Data Processing For Pilot Active Array Radar

A. Thriveni [1], S. Swarnalatha [2] , P. Srinivasulu [3]
[1]Department of ECE,SVU college of Engineering,Tirupati,Andhra Pradesh,India
[2]Associate professor Department of ECE,SVU college of Engineering,Tirupati,Andhra padesh,India
[3]Scientist Engineer-SG,NARL,Gadanki

Abstract

This paper describes an algorithm to process the data obtained from pilot active array radar developed at National Atmospheric Research Laboratory (NARL). The algorithms developed provides the wind information to study the dynamics of different layers of the atmosphere. The data obtained from the pilot active array radar is processed, to derive the atmospheric parameters like temperature, pressure, wind velocity etc. The derived winds are validated by comparing the winds obtained from the GPS sonde at NARL.

Key words: Active array radar, wind vector

I. Introduction

Pilot active array radar is developed at NARL, Gadanki. The specifications of the radar are given in Table 1. It is a Pulsed Doppler Radar which operates at 53 MHz. The triangular grid antenna array consists of 133 elements arranged in seven groups, each group with 19 elements. This radar operates in Doppler Beam Swinging (DBS) mode, which employs two off vertical beams in orthogonal directions and one vertical beam (zenith) in order to estimate the three dimensional wind vector.

IJERT

Pilot active array radar measures the echoes retuned from the back scattered electromagnetic wave due to tiny changes of the refractive index of air. In order to extract the efficient information from received echo signal, various signal processing techniques are applied on that received radar echo.

Pilot Active Radar signal processing includes sampling, decoding, coherent integration, DC removal, power spectrum computation and incoherent integration. For atmospheric radar these extracted parameters are referred as base parameters. Fundamental base parameters are Mean Doppler, power, Radial velocity and spectrum width.The drawback with this type of signal processing is that it is assumed that returned echo consists of a) signal that is owing to atmospheric scattering process and b) noise (different sources, cosmic noise, thermal noise etc).

The most serious problem is back scattered echo may be interfered with the echoes from the ground surrounding the radar.This leads to incorrect estimate of base parameters following signal processing applied to the contaminated signal

Data processing on the other hand, takes up where the signal processing leaves off.Data processing algorithms further process the signal in order to convey the information that is of use to the radar user .In this paper for Pilot Active array radar Data processing algorithms is applied in time domain.Data processing includes smoothing,noise level estimation, removal of ground clutter, moments calculation, UVW (wind vector) computation.

Table-1:Specifications of RADAR

	Parameter	**Specification**
1	Peak power (P_t)	1024 kW
2	Aperture (A)	1.69×10^4 m^2
3	Illumination efficiency (η_a)	100 %
4	Receive path losses (α_r)	2.5 dB (0.56)
5	Transmit path losses (α_t)	0.5 dB (0.89)
6	Pulse width (τ)	0.5 – 100 μs
7	Duty ratio	8.0 %
8	No of bauds (N_B)	200

II. Signal processing

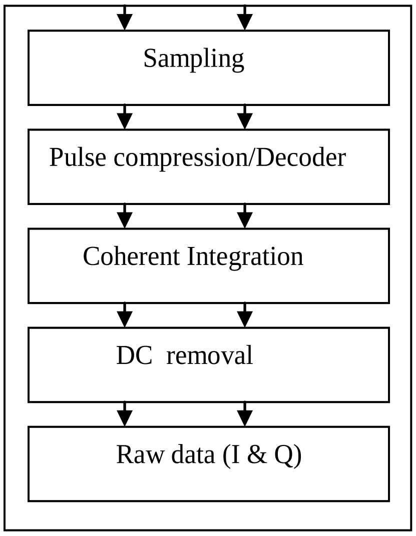


Figure-1.Steps of signal processing

Sophisticated signal processing techniques are required to extract the wind vector information burried in the received back scattered echo. The inphase (I) and quadrature phase (Q) components of the received echo, obtained from the radar receiver, are digitised and subjected for further processing.

(i).Pulse compression / Decoder: Pulse coding technique is required to have maximum height coverage with better range resolution. Pulse compression is achieved by transmitting pulses with bi-phase coding. Complementary codes are used for this. In the decoding process autocorrelation operation is performed on the received signal with the code used for transmitting pulse and adding the ACFs resulting.

