# FMCW Radar with enhanced frequency estimation

#Dong-hun Shin [1], Seong-Ook Park [2]
[1] Department of Electrical Engineering, KAIST
Daejeon, Korea, husido@kaist.ac.kr
[2] Department of Electrical Engineering, KAIST
Daejeon, Korea, sopark@ee.kaist.ac.kr

## Abstract

This paper researches on a X-band FMCW short range radar with enhanced frequency estimation. It has 600MHz bandwidth with 160us sweep time. Distance error using enhanced frequency estimation algorithm is less than 8cm in 5m range.

**Keywords :** FMCW, SRR, Frequency estimation.

## 1. Introduction

The technology about the precision range measurement and tracking system is classified according to source type. Ultra sound radar and microwave radar are used in spread. Ultra sound radar can implement accurate measurement of less than 10cm resolution and is mainly used in robotics and industrial equipment. But, it is sensitive to the weather condition. Range resolution is decreased in bad condition such as fog, rain, temperature, etc.

The localization and the acquisition of the rough shape of the obstacles can be carried out in any weather condition by means of a microwave radar system.[1] A microwave radar system used a short pulse signal or continuous-wave signals for the detection. Pulse radar can detect the distance of multiples targets. However, it needs high power source to detect an object. In contrast, FMCW radar can detect the distance of multiple targets and the speed of a moving object with lower power. In addition, it can be easily implemented due to the simple structure.[2] Microwave radar has a high technical accuracy for Precision range measurement and tracking.[3-5] In microwave system, the higher frequency, the size of the radar system is decreased but some disadvantages are expensive and difficult to produce. Regardless of the center frequency, range radar requires sufficient bandwidth in order to improve the distance resolution, but sufficient bandwidth is not allowed. So a compromise is needed in frequency band selection.

Proposed short range radar system is based on microwave FMCW radar using 10.2 ~ 10.8 GHz frequency. Modified picket fence algorithm is used for improving accuracy of the target distance.[6]

## 2. System Architecture

The whole architecture of the whole system is shown in Figure.1. Bi-static radar type is used for the isolation between Tx and Rx antennas. Isolators are inserted in front of antennas to remove the reflection signal from input port of antenna mismatch, receiving signal at Tx antenna and unwanted radiation from Rx antenna. The VCO is able to sweep on the range 10.2~10.8 GHz with 2dBm output power with triangular sweep type. Band pass filter is used for blocking the harmonics of VCO’s output frequency. The swept signal divided, by means of a power divider, and supplied with LO port of the mixer and the Tx antenna. Received signal from the Rx antenna is supplied to the RF port of the mixer. In the mixer, RF signal is mixed with LO signal and down converted to intermediate frequency signal. The IF signal, output of the mixer is amplified at Gain Variable Amplifier; after that the IF signal is sampled and acquired by PC and calculated the range.

## 3. Gain Variable Amplifier in SRR

In short range radar, noise (unwanted IF signal) such as reflected signal from ground, received signal directly from the Tx antenna and leakage signal in circuit is generated. Noise should be removed. Because this noise located near beat signal with high amplitude, it leads to error in calculating the distance.

In addition, radiated wave has path loss depending on the distance when propagating in free space. The path loss is inversely proportional to the square of wavelength and proportional to the square of distance. It leads to the difference of amplitude in IF signal.

Gain variable amplifier is used to remove noise and compensate the path loss. It has difference gain depending on the frequency. Characteristic of GVA is shown in Figure. 2.

## 4. Signal Processing and frequency estimation

The sampling frequency is 1Mbps and 1024 points are used for calculated. 160points are sampled when 1period sampling. Signal of 6periods is used and zeros are added to set 1024points. An analysis algorithm based on Discrete Time Fourier Transform (DTFT). Eq [1] is well known DFT equation.

$$Y(k) = \sum_{n=0}^{N-1} y(n) e^{-\frac{j2\pi}{N}kn} \tag{1}$$

The result of DFT, only 1peak frequency which connotes range is appeared ideally. But, some spurious near the peak frequency are exist. It caused from non-linearity of source. Better range accuracy is obtained by using picket fence algorithm.

