# A DDS and PLL-based X-band FMCW Radar System

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*Abstract*— **A DDS and PLL-based FMCW range meter system is described. The DDS is used as a reference clock of a linearly frequency modulated signal source, and the PLL is controlled by it. The bandwidth and the sweep time of the FMCW radar system are 150 MHz, and 270 us. Zero-padding and spectral centroid processing techniques are used to measure a target range, and the range resolution is less than 0.25 m.**

***Keywords-FMCW;radar;DDS;PLL***

## I. Introduction

A frequency modulated continuous wave (FMCW) technique is widely used in microwave range measurement systems such as level meter of liquid tanks, collision avoidance, and other short range measurement applications [1]. One of these systems design considerations is a linear modulation technique that determines the quality of the received IF signals. A voltage controlled oscillator (VCO) commonly used in FMCW radar is nonlinear active device, but it covers wide bandwidth, and high operational frequency. On the contrary, a direct digital synthesizer (DDS) supports a few hundred mega hertz bandwidth. However, a precise linear frequency modulation property is the advantage of the DDS. This paper describes the DDS and PLL-based X-band FMCW radar system whose VCO nonlinearity is controlled by a digitally generated reference signal to make up for wide band operation and linear frequency modulation.

## II. FMCW Radar System

Fig. 1 shows the overall block diagram of the DDS and PLL-based FMCW Radar system, and Fig. 2 shows the realized DDS and PLL system. The DDS controls the reference clock of the C-band PLL system, and the frequency range of the DDS is 82.031250~83.203125 MHz. Commercially available DDSs, such as Analog Device 995x, supports internally high speed clock source by a built-in PLL which reduces system complexity and cost. The binary code, necessary to decide the sweep time and the bandwidth of the DDS, is programmed in the micro controller unit (MCU) Atmega128. The C-band VCO frequency (5.25 ~ 5.325 GHz) is divided by two 1/8 prescalers, and compared with the reference frequency of the DDS. X-band frequency, which is 10.5 ~ 10.65 GHz, is generated by using a frequency doubler after the VCO. In the receiver part, the intermediate frequency (IF) signals are received by two passive balanced mixers, and a simple 90 degree delay line at carrier frequency is used to sample the quadrature signal. After sampling of the signals, the ADC transfers the 24 (12 x 2) bits serial data to the DSP. The sampling frequency is 1 MHz, and the modulation time of the proposed FMCW radar is 270 us. For FFT operation, the DSP samples 256 data within frequency modulation time. The DSP used in the radar system is TMS320C6713B. It receives the data by the multi channel buffered serial port (McBSP) module, and supports 32 bits floating points operation. The complex programmable logic device (CPLD) between the ADC and the DSP controls timing delay for proper data transfer operation. Spectral centroid is applied in signal processing for range estimation to enhance range resolution [2]. The advantage of this technique is low computation load in that it simply calculates the spectral average point. However, addition of the null data, such as zero-padding, is necessary to increase range accuracy. Thus, total number of FFT operation is 1024.

## III. Experimental Results

### A. Direct Digital Synthesizer

The measured spectrum of the DDS (AD9954) is shown in Fig. 3. The reference clock frequency of the DDS is 40 MHz, and it is multiplied inside the DDS. For high speed operation, the clock speed of the DDS is 400 mega-samples per second (MSPS). The linear frequency modulation range is 82.03125~ 83.203125 MHz during up-chirping of 270 us and down-chirping of 270 us. The output power is about -9 dBm. This signal acts as a PLL reference signal as shown in Fig 1.

### B. Measured I/Q Signals

Fig. 4 (a) and (b) show the received IF, I and Q signals from 2 balanced mixers. The quadrature signal is required to suppress the image spectrum. The distance between the radar system and a target is 1.5 m. A slight increase of the frequencies is due to a feed cable for TX/RX antennas. These signals are sampled with the rate of 1 MHz through the ADC (Analog to digital convertor) DSP module. In Fig 4. (a) and (b), a change of the rectangular signal state indicates the start and stop of the frequency sweep, and the interrupt signal of the DSP to start sampling. The change low into high state means the frequency sweep start, or vice versa.