(ii).Coherent integration: The time series data are averaged for N consecutive pulses[1],which results in reduction of the data volume and enhancement of gain by a factor of N.The coherent integration is a digital low pass filter provided with rectangular window in time domain. Sample I and Q data is shown in the Figure-2. It can be seen that there is a DC value in these signals.

(iii).DC removal: Any DC offset value is eliminated by subtracting the respecticve average value from the complex I and Q signals. The data at this stage is referred to as raw data.

IJERT

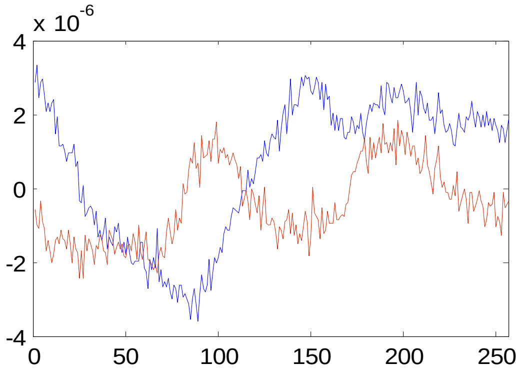


Figure-2. Inphase component (blue) and quadrature component (brown).

III. Data processing

(i).Power spectrum computation: Spectral analysis characterizes the frequency content of the signal. Sequence of data processing steps is shown in Figure-3. Complex time series data is converted into frequency domain by subjecting the to complex fourier transform. FFT algorithm is used to implement fourier Transform.Power spectrum can be calculated from the complex spectrum.

(ii).Incoherent integration: Succesive spectras are averaged to accomplish better signal detectability and SNR improvement. This is called incoherent averaging

(iii)Interpolation: Clutter, if present, can be removed in the frequency domain by considering the significant number of points on either side of the zero Doppler and the points are replaced by the average value of the two points bracketing the area being removed and by interpolating[5].This process is dynamic for each range bin.Figure4 illustrates the clutter removal in the frequency domain for a single rangebin.

(iii)Noise level estimation: Mean noise level for each range bin is estimated using the method explained by Hildebrand-Sekhon [3]. The estimated mean noise level is subtracted from the power spectra and the data is further processed to **compute moments** using the formulae given below. Zeroth, first and second moment represents the signal power, mean Doppler frequency and Doppler width respectively. An algorithm called adjacent **peak picking** is used to improve the moment estimation in weak SNR situations.

Zeroth moment or total power $M_0 = \sum_{i=0}^{N-1} \tilde{p}_i$

First moment or mean Doppler

$$M_1 = \frac{1}{M_0} \sum_{i=0}^{N-1} \tilde{p}_i f_i$$

Second moment or variance $M_2 = \frac{1}{M_0} \sum_{i=0}^{N-1} \tilde{p}_i (f_i - M_i)^2$

Doppler width (full) = $2\sqrt{M_2}$ Hz

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

UVW computation: Radial velocities obtained, from three or five beams is used to compute U (zonal), V (meridional) and W (vertical) components of the wind vector, by solving the following equation. Vx, Vy and Vz correspond to U, V and W repectively
Where i is the beam number, VDi is the radial velocity of that beam, ɵx, ɵy, ɵz are the angles that the beam makes with x, y and z axis.

$$\begin{bmatrix} V_x \\ V_y \\ V_z \end{bmatrix} = \begin{bmatrix} \sum_i \cos^2\theta xi & \sum_i \cos\theta xi \cos\theta yi & \sum_i \cos\theta xi \cos\theta zi \\ \sum_i \cos\theta xi \cos\theta yi & \sum_i \cos^2\theta yi & \sum_i \cos\theta yi \cos\theta zi \\ \sum_i \cos\theta xi \cos\theta zi & \sum_i \cos\theta yi \cos\theta zi & \sum_i \cos^2\theta zi \end{bmatrix}^{-1} * \begin{bmatrix} V_{Di\cos\theta Xi} \\ V_{Di\cos\theta Yi} \\ V_{Di\cos\theta Zi} \end{bmatrix}$$

