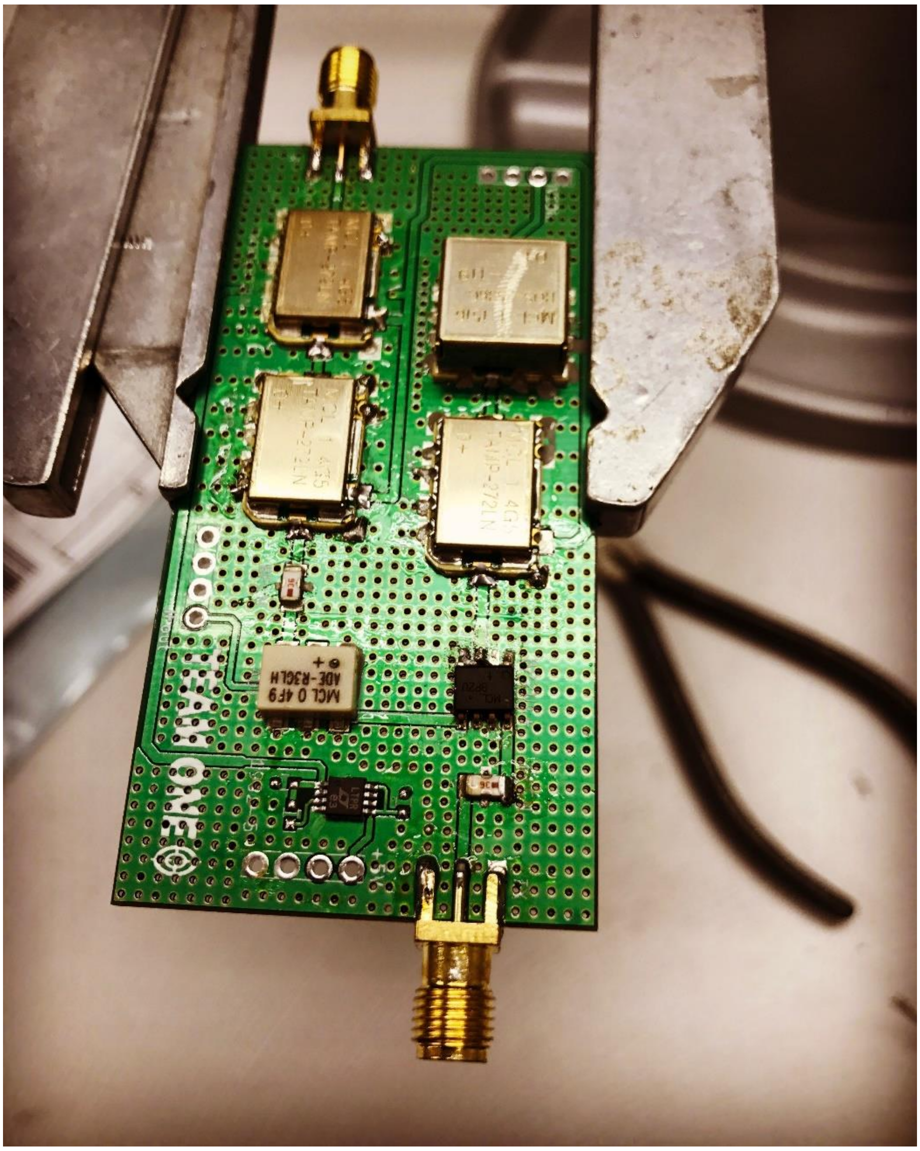

RF Board Design

EEC 134 Application Note

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Introduction

The objective of this application note is to outline the process of designing system and PCB layout for RF board which is used in FMCW radar. To implement the FMCW radar, the RF portion is a critical part which needs to be analyzed element by element and estimate system performance for certain application. Besides, different from baseband part, RF board layout needs more technical calculation and attention for wire routing. It is necessary to do the link budge analysis before choosing various components for the system. This application note will also mention the testing set up and show the results from that.

RF System Design

In this project, we are asked to build a long range, high resolution, compact and low power consumption radar system. As the final competition, there is a 0.3m x 0.3m metal plate as a target and the maximum and minimum rage of the targets are 50 meters and 5 meters. The final score calculation would include power consumption, total weight and accuracy of measured distance. These are all requirements we have so far to design our radar.