$$f_{beat} = \frac{\sum_{n=p-k}^{p+k} Y(n) \bullet f(Y(n))}{\sum_{n=p-k}^{p+k} Y(n)} \tag{2}$$

| | |
|---|---|
| p | Peak index |
| Y(n) | Amplitude of nth index |
| f(Y(n)) | Frequency of Y(n) |

## 5. Measurement

To evaluate the performance of FMCW radar, a set of simple test has been conducted. The specifications of the FMCW radar are summarized in TABLE 1. The microwave signals are transmitted and received via two pyramidal horn antennas (Gain : 22dBi, -3dB beam-width : $17^{o}$ @ 10.5GHz). The target (50 x 50 $cm^2$ piece of flat aluminum plate) is positioned in front of antennas at intervals of 10cm from 0.5m to 5m.

Figure. 3 shows the result of measurement. The solid line means measured result and the dash line means calculated result. The maximum measurement error without frequency estimation is 17cm.

The measurement result using picket fence algorithm is shown in Figure. 4. The maximum measurement error is 8cm. It is less than a half of the result without algorithm.

## 6. Conclusions

Short range radar system has been presented. The proposed FMCW short range radar has 600MHz bandwidth and 160us sweep time (80us rising sweep and 80us falling sweep) with triangular sweep type. Beat frequency was calculated using picket fence algorithm. The characterization of the system has range error without algorithm less than 17cm in 5m range and with algorithm less than 8cm. This system can be implemented in many functions such as the parking aids, the stop-and go and the pre alarm of the air bags.

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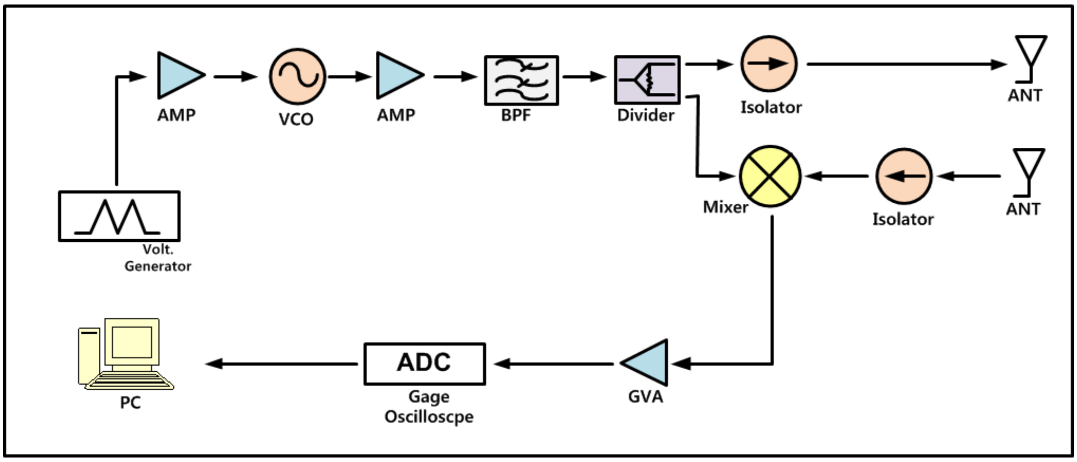


**Figure 1. Block diagram of Radar System**

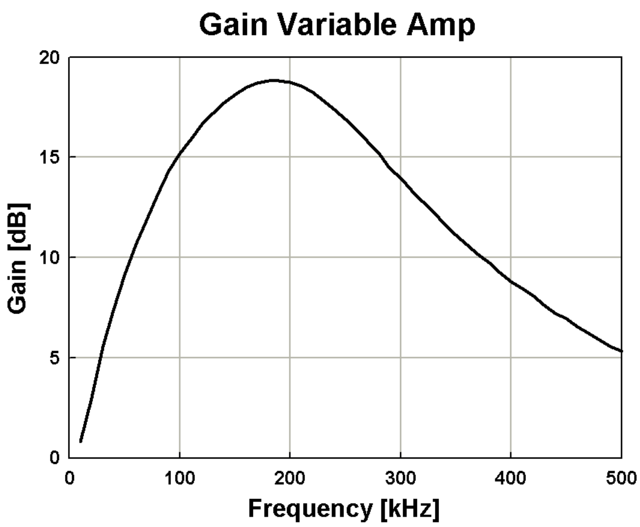


**Figure 2. Gain Variable Amplifier**

**Table 1. Specifications of FMCW Radar**

| | |
|---|---|
| Frequency | 10.2~10.8GHz (600MHz) |
| Range Resolution | 0.25m |
| Sweep type | Triangular |
| Sweep time | 160us |
| Sampling Frequency | 2Mbs |
| Target Range | 0.5~5m |
| Target | 50 x 50 $cm^2$ Aluminum |

