Technical Note: Basics of Radar system and designing

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Radar system

Radar is an object detection system that uses radio waves to determine the position (distance), angle, or velocity of objects. The importance of radar in this modern world is very important. Few decades ago, the use of radar system is limited for military purposes to detect aircraft, ships, spacecraft, guided missiles, and so on. But, nowadays, a radar system is part of our lives, for instance, the forecast of weather information is entirely depend on the radar system, and radar system is a major component of self-driving cars.

There are two major types of radar system pulsed radar and Frequency-Modulated continuous-wave (FMCW). The pulsed radar detects the range to a target by emitting a short pulse and observing the time to reach the target object and return back to the receiver. For our radar system we used the FMCW radar system. Frequency-modulated continuous-wave (FMCW) radars achieve similar results using much smaller instantaneous transmit powers and physical size by continuously emitting periodic waves whose frequency content varies with time. To summarize the process in a simple words, in FMCW radar system, the transmitted signal is a linear frequency modulated continuous wave sequence, whose frequency vs time characteristics follows the saw tooth pattern as shown below in the figure. The local oscillator (LO) module generates a linear frequency modulated continuous wave signal and amplified by the power amplifier. This amplified wave transmitted from the antenna.

The target object illuminated by the radar reflects back the transmitted signal. The receiver (antenna) receives the reflected signal and passes to the LNA, and the LNA amplifies the signal. The received signal mixes with the LO signal to produce the intermediate frequency (IF) output, which the ADC digitizes and subsequently to process it. Pictorially, it presented below.

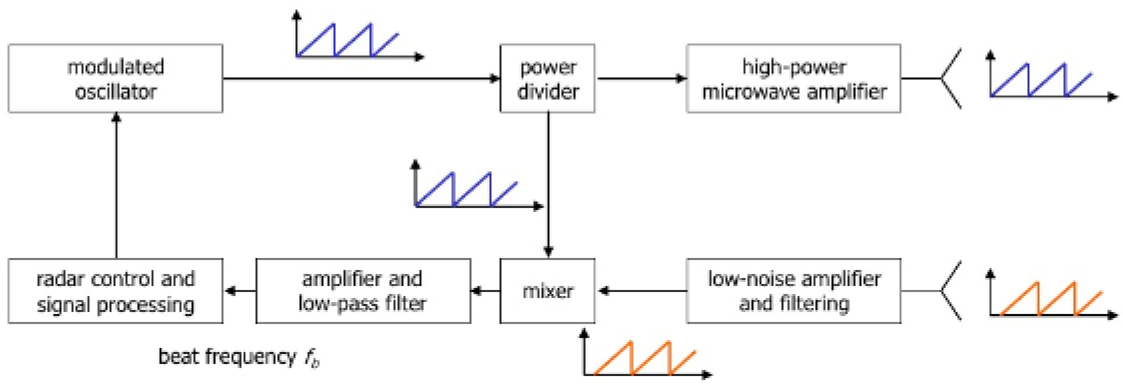

Fig 1. The FMCW radar system.

Analysis of the computation

Unlike the pulsed radar, FMCW radar uses a continuous wave signal for transmission. As stated above the frequency changes with respect to time in a specific pattern such as a saw tooth wave or a triangle wave. A triangle wave example is shown below. These patterns are achieved by ramping the control voltage of the VCO in the transmitting side up and down.

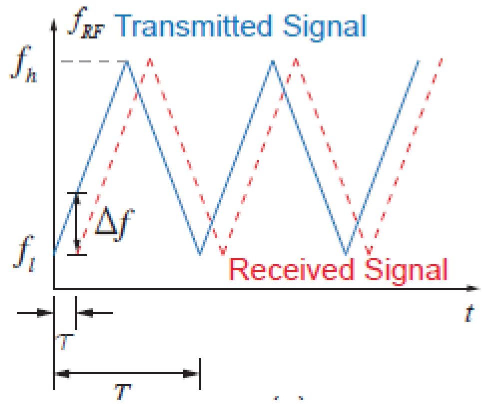

Fig 2. Wave form of the transmitted and received signal.

As shown on the above figure, the transmitted and received signals have different frequency. These differences in frequency of the two signals are extracted by the mixer. The main point on here is that, this frequency difference is proportional to the round trip delay of the radar signal to and from the target object. Hence, the distance of the target object is calculated by examining the frequency difference. The general calculation is presented below.

$$t = \frac{2d}{c}$$

Where t- the time required the wave reaches to the target and comeback to the source.

d- is the distance of the target object

c- Speed of light.

The difference of the frequency is proportional to the distance of the object.

$$\Delta f = kt = \frac{2kd}{c}$$

$$d = \frac{c\Delta f}{2k}$$

Designing the radar system

For our radar system, we used the general block diagram of FMCW radar system presented on the lab manual 6. The block diagram is presented below.