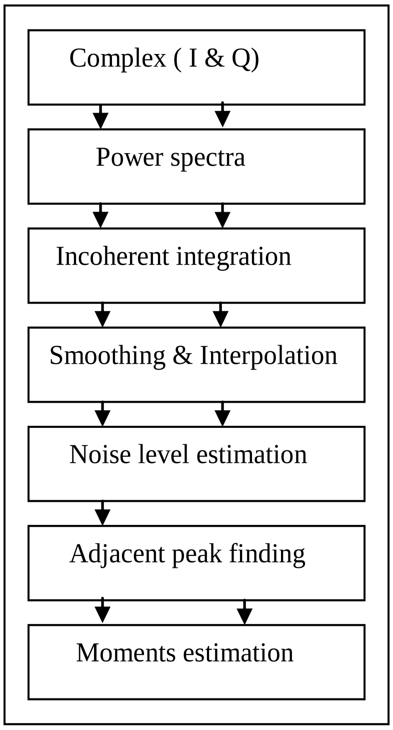


Figure- 3.Steps of data processsing

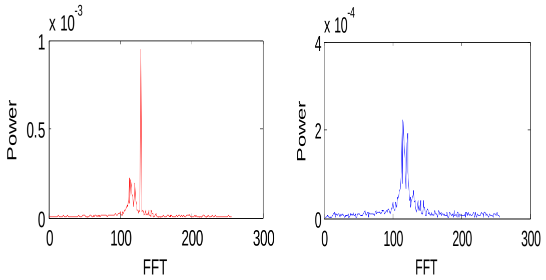


Figure-4.Power spectra with clutter(red) and removal of clutter (blue).

IV. Results

Data is collected from the radar on 1st September 2012.Five beams are operated namely zenith beam and four off vertical beams, tilted 15^0 from zenith towards east, west, north and south. Parameters of the experiment are given in the Table-2.

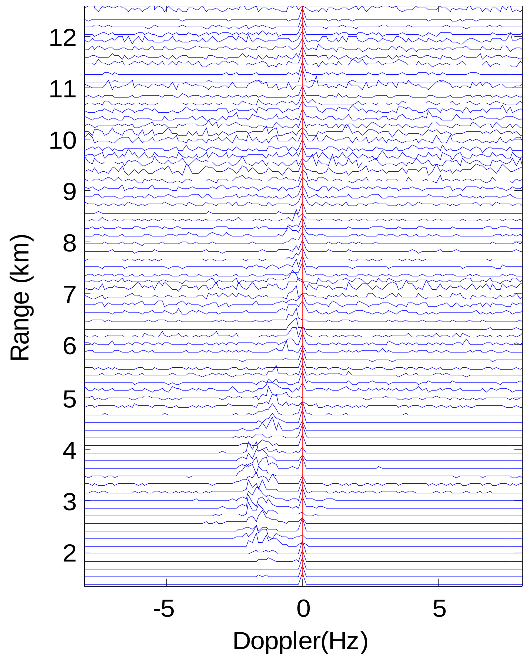
Table-2: experimental specifications

	Parameter	Range		Parameter	Range
1	Pulse width	8 µsec	6	FFT	256
2	IPP	125 µsec	7	Coherent integrations	256
3	codelength	8	8	Incoherent integrations	4
4	Baudlength	1 µsec	9	Mode of operations	DBS
5	Beams	5	10	Range resolution	150m

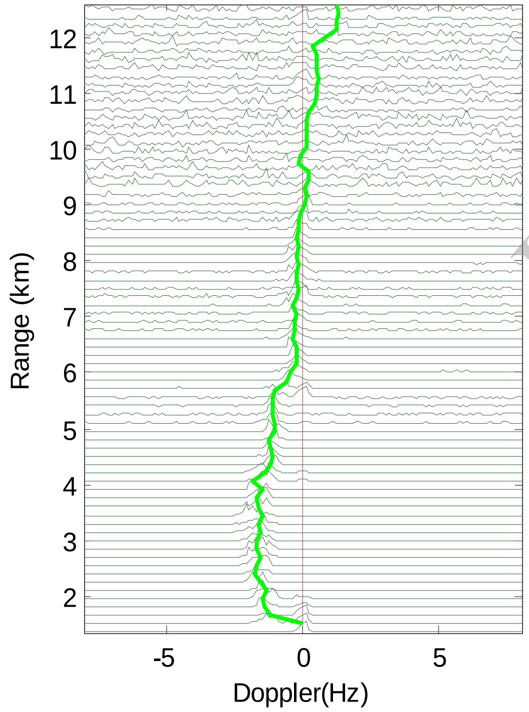
IJERT

The obtained data is processed with the algorithms explained above.Figure-5 (a) and (b) shows the original and processed range doppler spectra for east beam . It can be observed that the DC and clutter present in the orginal spectra is removed in the processed spectra and the data can be seen continuously upto about 9-10 km. (green line shows the mean doppler frequency estimated)

Moments computed for the same beam shown in Figure-6. U and V computed are compared with collocated GPS sonde as shown in Figure-7. A good agreement can be seen between the two.



