EEC 134AB

Application Note

Radar System Design

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Group: RF Eater

1. Deciding the Radar Frequency

The first step to improve the overall radar system based on our quarter 1 project is to determine the work frequency of the radar system. Once we decide the working frequency, we can then choose the components for each part of the system such as VCO (voltage control oscillator), power splitter, mixer etc.. One important factor I took into consideration when deciding the operating frequency is the radar resolution. In spite of the fact that system with a higher operating frequency will have higher resolution and will be more related to industrial application, I finally choose the operating frequency to be 2.4 GHz which is the same as the frequency of our quarter 1 system because of the technical challenge of raising working frequency. There are also some other advantages of keeping the frequency to 2.4 GHz:

A. Components will be similar to those in quarter 1 design

B. We do not have to redesign the antenna so we can continue to use the coffee can.

C. We can directly use the code for Teensey to generate signal for Vtune of VCO.

D. We can directly use the python code for audio signal processing of the receiving signal.

E. Power input will be the same.

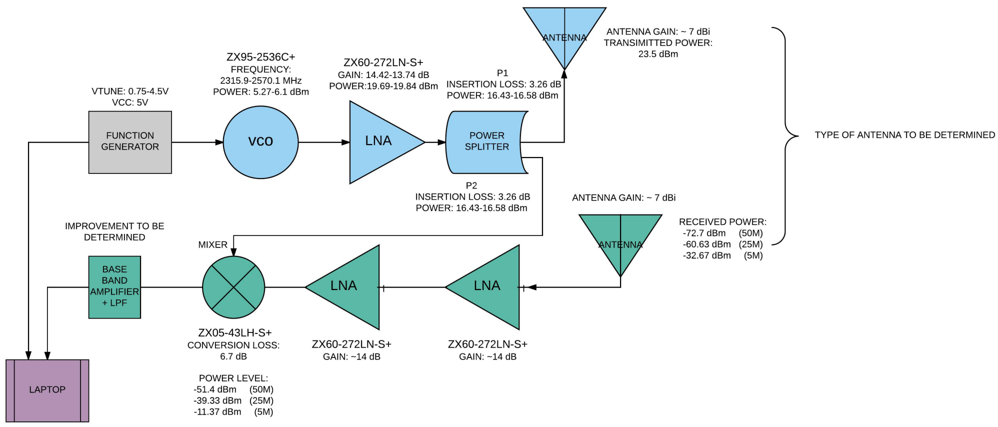
F. The budget will be kept low.

2. Deciding Whether to Use on Board Processing or Not

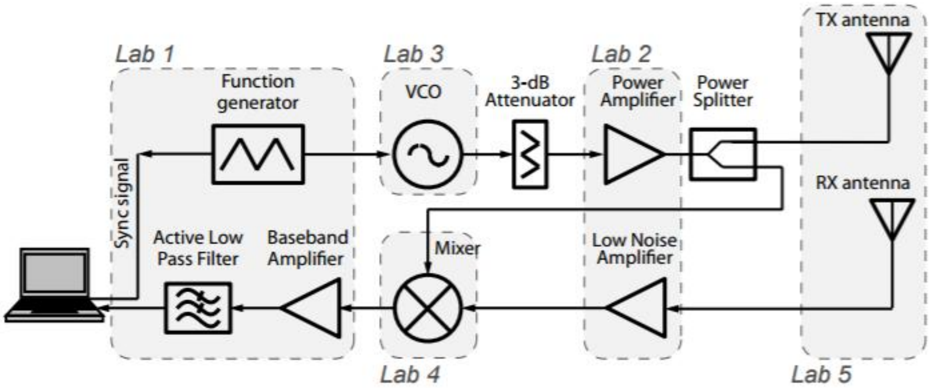
As mentioned in the quarter 2 project guidelines from Smartsite, “if we choose to use an on-board signal processor whose weight will be counted, a bonus multiplier of 0.2 will be applied to the total score,” which is a very attractive bonus. However, since none of the team members have an experience of digital processing or touch board programming, we decide to give up the idea of involving an on-board signal processor.

3. System Block Diagram Design

Below is the final block diagram I designed. Notice that I choose to remove the attenuator and add an extra low noise amplifier (LNA) to the receiving side based on our calculation.



