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Radar Exciter Signal Generation by Using DDS & Data Processing With Noise Level Estimation and Moments Estimation

Y.Yamini

Teaching Assistant, Department of Electronics and Communication, SVU College of Engineering, Tirupati, India

ABSTRACT: In Radar signals processing, general EM WAVES are sent to the atmosphere in order to analyze the atmosphere and weather. The quality of analysis mostly depends upon stability of our input RF wave. The pulsed RF signal 53MHZ is modulated internally in DDS with the help of control pulse, and frequency word which are controlled through Microcontroller. The required amplitude will be obtained by using proper amplifier. After receiving the echoes from the radar receiver, data processing steps have to be done to test the DDS and to get wind velocitieswith noise level estimation and moments estimation.

KEYWORDS: DDS, ATMEGA 32, FTW, CodeVisionAVR

I.INTRODUCTION

As per the standards of ITUthe rangeof radio frequency electromagnetic waves(radio waves) from 30 MHz to 300 MHz are the **Very high frequency** (**VHF**) .The operating frequency of Indian MST is 53MHz as the selection of frequency depends on the size of irregularities that are present in the atmosphere, upto the height of mesosphere. In order to find those movements of irregularities, the Bragg scattering reflection principle is used which says that a very high frequency (VHF) radio frequency signal is selected with wavelength (λ) which has to be double the size of irregularities. To satisfy Bragg principle a radio frequency of 53 MHz, whose λ is 5.66 meter which is almost double the size of 3 meter irregularities, is selected as operating frequency for Indian MST.

II. SYSTEM BLOCK DIAGRAM

The sub systems of pilot active array radar are exciter,TR modules ,RF distribution network, Antennaarray, RADAR controller, Digital receiver

A)EXCITER

Exciter is the heart of the radar system. Direct Digital Synthesizer (DDS) based system is used in exciter to generate the required RF signals for radar operation. It has a highly stable reference master oscillator, which generates 10 MHz clock

B)TR MODULE

TR stands for transmit and receive modules. There are 133 TR modules located in the field, each feeding one antenna element. The TR module receives a reference trigger pulse called as IPP marker and 16 MHz clock from the radar controller for the synchronization with radar controller. TR modules also receive radar operational parameters from the radar controller via optical Ethernet interface. All the timing and control signals required for operation are generated within the TR module with respect to IPP marker pulse.

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C)ANTENNA ARRAY

The antenna array is divided into seven segments, each with 19 elements, and entire array is operated in Doppler beam swinging (DBS) mode. This network receives the 53 MHz pulse modulated from the Exciter. It splits them into seven. Each of these signals is given to one T/R switch and Transmit port of the T/R switch is brought as the output. Thus there will be seven transmit outputs, from this unit. The receive port of the T/R switch is given to an SPDT switch. One of the SPDT ports will go as the output from this unit. Other port will be connected to a 7:1 combiner

.

Fig.TR module and 133element Pilot active array antennas.

D) RADAR CONTROLLER

Radar operates under the instructions from the Radar Controller (RC), which executes an experiment according to the data given in the form of an Experiment Specification File (ESF) given by the operator.

E)DIGITAL RECEIVER

The received signals after being amplified and processed in the back end receiver units are given to this Digital Receiver unit.

III .DDS OVERVIEW

Direct Digital Synthesis (DDS) is a procedure of digital data processing blocks as a way to generate a frequency and phase tunable output signal that can be referenced to a fixed frequency clock source. In quintessence, the reference clock frequency is divided down in DDS architecture by the scaling factor set forwards in a programmable binary tuning word. The tuning word is usually 24-48 bits long with the purpose that enables a DDS realization to afford advanced output frequency tuning resolution. The integration of a cost, high-performance, D/A converter and DDS architecture onto a particular chip enabled this technology to target a wider range of applications and provide in many cases a striking a different to analog based PLL synthesizers. For numerous applications, the DDS solution holds some distinct advantages over the equivalent agile analog frequency synthesizer employing PLL circuitry.

A) DESCRIPTION OF DDS SYSTEM

In a simple way, a DDS can be implemented using a precision reference clock, an address counter, a Programmable Read Only Memory (PROM), and a D/A converter.

