accurate model of the diode. Using the datasheet (see references) for the HSMS-2850 all of the small signal parameters are entered into ADS. Since the diode will be used without a DC bias we are interested on the large signal characteristics. As in all RF circuits the behavior of the diode is strongly dependent on the DC bias point and input power. In this case there is no DC bias so we sweep input power.



The schematic below shows the matching network for the diode detector. Notice that parasitics have been added due to the diode’s packaging per app note Avago Technologies 1124. The short circuited stub serves two purposes, its is used as a matching network but more importantly it serves as a path to ground when the diode is not conducting.



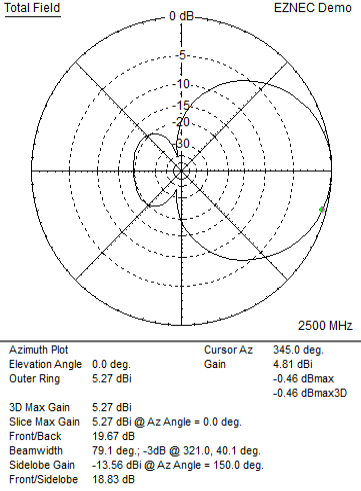
**Display**

A 7-segment display along with some digital logic was used to display when data has been received. The output of the diode detectors is sent to comparators, which sends signals to an OR gate and a 7-segment display driver to decide when to light up the display, and whether the signal is 2.4GHz or 2.6GHz. If the signal is 2.4GHz, the display will show a ‘0’ and when the input signal is 2.6GHz, the display will show a ‘1’.

The comparators have a comparison threshold of approximately 10mV, which is set by a resistive voltage divider. In total, there are three comparators that are being used; the first is used to detect the 2.4GHz signal, the second and third are used for the 2.6GHz signal. When the output of the 2.4GHz diode detector goes above 10mV, the output of comparator 1 goes high, this sends a signal to the OR gate, which allows the display to turn on. Comparator 2 is used in the same way for the 2.6 GHz signal, and comparator 3 is used in parallel with comparator 2 to send a signal to the 7-segment display driver to make the display show a 0 if it is low or a 1 if it is high. Shown below in figure XX is the display showing both conditions.

**Antenna**

To allow the receiver to pick up wireless signals, an antenna was added to the input to the LNA. There were two types of antennas that were explored, a folded dipole, and a Moxon antenna. A Folded dipole antenna is a lambda/2 antenna that has an input impedance around 300 ohms. The antenna is folded to include aTo transform this impedance to 50ohms, typically a balun with an appropriate turns ratio would be used, however the antenna seem to still work fine without it.

The Moxon antenna is another form of a lambda/2 antenna, however there is a reflector element in the near field that reflects the rear lobe of the radiation pattern to the front, which increases directivity and antenna gain. Below is a simulated Azimuth radiation pattern from EZNEC software.

**Board Layout**

The majority of the PCB layout was done in Cadsoft’s Eagle CAD.

**Measurements**

Intermod distortion

Input power to output voltage

Detector output bandwidth

**Conclusion**

**References**