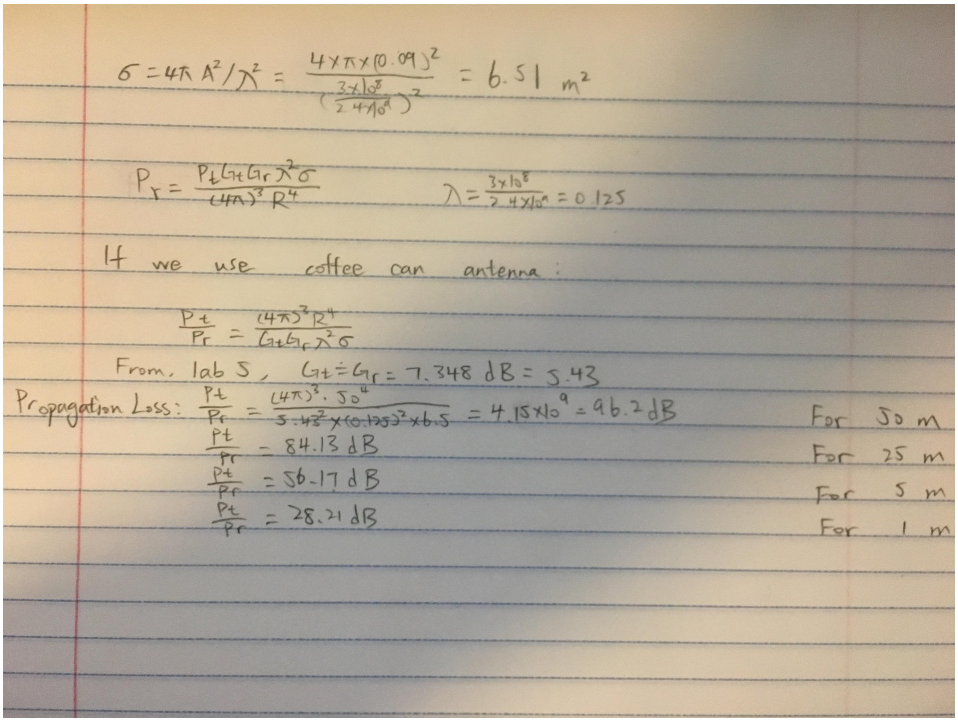
When designing the block diagram of quarter 2 system, it will be very helpful if you reference to quarter 1’s block diagram which is provided in the lab manual 6. Here is block diagram from lab 6.



Next step is to calculate the transmitting power and the receiving power of the signal, it will be very helpful if you use the following formula:

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

In fall quarter, we measured the gain of our can antenna and it is 7.348dB. Based on this value and the equation above, we calculated the propagation loss for our system.



$\sigma = 4\pi A^2/\lambda^2 = \frac{4\times\pi\times(0.09)^2}{(\frac{3\times10^8}{2.4\times10^9})^2} = 6.51\ m^2$

$P_r = \frac{P_t G_t G_r \lambda^2 \sigma}{(4\pi)^3 R^4}$ $\lambda = \frac{3\times10^8}{2.4\times10^9} = 0.125$

If we use coffee can antenna:

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

From, lab 5, $G_t \doteq G_r = 7.348\ dB = 5.43$

Propagation Loss: $\frac{P_t}{P_r} = \frac{(4\pi)^3 \cdot 50^4}{5.43^2 \times (0.125)^2 \times 6.5} = 4.15\times10^9 = 96.2\ dB$ For 50 m

$\frac{P_t}{P_r} = 84.13\ dB$ For 25 m

$\frac{P_t}{P_r} = 56.17\ dB$ For 5 m

$\frac{P_t}{P_r} = 28.21\ dB$ For 1 m

Distance	Propagation loss
50m	96.2dB
25m	84.13dB
5m	56.17dB
1m	28.21dB

Table 1. Propagation Loss

4. Components Choice

As I mentioned above, the components are the same as those in quarter 1. Please find their data sheet online and carefully read through them to find out all the important parameters. Here is the important data sheet pages for our system design.

a) VCO: ZX95-2536C+

• TD-SCDMA / HSDPA

Electrical Specifications

MODEL NO.	FREQ. (MHz)		POWER OUTPUT (dBm)	PHASE NOISE dBc/Hz SSB at offset frequencies,kHz Typ.				TUNING					NON HARMONIC SPURIOUS (dBc)	HARMONICS (dBc)		PULLING pk-pk @12 dBr (MHz)	PUSHING (MHz/V)	DC OPERATING POWER	
								VOLTAGE RANGE (V)		SENSI-TIVITY (MHz/V)	PORT CAP (pF)	3 dB MODULATION BANDWIDTH (MHz)						Vcc (volts)	Current (mA)
	Min.	Max.	Typ.	1	10	100	1000	Min.	Max.	Typ.	Typ.	Typ.	Typ.	Typ.	Max.	Typ.	Typ.		Max.
ZX95-2536C+	2315	2536	+6	-75	-105	-128	-148	0.5	5	57-77	13.6	70	-90	-18	-10	2.5	2.5	5	45

Maximum Ratings

Operating Temperature	-55°C to 85°C
Storage Temperature	-55°C to 100°C
Absolute Max. Supply Voltage (Vcc)	5.6V
Absolute Max. Tuning Voltage (Vtune)	7.0V
All specifications	50 ohm system

Permanent damage may occur if any of these limits are exceeded.