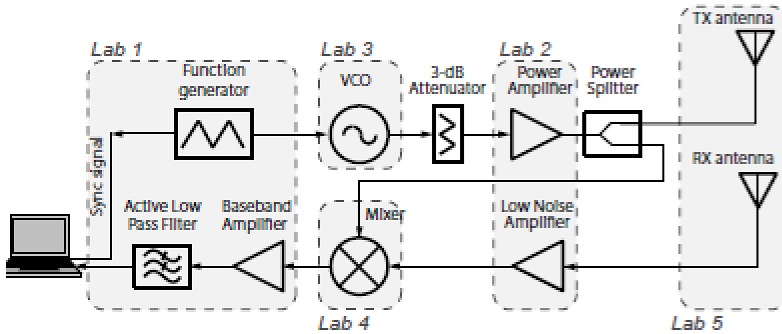

Fig 3. Block diagram of the FMCW radar system.

The main requirement of our design is to measure accurately the distance between our radar an object 5-50m away. The calculated maximum path loss for an object 50m away determines the minimum requirements for our transmit and receive system. The received power at 5m and 50 calculated as follows:

$$Pt = 21.7\ dBm = 0.14791\ W$$

$$Gt = Gr = 10\ dBi$$

$$\sigma = \ 0.3 * 0.3 = 0.09\ m^2$$

$$Aeff = \frac{\lambda^2 Gr}{4\pi} = \frac{\left(\frac{c}{f}\right)^2 Gr}{4\pi} = \frac{\left(\frac{3E8}{2.4E9}\right)^2 10}{4\pi} = 0.01243\ m^2$$

$$Pr = \frac{PtGt\sigma Aeff}{16\pi^2 R^4}$$

$$Pr\ (5\ m) = \frac{PtGt\sigma Aeff}{16\pi^2 R^4} = \ \frac{0.14791 * 10 * 0.09 * 0.01243}{16\pi^2 5^4} = 1.67653E - 8\ W$$

$$= -47.75\ dBm$$

$$Pr\ (50\ m) = \frac{PtGt\sigma Aeff}{16\pi^2 R^4} = \frac{0.14791 * 10 * 0.09 * 0.01243}{16\pi^2 50^4} = 1.67653E - 12\ W$$

$$= -87.75\ dBm$$

Then we select components; we primarily considered the power level at each stage which fits to our system. To calculate the power level at each stage, we used ADIsimRF. The block diagram of our radar system and the power level at each stage is presented below.

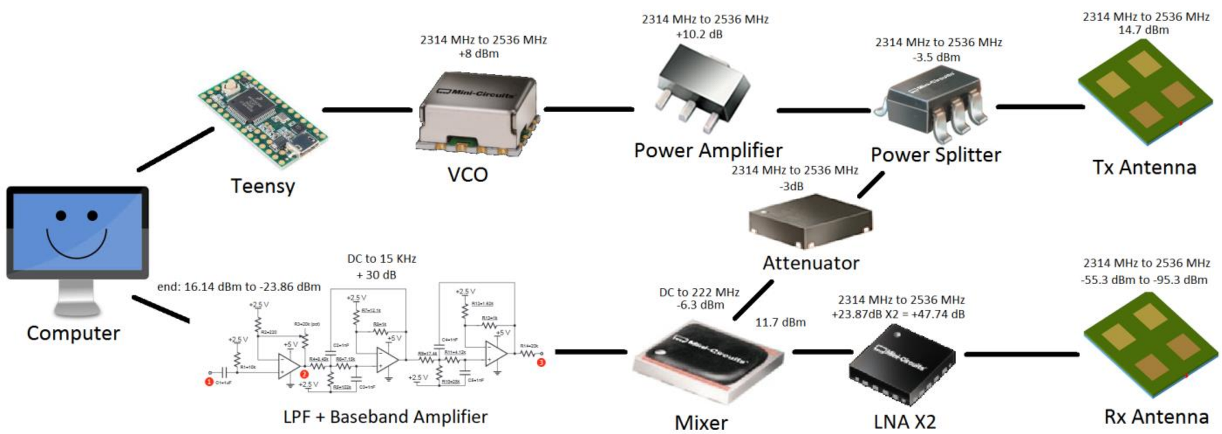

Fig 4. Block diagram and component of our FMCW radar system.

The ADIsimRF of the transmitter and receiver of the system is presented below.