- System Block Diagram

  For this project, our system structure is based on the one in last quarter. In order to have a compact system with low power consumption, we are using

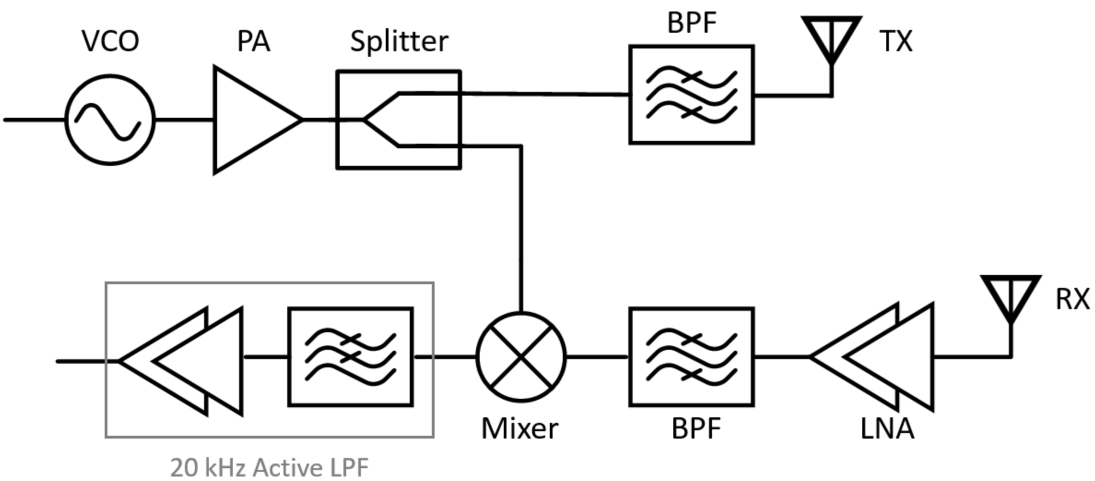

Fig. 1. RF system block diagram.

❖ Design Specifications

It is important to set the link budget while build up a RF system. From the system block diagram above, we can calculate cascaded noise figure from equation according to lectures 9 slides.

$$NF = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \ldots$$

So far, we are planning to use TAMP-272LN+ as low-noise amplifiers and ADE-R3GLH+ as a mixer in our system. From their data sheets provide on the website, we are able to know LNA has 14.5 dB gain and noise figure is 0.85 dB plus mixer has 5.2 dB conversion loss and therefore 5.2 dB noise figure. Our receiver structure is two stages LNA and come with passive mixer then feed the signal into 20 kHz active low pass filter. From the equation above, we can estimate the noise figure of our receiver is about 0.87 dB.

It would be reasonable to set the minimum S/N for the input of demodulator 10 dB in our case. For radar system, the SNR determines whether a successful detection can be achieved. Now, we are able to calculate the receiver input SNR ratio by this equation

$$10\log\left(\frac{SNR_i}{SNR_D}\right) = NF \Rightarrow SNR_i = 12.2 \text{ dB}$$

$$\text{Sensitivity (dBm)} = -174 + NF(dB) + SNR_D^{\min}(dB) + 10\log\left(\frac{B_{IF}}{1Hz}\right)$$

$$= -174 + 0.86 + 10 + 10\log(20\times10^3) \simeq -120\ dBm$$

We set the margin about 15 dB which means the received signal power should at least be -105 dBm. After that, we need to set the specification according to the requirement of competition. The maximum distance is 50 meters away and the size of the target is 0.09 m^2. Our radar system operates at center frequency 2.4 GHz. Here, we check the typical antenna gain for patch antennas from several products then assume our antenna gain should be about 5 dB for both receiver and transmitter.

$$P_r = P_t \frac{G_t G_r \sigma}{(4\pi)^3 R^4} \frac{c^2}{f^2}$$

$$\Rightarrow P_r(dBm) = P_t + G_r + G_t - 10\log\left(\frac{(4\pi)^3 R^4 f^2}{\sigma c^2}\right)$$

The last term in above equation represents the free space loss while target is at 50 meters away. Therefore, we know the required transmitted power is 14.45 dBm. Now, we can pick up components we would like to use and to see whether they meet the specification.