NOTE: When soldering the DC connections, caution must be used to avoid overheating the DC terminals. See Application Note AN-40-10 .

Outline Drawing

b) Power splitter ZX10-2-42+

Electrical Specifications (T_{AMB}=25°C)

FREQ. RANGE (MHz)	ISOLATION (dB)		INSERTION LOSS (dB) ABOVE 3.0 dB		PHASE UNBALANCE (Degrees)	AMPLITUDE UNBALANCE (dB)
f_L-f_U	Typ.	Min	Typ.	Max.	Max.	Max.
1900-4200	**23**	**10**	**0.2**	**1.2**	**5.0**	**0.3**
2600-3400	23	17	0.2	0.6	4.0	0.3

Typical Performance Data

Frequency (MHz)	Total Loss[1] (dB)		Amplitude Unbalance (dB)	Isolation (dB)	Phase Unbalance (deg.)	VSWR S	VSWR 1	VSWR 2
	S-1	S-2						
1900.00	3.45	3.45	0.00	12.33	0.70	1.79	1.08	1.07
2040.00	3.42	3.44	0.02	13.42	0.71	1.71	1.09	1.08
2180.00	3.37	3.36	0.01	14.64	0.74	1.62	1.10	1.09
2460.00	3.26	3.26	0.01	17.92	0.91	1.47	1.09	1.08
2600.00	3.19	3.19	0.00	20.16	1.05	1.39	1.08	1.08
2760.00	3.19	3.18	0.01	23.66	1.02	1.26	1.05	1.05
2920.00	3.10	3.12	0.02	27.75	1.18	1.14	1.02	1.03
3240.00	3.11	3.11	0.00	23.53	1.50	1.07	1.03	1.02
3400.00	3.13	3.16	0.03	20.10	1.54	1.19	1.05	1.10
3540.00	3.23	3.27	0.04	17.91	1.30	1.31	1.07	1.05
3680.00	3.26	3.29	0.03	16.12	1.55	1.40	1.07	1.06
3820.00	3.31	3.36	0.05	14.58	1.52	1.51	1.09	1.08
4100.00	3.48	3.52	0.03	12.21	1.48	1.78	1.15	1.15
4150.00	3.54	3.58	0.04	11.90	1.37	1.83	1.16	1.16
4200.00	3.52	3.55	0.03	11.51	1.50	1.87	1.17	1.18

1. Total Loss = Insertion Loss + 3dB splitter loss.

b) Mixer ZX05-43LH-S+ :

Frequency Mixer WIDE BAND

ZX05-43LH+

Level 10 (LO Power +10 dBm) 824 to 4200 MHz

CASE STYLE: FL905

Connectors	Model
SMA	ZX05-43LH-S+

+RoHS Compliant
The +Suffix identifies RoHS Compliance. See our web site for RoHS Compliance methodologies and qualifications

Maximum Ratings

Operating Temperature	-40°C to 85°C
Storage Temperature	-55°C to 100°C
RF Power	50mW

Permanent damage may occur if any of these limits are exceeded.

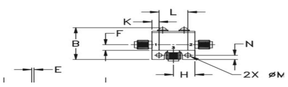
Coaxial Connections

LO	2
RF	3
IF	1

Features
- wide bandwidth, 824 to 4200 MHz
- low conversion loss, 6.1 dB typ.
- excellent L-R isolation, 35 dB typ.
- rugged construction
- small size
- useable as up and down converter
- protected by US patents, 6,790,049 and 7,027,795

Applications
- cellular
- defense and weather radar
- defense communications
- PCN
- WCDMA
- WIFI
- blue tooth
- VSAT
- ISM

Outline Drawing



Electrical Specifications

FREQUENCY (MHz)		CONVERSION LOSS* (dB)			LO-RF ISOLATION (dB)		LO-IF ISOLATION (dB)		IP3 (dBm)
LO/RF f_L-f_U	IF	Typ.	σ	Max.	Typ.	Min.	Typ.	Min.	Typ.
824-4200	**DC-1500**								
824-2500		6.3	0.1	8.1	35	28	24	7	15
2500-4200		5.7	0.1	8.8	28	23	20	11	14

1 dB COMPR.: +5 dBm typ.
* Conversion loss at 30 MHz IF. σ is a measure of repeatability from unit to unit.