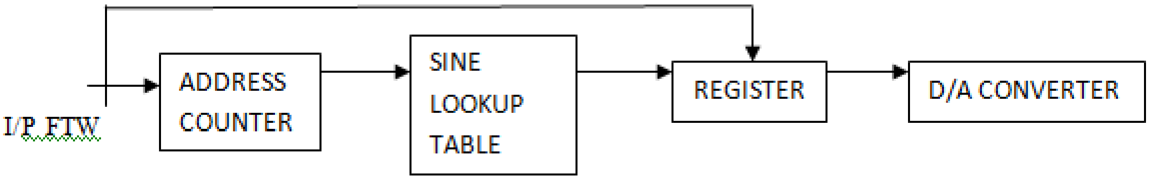
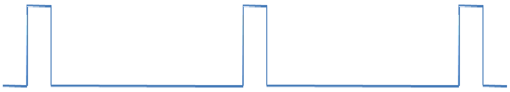


Fig. Simple DDS system

The digital amplitude data that corresponds to a complete cycle of a sine wave is stored in the sine lookup table shown in figure which is PROM. The address counter steps all the way through and accesses each of the PROM's memory locations and the correspondent sine amplitude words are obtainable to a high speed D/A converter.
The output frequency for DDS implementation is dependent on
1) The frequency of the reference clock and
2) The frequency tuning word. $FTW = \frac{(F_{OUT} * 2^{N})}{REFCLK}$
Changes to the value of FTW in the DDS architecture outcome in immediate and phase continuous changes in the output frequency. In practical, the FTW value is overloaded into register of DDS device.

$F_{Resolution}$ = REFCLK /2^N

After sending the FTW into the DDS the output that we get is 53 MHz continuous radio frequency signal with tuning frequency resolution of 0.0372Hz which is used for the transmitting the signal at radar Exciter. To send the FTW we are using microcontroller ATMEGA32 and a programmer is used as a interfacing unit in between PC and microcontroller. After getting continuous wave of 53MHz from DDS we need to do pulse modulation to obtain RF signal of 8micro seconds ON time and 125 micro seconds OFF time



ON TIME OFF TIME ON TIME OFF TIME
8µsec 125µsec 8µsec 125µsec

Fig .Output RF signal with ON and OFF time

B)SOFTWARE DESCRIPTION -CodeVisionAVR

CodeVisionAVR is the software used to program microcontrollers, in 2006 Atmel released microcontrollers based on the new, 32 bit, AVR32 architecture. They include SIMD and DSP instructions, along with other audio and video processing features. This 32-bit family of devices is intended to compete with the ARM based processors.

IV. OBSERVATIONS AND RESULT

After the program is loaded into the device the output at the DAC we will get is the continuous sine waveform of 53MHz as shown in figure 3.9, and it is pulse modulated by using ADG 918 a SPDT switch. Finally the output of SPDT switch is the radio frequency pulsed waveform, which is having predefined ON and OFF times. In the radar experiment specification file, it is operating with 8µ seconds of ON time and 125µ seconds of off time. The required RF signal is generated using DDS as shown below in figure is used at the radar exciter.