Function	Components	Part Number	Crucial Specification	Power Consumption	Cost	Number
RX	LNA 2.3-2.7 GHz	TAMP-272LN+	Gain:14.5 dB NF: 0.85 dB	Voltage= 5 V Current= 55 mA	$ 9.95	2
	Mixer 2.0-2.7 GHz	ADE-R3GLH+	LO Power: +10 dBm Conversion Loss: 5.2 dB LO-RF Isolation: 35 dB	passive	$ 3.85	1
	BPF 2.3-3.1 GHz	BFCN-2435+	Insertion Loss: 1.5 dB Return Loss: 20 dB	passive	$ 3.95	1
TX	VCO 2.3-2.5 GHz	ROS-2536C-119+	Power Output: +6 dBm	Voltage= 5 V Current= 45 mA	$ 18	1
	Splitter 1.7-3 GHz	BP2U1+	Insertion Loss: 3.5 dB	passive	$ 0.96	1
	PA 2.3-2.7 GHz	TAMP-272LN+	Gain:14.5 dB NF: 0.85 dB P1dB: 19.5 dBm	Voltage= 5 V Current= 55 mA	$ 9.95	1

This chart is the summary of components using in RF system. It would be very helpful to list the key specifications of each component. We are ready to estimate system performance for RF part.

❖ Estimated System Performance

Fig. 2 shows the testing set up for RF board. Since it would be better if we test RF and baseband board separately, we need USB synthesizer to offer a low power received signal. The lowest power we can get from synthesizer might be -20 dBm. Besides, it is important to check the data sheets to see whether the system have saturation problem on amplifiers (P1dB, IP3…).

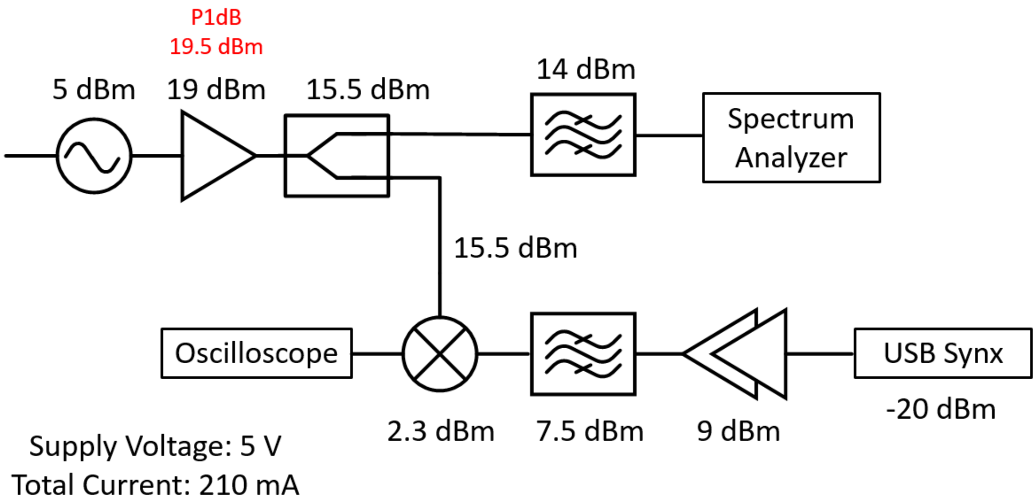

Fig. 2. Testing set up for RF board.

RF PCB Layout

After picking up proper components, Fig. 3 shows the schematics of our RF board. It is good that the low noise amplifier TAMP-272LN+ from Mini Circuits already integrated bias matching and stabilization circuits in the chip. The schematics of RF board is pretty simple but the layout of it needs more technical knowledge.

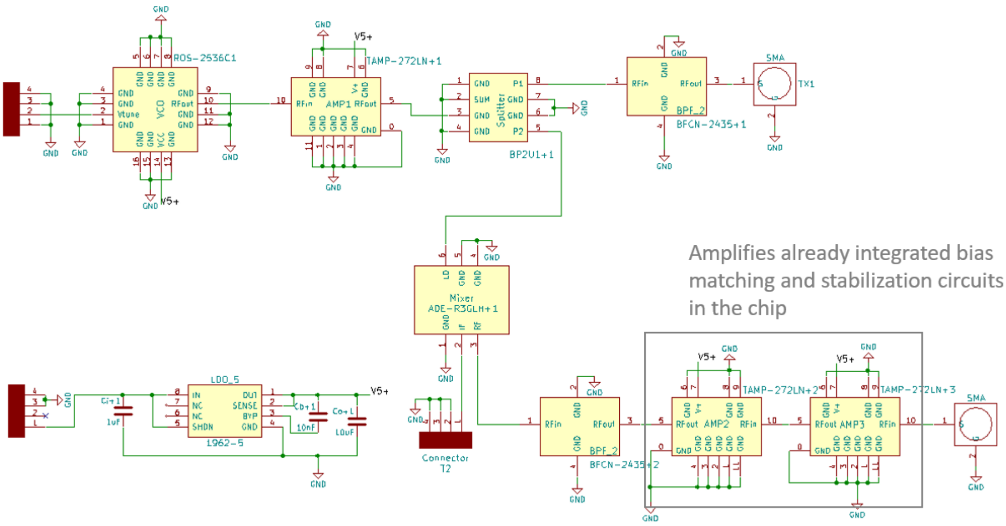

Fig. 3. Schematics of RF board.