5. Antenna

Considering the weight, size and the stability of the whole system, we decided not to use coffee cans for both transmitting and receiving antennas from last quarter. We finally decided to use can antenna only for the transmitting antenna because the gain for can antenna is bigger than the patch antenna. Since patch antenna are more light and steady, we decided to use patch antenna as the receiving antenna. By considering the operating situation we need, we purchased the Yagi Antenna online as our patch antenna. The Yagi antenna is able to operate at 2.4GHz.

Due to the measurement with the spectrum analyzer, we calculated out the patch antenna gain to be :

-29.5dBm = 0.00117 mW

$G = (4\pi * 1/ 0.125) * \sqrt{(0.00117 / 1)} = 3.439 = 5.364\text{dBi}$

With the help from the TA, we performed the coupling tests for the two antennas and decided that the distance between two antennas should be 10 inches.

Fig 1. Coupling test

According to the test for return loss (S11), the patch antenna and can antenna were working with reasonable frequency. The bandwidth for the patch antenna is 0.6GHz, and the bandwidth for the can antenna is 0.45GHz.

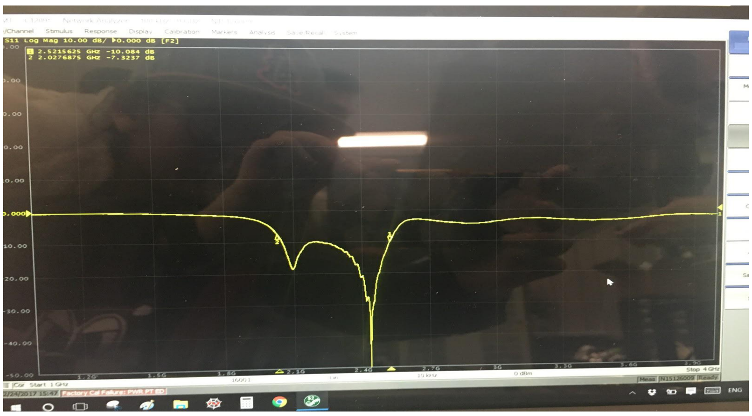


Fig 2. S11 result for patch antenna

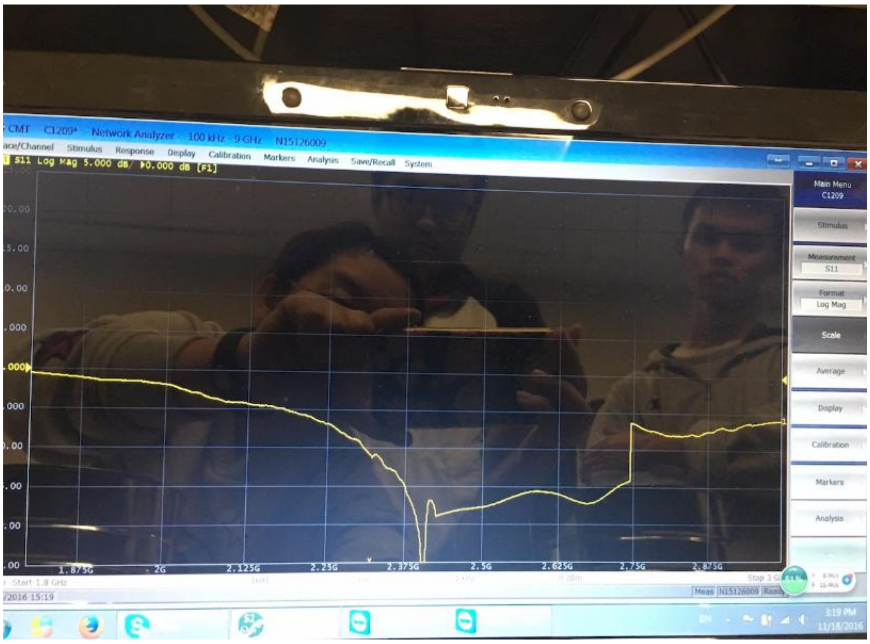


Fig 3. S11 result for can antenna

5. Conclusion and Some Useful Tips

A. There all many useful online block diagram design tools which will make your block diagram much clearer, interesting and understandable.

B. Be sure to consider power loss between connection of different components, the data from data sheet is the perfect theoretical value which in fact will be much greater than the actual tested value.

C. Make sure that all the components are worked in the same frequency range and make sure that power supply to them is neither too big nor too small.

D. If possible, please choose to use the components that are mountable on PCB because it can reduce the weight of your entire system significantly. In my case, I did not choose to use mountable splitter, mixer and VCO.

E. Make sure that you have a back-up plan. There is a large possibility that your plan A will not work as expected.

F. EEC 134 AB is a very useful course and will definitely provide you experience which will be very helpful for career in the future, so work hard and have fun!