Waveform Generation Based on Complete DDS Tech.for RADARs

Raeshma. K.V
M.Tech
National Institute of Electronics and Information Technology (NIELIT)
Calicut-673601, Kerala, India

***Abstract*— This paper includes the project work done by the author for controlling a complete DDS through serial programming and thereby generating various waveforms like CW, LFM and SFCW, which are used in a variety of applications such as RADAR Exciter-Receiver, Signal generators, Function generators etc. The firmware for the same is implemented on FPGA.**

Keywords—DDS, CW, LFM, SFCW, FPGA

I. INTRODUCTION

Direct Digital Synthesis (DDS) is a technique used to generate frequency and phase tunable output signal from a fixed frequency clock using various digital data processing blocks. In this paper AD9914 DDS is used to generate various radio signals. The Implementation using AD9914 DDS is to generate various radio signals which can use in all signal/waveform related applications especially in RADAR applications. The main waveforms generated in this implementation work are CW, LFM and SFCW waveforms. SFCW and LFM have important role in RADAR applications.

II. WAVEFORMS- CW, LFM AND SFCW

A. Continuous Waveform(CW)

Continuous Waveform has a single frequency. Continuous wave Radar uses a combination of a pulse and CW waveform to get the range information of the intended target. Such Radar needs more power as the signal energy is low. They use Doppler Shift to find out target Range information.

B. Linear Frequency Modulated Waveform(LFM)

In an LFM waveform the frequency is modulated (increase or decrease) from one frequency (start frequency) to another frequency (stop frequency).They are also known as Chirp signals. By using an LFM waveforms one can attain more Bandwidth, energy and hence the needed power is less than that of CW Radar and also good resolution can attain.

C. Stepped Frequency Continuous Waveform(SFCW)

Stepped Frequency Continuous Waveform is discrete version of an LFM wave. Here, the waveform consists of a group of N coherent signals, whose frequencies are increased from signal-to-signal by a fixed frequency increment. Radars using SFCW can attain high range resolution. Using SFCW waveform at the receiver side the 3D image of the target can calculate as SFCW waveform contains many frequencies and hence in ground penetration radars and through wall radars, this waveform can be deployed.

III. DIRECT DIGITAL SYNTHESIZER

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DDS is a technique in which the fixed frequency clock called Reference clock is divided down by a tuning word (scaling factor) stored in a programmable register."Complete-DDS" is a DDS device which includes an integrated Digital to Analog Converter (DAC) and other digital functional blocks which can be added as per the requirement A simple DDS has digital functional blocks – address counter, programmable read only memory (PROM) and digital to analog converter is shown in Fig 1.PROM acts as a sine look up table. Digital form of information that corresponds to a complete sine wave is stored in the PROM. As the address counter starts, the information stored in each location of PROM can access at each step of counting and that is given to the DAC to generate a sine wave.

The output frequency of DDS depends upon two main factors. (i)The Reference clock frequency and (ii) the sine wave step size stored in the PROM. Tuning flexibility and high speed frequency hopping is the main problem in simple DDS.

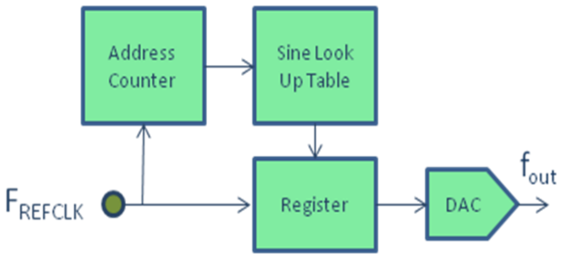

Fig 1. Simple Direct Digital Synthesizer

Combination of an N-bit variable modulus counter and phase register are used as a replacement for the address counter in advanced DDS to attain tuning flexibility and high speed. This architecture is shown in Fig 2, called Numerically Controlled Oscillator (NCO). Phase accumulator is the heart of DDS device. The carry function allows Phase accumulator to function as a phase wheel. Fig 3 shows a digital phase wheel. Each point on the phase wheel represents corresponding point on a sine wave cycle. As the wheel rotates, corresponding output sine wave is generated. The output from the phase accumulator is linear and hence to generate a sine wave or other waveform a phase to amplitude converter is used. It helps to get the amplitude information and then it is passed to the Digital to Analog Converter (DAC). The number of points in the phase wheel is determined by the resolution of phase accumulator (N).