First, we can use ADS to get the proper width of CPWG line at 2.4 GHz on FR4 PCB board. As we learned from last quarter, the width and the gap of CPWG is 34 mil and 6 mil for 50 ohms line. More information shows on Fig. 4. Different board has various parameters and it might be able to find it on the website of manufactory.

There are some critical issues on our original layout of RF board. Fig. 5 circle those parts where might affect the impedance of CPWG line. While doing layout, just be careful to avoid crossing from RF path.

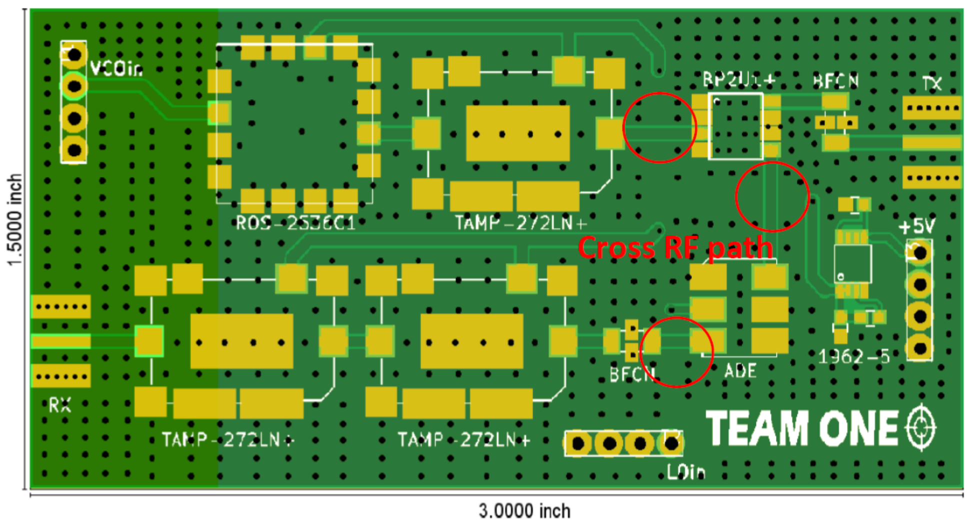

Fig. 5. Original RF board layout.