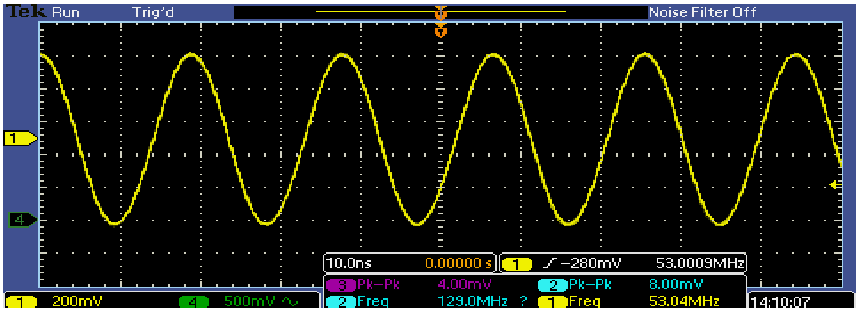


Fig. Continuous RF signal of 53MHz sine wave

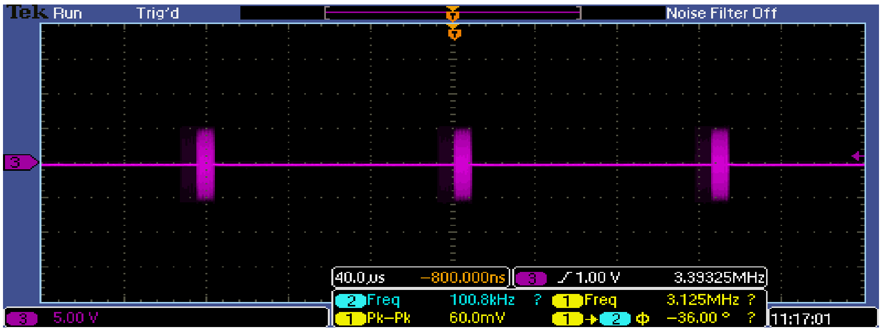


Fig.pulsed RF signal of 53MHz sine wave with ON and OFF time

The Figure shows the RF pulses that are transmitted at transmitter. To test the DDS the scattered echoes from the atmosphere are received using digital receiver. These received echoes have to be processed using data processing steps to derive wind velocities in different directions. The purpose of radar signal processing is to extract desired data from the radar backscattered echoes. The accuracy of the data available from a radar is also limited by noise introduced by the receiver, echoes from targets of no interest also known as clutter, and interference generated. So, signal processing of back scattered data is used to enhance the signal, suppress the unwanted data and noise and to extract the desired parameters.

V. DATA PROCESSING STEPS

Radar data has to be processed in step wise manner, the figure shows the functional block diagram of various processing stages involved in the extraction and estimation of atmospheric parameters.

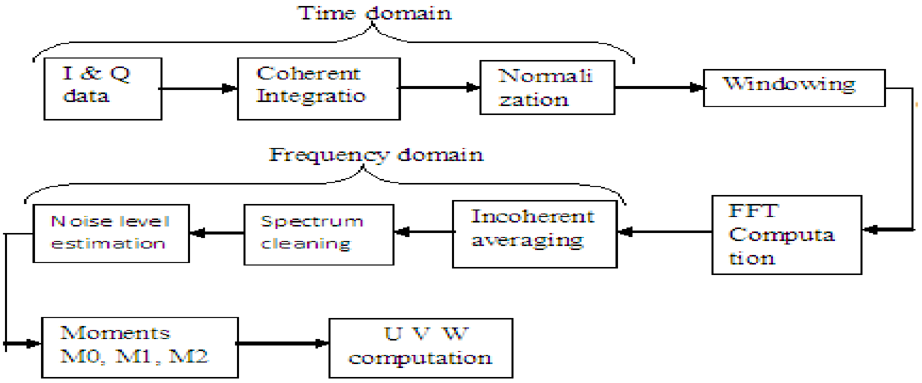


Fig. Data processing steps

The complex time series of I and Q data are collected as echoes using the Quadrature detector digital receiver. The data will be in the form of matrix of size [75×256], which indicates that 75 range bins specifies the height, and 256 FFT points resolution specifies the frequency shift or Doppler shift for each range bin. Each range bin data gives the information about 150 meters of height.Then process of coherent integration is carried out on total data in the receiver itself. Normalization is the first step that has to be done in offline data processing steps. FFT computation is to convert time domain data into frequency domain data and proper window function on the data while computing FFT. After FFT power spectrum is recorded by doing complex multiplication of obtained FFT data. In the power spectrum the Doppler spectra are recorded. After getting power spectrum Incoherent averaging is carried out to improve the detectability of Doppler shift.

A)COHERENT INTEGRATION

The Coherent Integration will reduce the data volume as well as extraction of maximum Doppler content in the data, and it improves the gain by the factor of number of inter pulse periods that we are integrating. The detected Quadrature signals are usually integrated for many pulses to improve the signaltonoiseratio.This digital signal processing is called coherent integration.

$$Y(n) = x(n) + v(n) for n = 0,1,2,\ldots..N-1$$

Figure illustrates the coherent integration process for a simulated weak sinusoid signal combined with strong random noise. Coherent integration is achieved by adding the complex digital data samples for a pre defined number (NCI) which is of 256.