(a)Before



(b)After

Figure 5.(a) shows before data processing (a) and figure 5.(b) shows after data processing , the green line shows the mean doppler

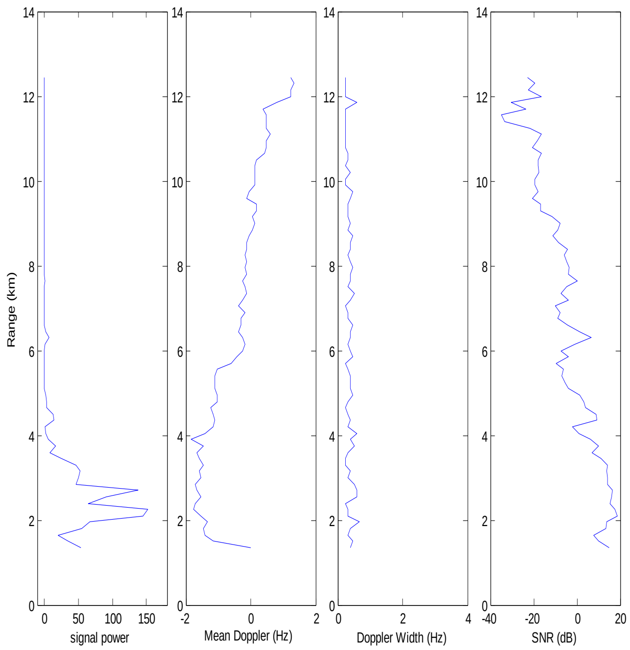


Figure6.Moments(Signalpower,Meandoppler,Dopplerwidth,SNR)

IJERT

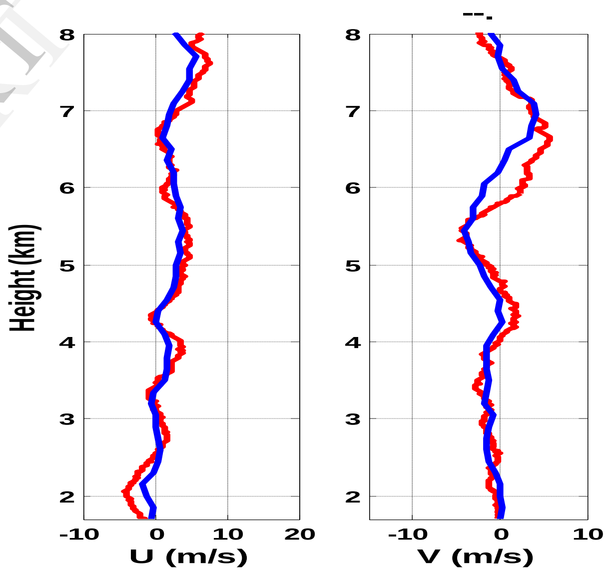


Figure 7.(Red is Gps and Blue is Radar)

REFERENCES

[1].Strautch., R.G., D.A. Merritt, K.P. Moran, K.B.Earnshaw and D.W. van de kamp, “The Colorado wind-profiling nework”, *J. Atmos. Oceanic Technol.*, volume 1, 37-49, 1984.

[2] .May.P.T., and Richard G. Strauch, 1998: “Reducing the Ground Clutter on Wind Profiler Velocity Measurements”, *J. Atmos. Oceanic Technol.*, volume **15**, 579-586.

[3].Hildebrand, P.H and R. S. Sekhon, 1974: “Objective determination of the Noise level in Doppler spectra”, *J. Appl. Met*, volume **13**, 808-811

[4]Woodman, R. F., 1985: “Spectral moments estimation in MST radars”, *Radio Sci.*, volume 20, 1185–1195.

[5] Barth,M.F., R.B.Chadwick, D.W.van de Kamp, 1994: “Data processing algorithms used by NOAA‟s wind profiler demonstration network”, *Ann.Geophysicae*, volume **12**, 518-528.

IJERT