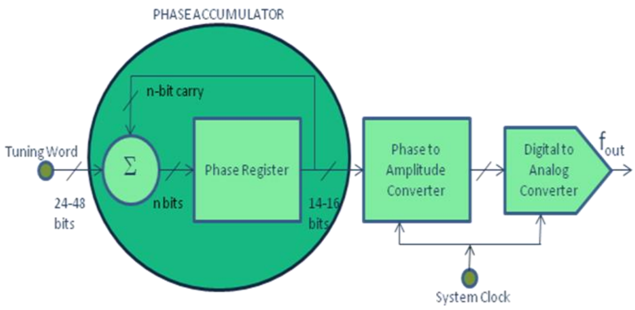

Fig 2. Frequency tunable DDS System

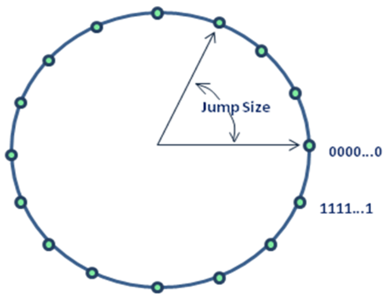

Fig 3. Digital Phase Wheel

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IV. IMPLEMENTATION

Here AD9914 DDS is used to generate the required wave forms – CW, LFM and SFCW. The device can be controlled either through serial programming or parallel programming. Here, serial programming is used in firmware development for controlling and generating the waveform. Corresponding code is written in VHDL language and is ported on FPGA which controls the device AD9914 DDS to generate the waveforms. Final output is taken from the AD9914 device, which is the DDS output. Fig 4 shows the Implementation set up.

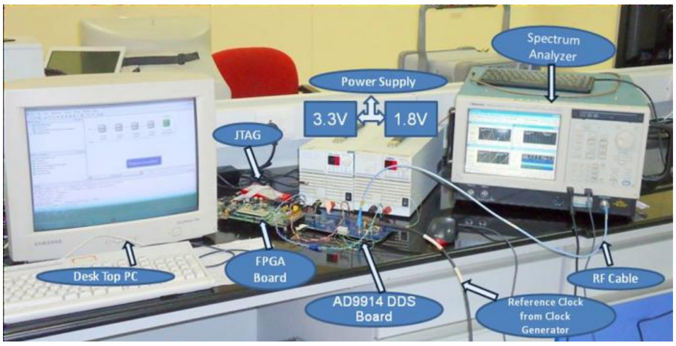

Fig 4. Implementation Setup

V. RESULTS

Implementation result is verified using a Frequency Spectrum Analyzer. Tektronix Real Time Spectrum Analyzer (RTSA) – RSA6114A RTSA is used for the verification. By using a RTSA, it is possible to measure frequency vs. time, amplitude vs. time, phase vs. time, power vs. time etc. The characteristics of waveform generated are given in figures from Fig 5 to Fig 9. Fig 5 is the Spectrum output of the Reference clock. Reference clock given is 3.5GHz, which is the maximum frequency that can be given to AD9914 DDS. Fig 6 shows the Implementation result of continuous waveform (CW) (single frequency) at a frequency of 200MHz and is shown by the marker in the DPX Spectrum plot. Fig 7(a) and (b) are the Implementation result of Linear Frequency Modulated waveform generation (LFM). Implementation is done for the following specification

- 500MHz to 600MHz range frequency
- Frequency step size of 2MHz
- Ramp Rate of 4us.

In DPX Spectrum, markers show each frequency is having 1.98MHz, and since ramp rate given is 4us 51 steps are there from 500MHz to 600MHz frequency range. From the second figure Fig 7(b), in frequency vs. time plot the markers show 4us between each frequency. Fig 8(a) and (b) are the Implementation result of Stepped Frequency Continuous Waveform (SFCW). Implementation is done for the following specification

- 500MHz to 600MHz range frequency
- Frequency step size of 12.5MHz
- Frequency increasing at a rate of 200us.

In DPX Spectrum, markers show each frequency having 12.54MHz, and since frequency increasing rate given is 200us, 9 steps are there from 500MHz to 600MHz frequency range. From the second figure Fig 8(b), in frequency vs. time plot the markers show 200.215us between each frequency. Fig 9 is the Spectrum of Continuous Waveform (CW) generated at 200MHz.The signal generated at 200MHz is called the carrier signal, which is marked in the figure. Other signals, called spurs, are shown by numbering from 1 to 11. These spurs also include harmonics of signal at 200MHz.Marker M1 shows a spur at -60.77dBm at 1.497GHz, and is the maximum of all other spurs in the given 2GHz range. The difference between the carrier level (which is the desired signal) and the maximum level of noise or harmonics of the carrier frequency is called spurious free dynamic range (SFDR).Higher SFDR value is preferable in radar applications. Here, SFDR obtained is -61.28dB, which is shown on the spectrum plot (ΔM1). This maximum spur is outside the required range of application.