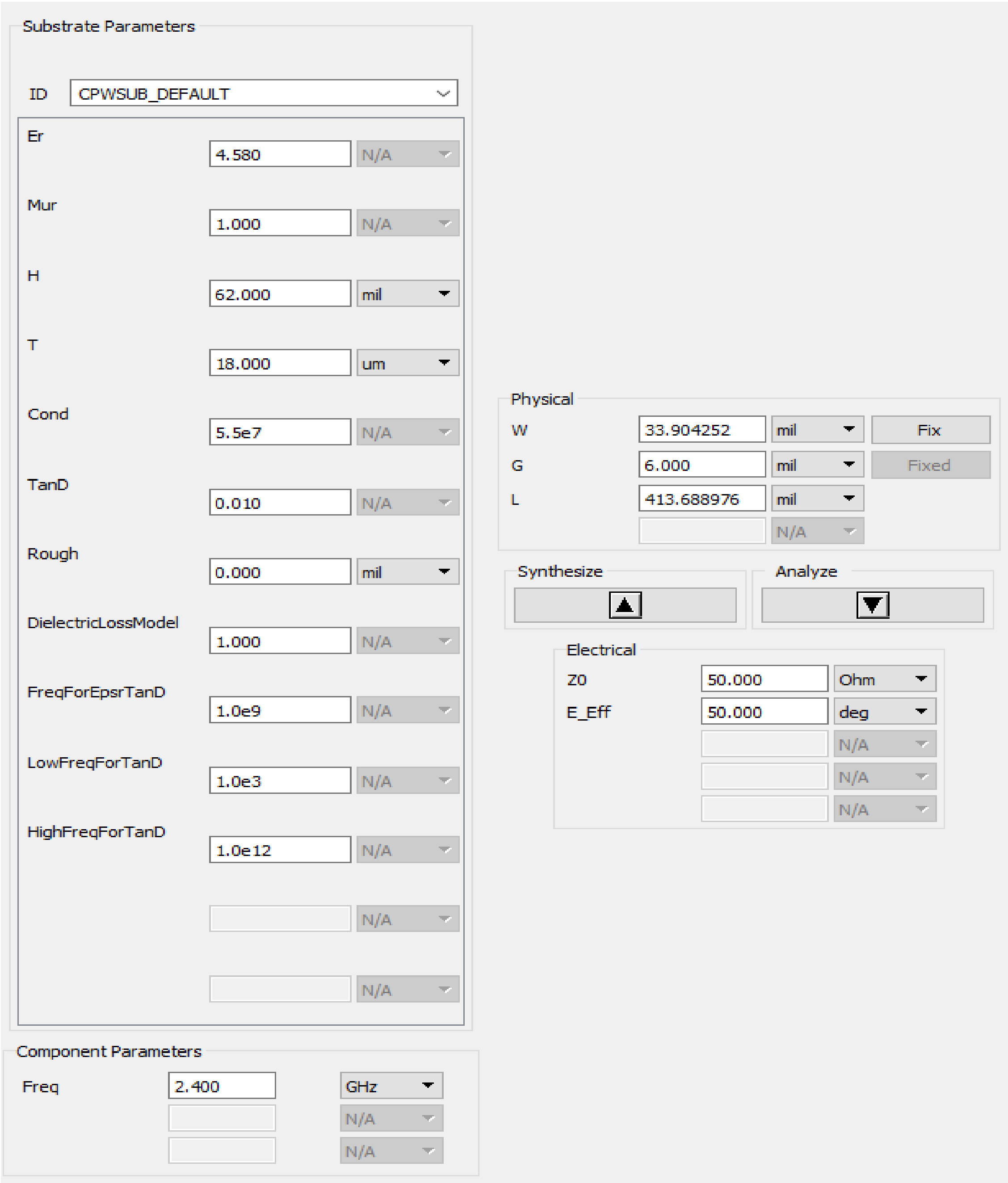

Fig. 4. Simulation results for CPWG line using ADS.

You can find reference layout design from their data sheets and follow the pattern they provide. Sometimes, they would also offer specific width and gap for RF input and output line but based on different PCB board. Check the type of boards they are using and double confirm from the results you get is necessary. Fig. 6 is revised version of our RF board. Instead of crossing below RF path, we router the DC wire below the components.

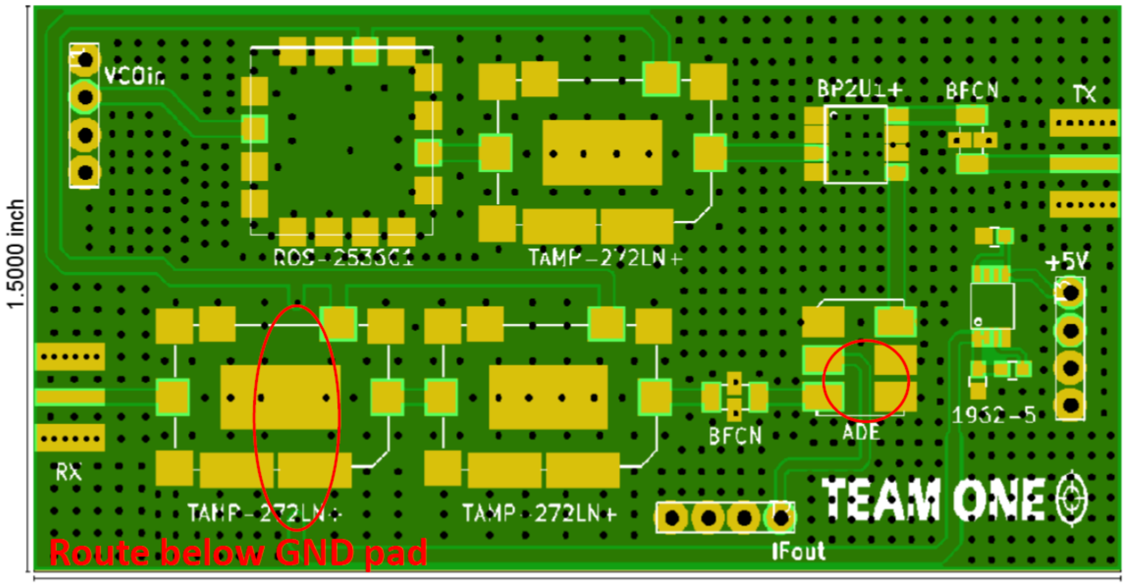

Fig. 6. Revised layout of RF board.

Test Results