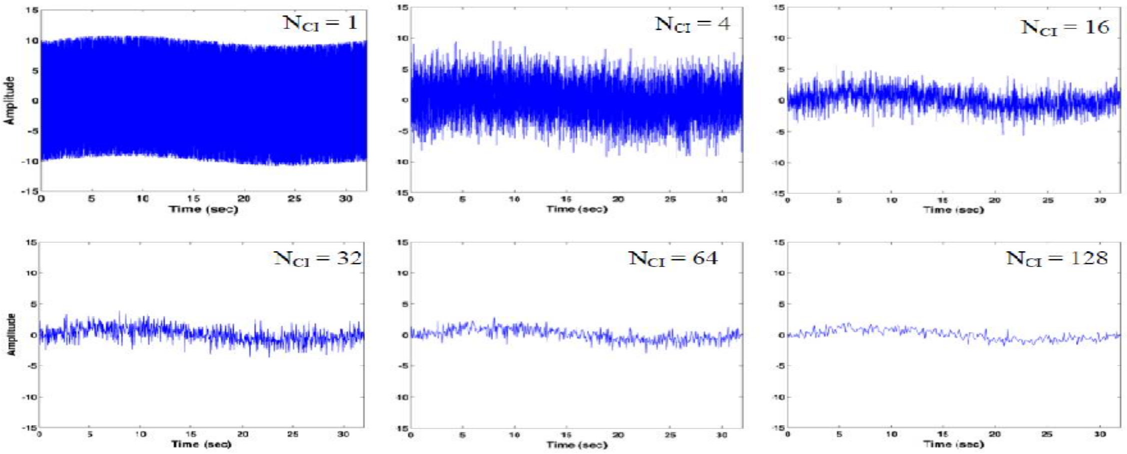


Fig.Coherent integration for different number of integrations

B)NORMALIZATION

The input data is to be normalized by applying a scaling factor S in the expression corresponding to the operation done on it. This will reduce the chance of data overflowing due to any other succeeding operation. The process is carried out for every range bin is known as normalization.Then the Normalization factor S is

$$s = \frac{\Delta v}{w * M * N}$$

C)WINDOWING

Windowing is a technique for shortening the signal to a finite number of sample points. It is also used to reduce the edge effects that results in spectral leakage in the FFT Spectrum.

We applied flattop window function expression (4.4) on the data. It is a partially negative valued in the frequency domain. This is choosenbecause, they have very low amplitude measurement error.

$$w(n) = a_0 - a_1 \cos\left(\frac{2\pi n}{N-1}\right) + a_2 \cos\left(\frac{4\pi n}{N-1}\right) - a_3 \cos\left(\frac{6\pi n}{N-1}\right) + a_4 \cos\left(\frac{8\pi n}{N-1}\right) \quad (4.4)$$

Where $a_0 = 1, a_1 = 1.93, a_2 = 1.29, a_3 = 0.388, a_4 = 0.028$

D)FOURIER ANALYSIS

Spectral analysis is connected with characterizing the frequency of a signal. A large number of spectral analysis techniques are available which can be broadly classified in to non-parametric or Fourier analysis based method.

E)POWER SPECTRUM

Power spectrum is calculated from the calculated FFT, complex spectrum P_i isin expression. The signal in frequency domain is multiplied with its complex signal to get power spectrum. For i= 0,1,…..N-1

$$P_i = {X_i}^2 + {Y_i}^2$$

F)INCOHERENT INTEGRATION

Incoherent integration is the averaging of the power spectrum by number of times. The advantage is that it improves the detectability of the Doppler spectrum. Generally averaging four power spectrums as mentioned in ESF.

G)POWER SPECTRUM CLEANING

Due to various reasons the radar echoes may get corrupted by ground clutter, system bias, interference, image formation etc. The data is to be cleaned before going for analysis from these problems.