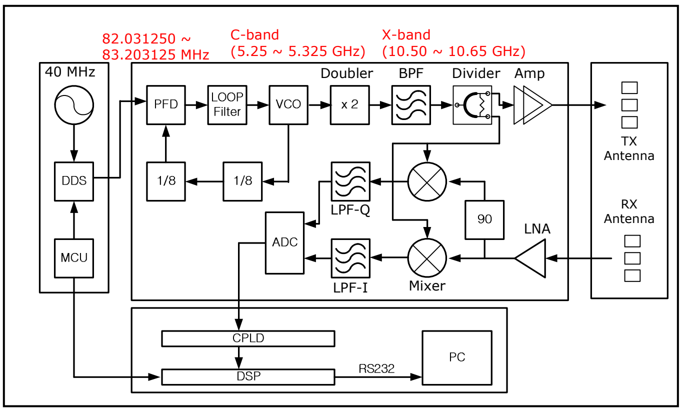
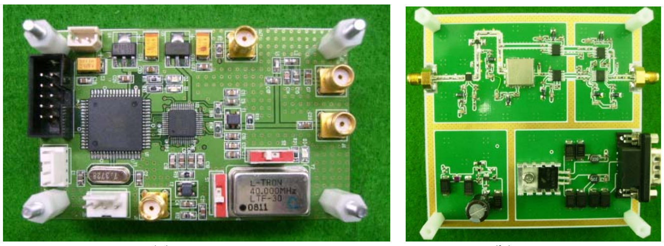



Figure 1. The block diagram of the X-band FMCW radar



(a) (b)

Figure 2. Baseband DDS (AD9954) and X-bamd PLL system

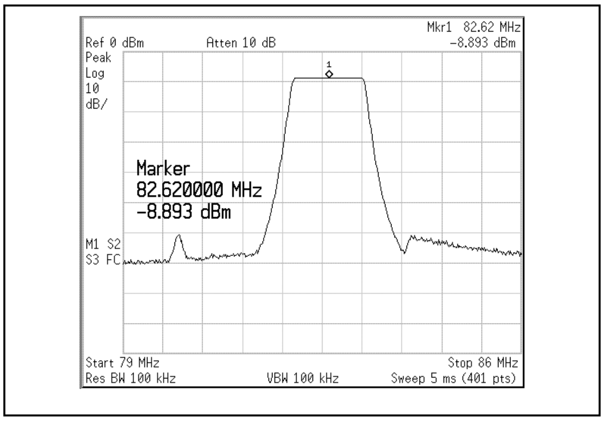



Figure 3. The spectrum of the DDS output (AD9954)

## IV. Conclusion

A DDS and PLL-based FMCW radar is designed and experimentally tested. The DDS is suitable for linear frequency modulation, and it is easily controlled by programming binary code. A VCO in PLL is useful to cover wide band operation. Thus, the combination of a DDS and a PLL is good for wide band linear modulation. The signal processing techniques to enhance the range resolution are zero-padding and spectral centroid processing. Its advantages are simple, fast, and accurate. The enhanced range resolution is less than 0.25m.

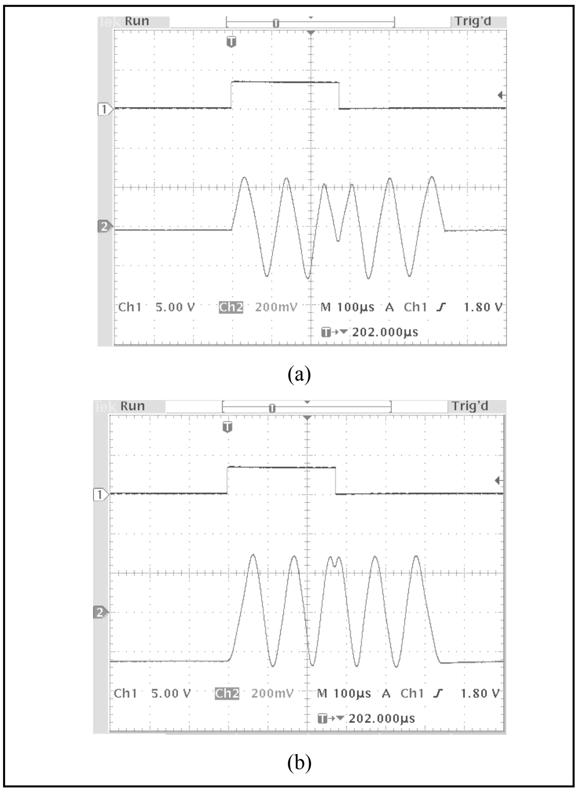



Figure 4. The measured in-phase and quadrature signals (a) I (b) Q

## References


[1] Merrill I. Skolnik, Introduction to Radar systems 3rd, McGRAW-HILL, 2001.

[2] Andreas Stelzer, "Resoultion Enhancement with Model-based Frequency Estimation Algorithms in Radar Signal Processing," *Subsurface Sensing Technologies and Application*s, Vol. 4, No. 3, pp 241-261, July 2003.