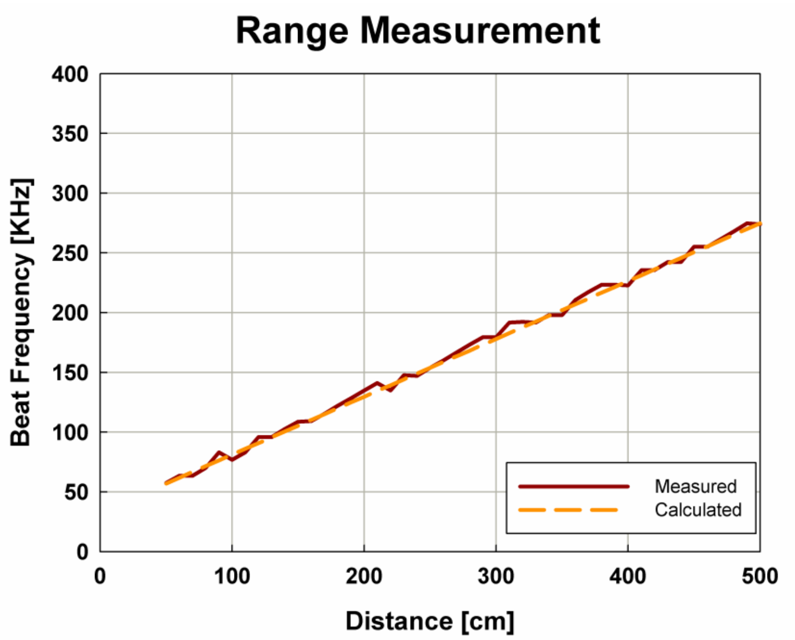


**Figure 3. Range measurement without frequency estimation**

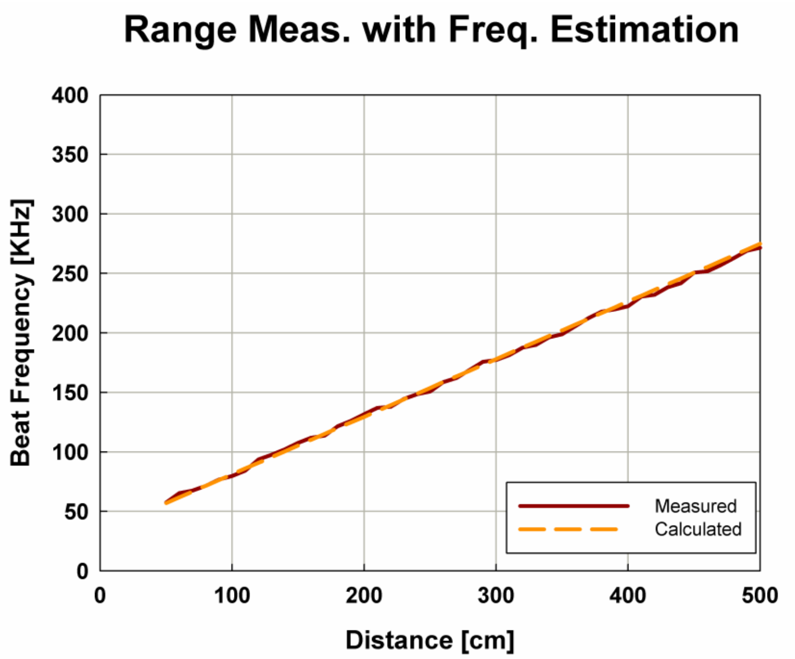


**Figure 4. Range measurement with frequency estimation**