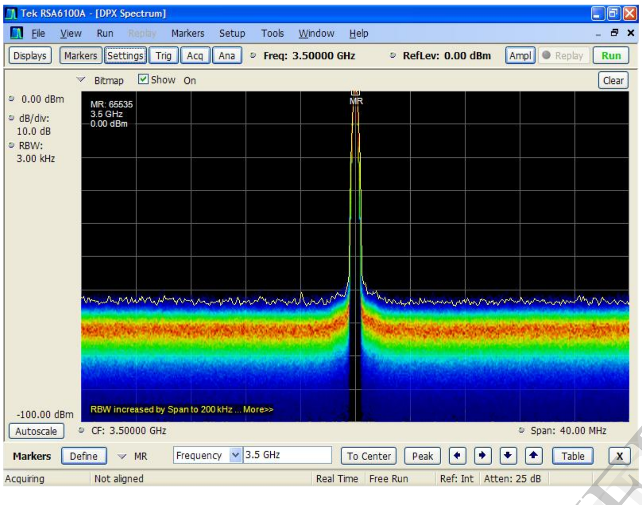

Fig 5. Reference Clock given to the DDS

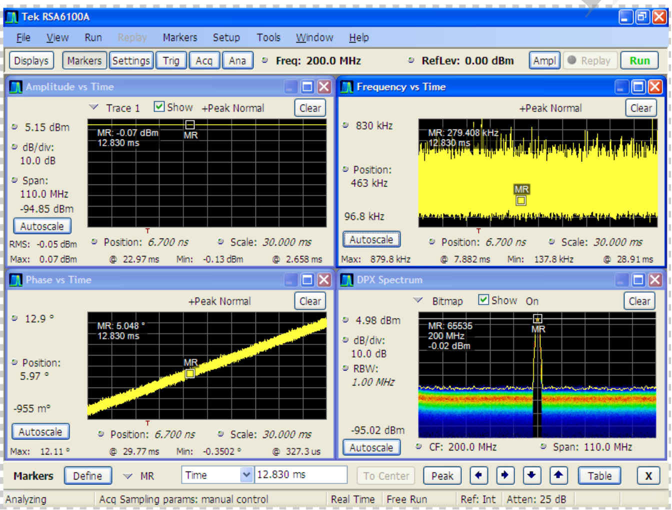

Fig 6. CW waveform output of AD9914 DDS

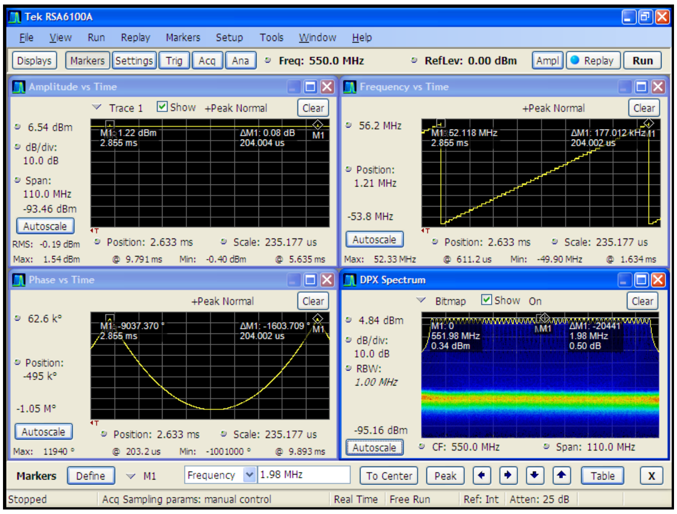

Fig 7. (a) LFM waveform output of AD9914 DDS

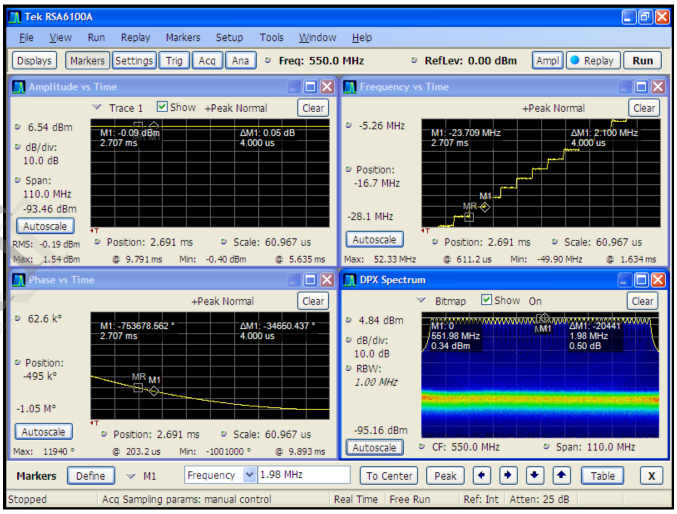

Fig 7. (b) LFM waveform output of AD9914 DDS

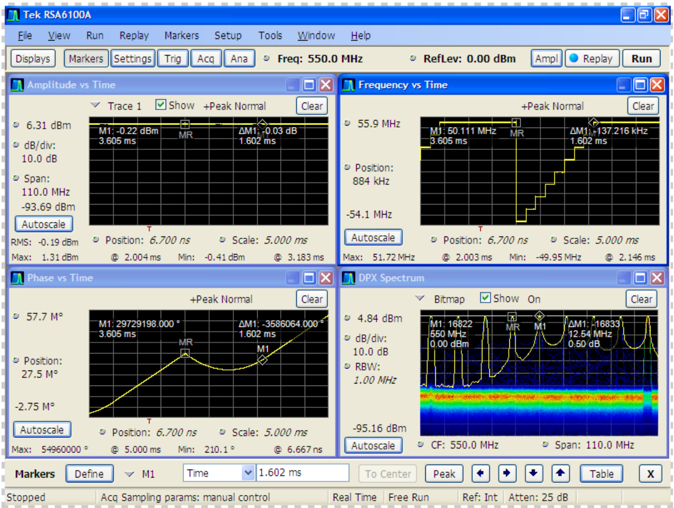

Fig 8. (a) SFCW waveform output of AD9914 DDS

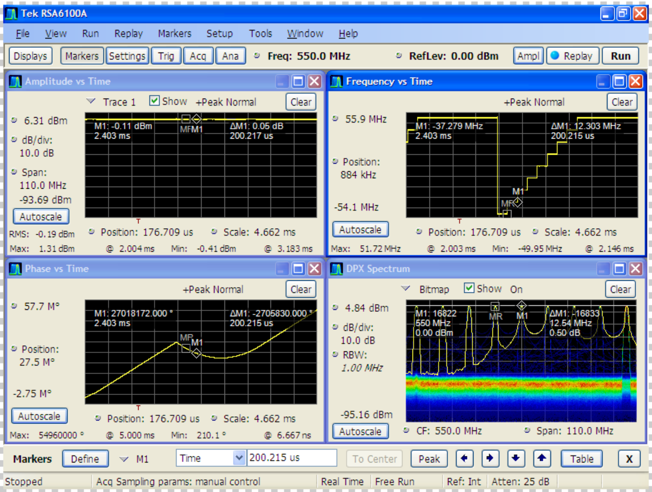

Fig 8. (b) SFCW waveform output of AD9914 DDS

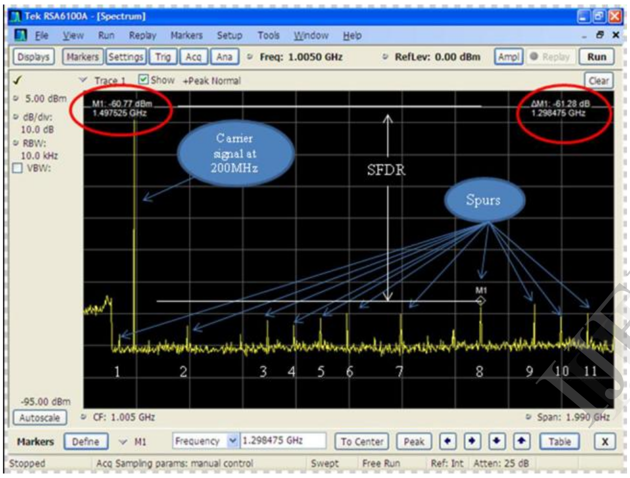

Fig 9. Spectrum of CW waveform

VI. CONCLUSION

In this paper the AD9914 DDS is used to generate various Waveforms. Using AD9914 DDS implementation we can generate LFM and SFCW waveforms having good range resolution. The waveforms which give high range resolution have high importance in radar applications. Hence LFM and SFCW waveforms can be deployed in radar field. Using AD9914 DDS it is also possible to generate waveforms having higher frequency without using multiplier and amplification. Because of this property the waveforms generated using the AD9914 DDS can be used in Through Wall Radars and Ground Penetrating Radars.

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