The basic operation carried out here is,

$P_{n/2} = \frac{P_{\frac{N}{2}+1} + P_{\frac{N}{2}-1}}{2} \frac{\mathrm{N}}{2}$ corresponds to zeroth frequency

H) NOISE LEVEL ESTIMATION

The extraction of zeroth, first and second moments is the key reason for doing all the signal processing and there by finding out the various atmospheric and turbulence parameters in the region of radar soundingThere are many methods adapted to find out the noise level estimation. Basically all methods are statistical approximation to the near values. The method implemented here is based on the variance decided by a threshold criterion, Hildebrand and Sekhon. This method makes use of the observed Doppler spectrum and of the physical properties of white noise, it does not involve knowledge of the noise level of the radar instrument system. This method is now widely used in atmospheric radar noise threshold estimation and removal.The noise level threshold shall be estimated for every range bin to the maximum level L.

Step 1

Reorder the spectrum {P_i, i = 0,1,…… N-1} in ascending order. Where N denotes number of FFT points. Let this sequence be written as {A_i, i = 0,1,….. N-1} and $A_i < A_j$ for i < j.

Step 2 Compute

$$P_n = \sum_{i=0}^{n} \frac{A_i}{(n+i)}$$

Where n = 0 to NFFT

$$Q_n = \sum_{i=0}^{n} \frac{{A_i}^2}{(n+1)} - {P_n}^2$$

$$\text{and if } Q_n > 0, R_n = \frac{{P_n}^2}{(Q_n * M)}$$

$$\text{for} \quad n = 1,2,\ldots,N$$

Then noise level is estimated for each range bin in the power spectrum.

Step 3

Noise level (L) = P_k where k = minimum of 1 to n

I)MOMENTS ESTIMATION

The extraction of zeroth, first and second moments is the key reason for doing all the signal processing and there by finding out the various atmospheric and turbulence parameters in the region of radar sounding [7]. The basic steps involved in the estimation of moments, are given below.

The moments are computed as

Step 1

$$M_0 = \sum_{i=0}^{n} P_i$$

Step 2

$$M_1 = \frac{1}{M_0} \sum_{i=0}^{n} P_i \, f_i \qquad \text{Where } f_i = \frac{(i - \frac{N}{2})}{IPP * n * N}$$

Step 3

$$M_2 = \frac{1}{M_0} \sum_{i=0}^{n} P_i (f_i - M_1)^2$$

Step 4

$$\text{Signal to Noise Ratio SNR} = 10 \log \left[\frac{M_0}{(N * L)}\right] \text{dB}$$

Using expressions signal to noise ratio is computed. Using the same procedure moments, SNR are estimated for five power spectrums which are in the directions of East, West, Zenith, North and south.

VI. STIMULATION RESULT

UVW Computation

The prime objective of atmospheric radar is to obtain the vector wind velocity. Velocity measured by a radar with the Doppler technique is a line of sight velocity, which is the projection of velocity vector in the radial direction. The DBS method shown in figure 4.3 uses a minimum of three radar beam orientations (Vertical, East-West, and North-South) to derive the three components of the wind vector (Vertical, Zonal and Meriodional).

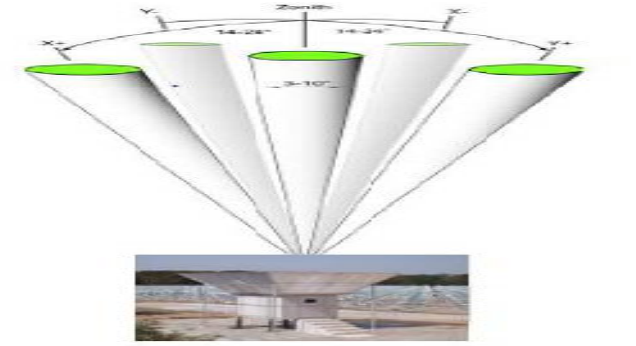


Fig. Doppler Beam swinging beam formation

VII. CONCLUSION AND FUTURE SCOPE

In this work the signal which is required at exciter unit of radar is generated using DDS technology. In this approach we configured 32 bit frequency tuning word, which offers with tuning frequency resolution of 0.0372Hz. After transmitting the RF signal the echoes are received and then echoes are processed using data or echo processing steps to derive the wind velocities.This work has been successfully developed in CodeVisionAVR2.1 software, and Data processing is done by using MATLAB-R2010a.In the present day scenario, due to fast technology in DDS systems the frequency tuning word which is of 48 bits, length is programmed using different microcontroller which will improve the frequency resolution of the signals.

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