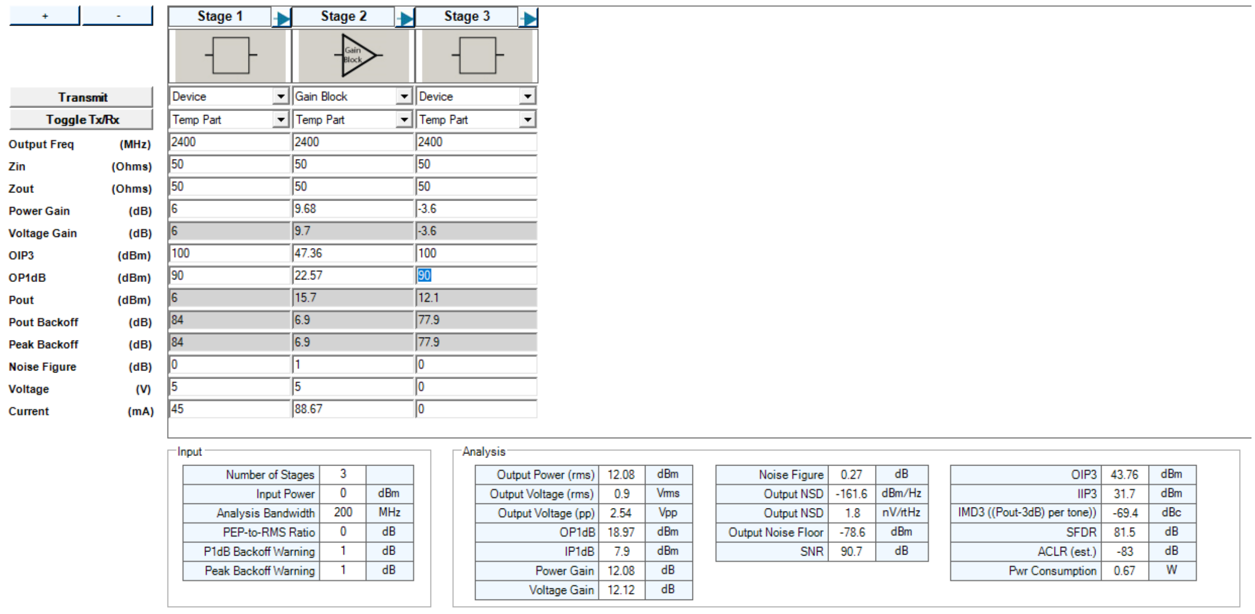

Fig 5. The ADIsimRF simulation of the transmitter side.

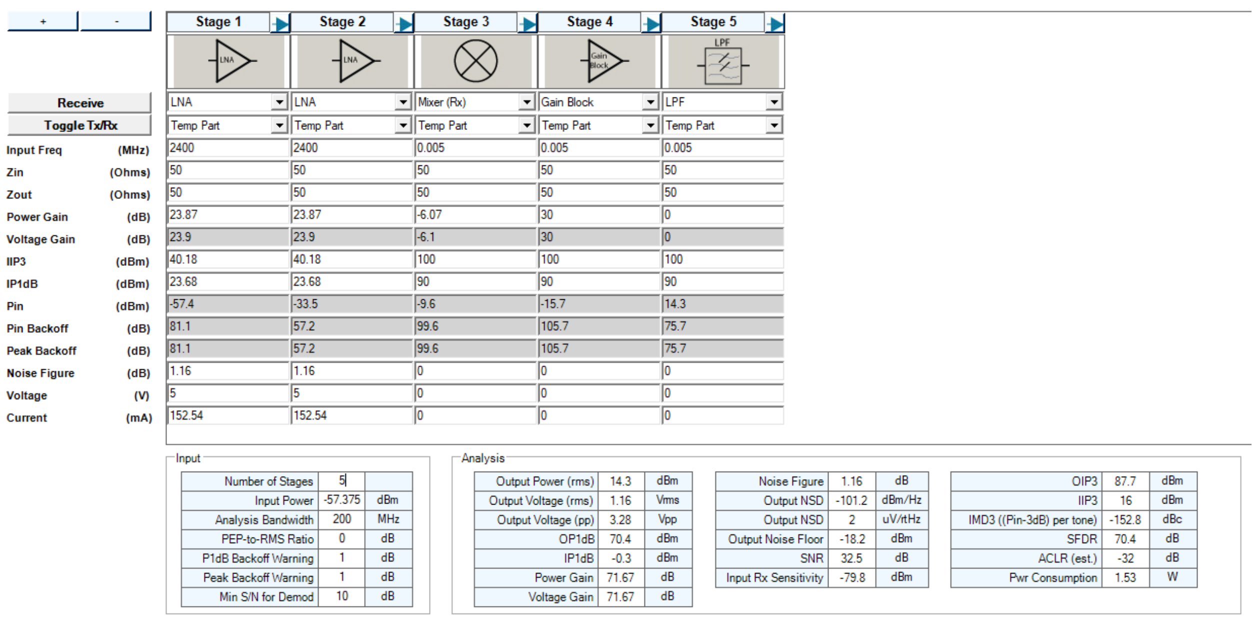

Fig 6. The ADIsimRF simulation of the receiver side.