Calibration of DWR-Receiver for a constant Bias Of Differential Parameters Over Dynamic Range

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Abstract:-
Calibration of Receiver for Polarimetric Doppler Weather Radar to obtain a constant bias value over the dynamic range which helps in increased accuracy of estimation

Key words:-Calibration, dynamic range, polarimetric

INTRODUCTION

Doppler Weather radar (DWR) System is meant for long-range weather surveillance and is capable of detecting and estimating the parameters of cyclone and other severe weather conditions. DWR is an important sensor for operations and research in the atmospheric and meteorological sciences and presently is an indispensable Sensor in the measurement and forecasting of atmospheric phenomena. DWR is globally used for forecasting storms, cyclones and other severe weather conditions, so that necessary preventive steps can be initiated to alleviate the impact of natural disasters on life and property of millions of people.

Weather Radars basically operate by extracting the phase and amplitude information contained in the return echoes. It has been established that significant information is contained in the polarization state of the scattered wave which supports better product derivation particularly rain estimation. Polarimetric weather radars are used for improved estimation of the rainfall and for characterizing the hydrometeors. Since polarimetric radars measures intensities and phases for two polarized waves in two different directions, they provide additional data about size distribution, shape, orientation, and type of hydrometeors, compared to conventional radar. Significant improvements in rainfall estimation, precipitation classification, data quality and weather hazard detection are possible using polarized radar .

Dual polarization radars transmit and receive both horizontal and vertical radio waves thereby being able to measure both the horizontal and vertical dimensions of the precipitation particles

Dual polarization technology will allow forecasters to better discern the size, shape and variety of not only precipitation particles, but non precipitation particles as well. Forecasters will even be able to better distinguish between precipitation type (i.e., hail, rain, snow)

IMPORTANT PARAMETERS OF DUAL POLARIMETRIC RADAR

Zdr-(Differential Reflectivity): Zdr is the ratio of the backscattered horizontal to vertical power. Zdr values typically range from -3 to +8 dB. Zdr value close to zero represent spherical hydrometers such as hail while larger values are likely large, more oblate rain drops

ρ_{hv}-(CorrelationCoefficient): The correlation between the reflected horizontal and vertical power returns. ρ_{hv} is measured on a scale from 0 to 1 with values above 0.96-0.98 indicating hydrometeors with constant size, shape, orientation and/or phase and values below 0.96 indicating a mixture of these within sampled volume.

Φ_{dp}-(Differential phase): This is the measured difference in phase shift between horizontal and vertical polarized pulses. When the range-integrated horizontal phase shift is larger than vertical then Φ_{dp} is positive. Φ_{dp} is largely immune to attenuation effects of hail and other more spherical scatters since these targets produce approximately the same phase shift in both the horizontal and vertical.

K_{dp}-(Specific Differential Phase): K_{dp} is the range derivative of Φ_{dp}, and therefore is not directly measured by the radar. Increases in K_{dp}(high values are 2°/Km), imply the presence of significant amount of liquid water and/or highly oriented (i.e., oblate) shapes. K_{dp} is very good estimator for rainfall because it is also immune to attenuation.

OBJECTIVE

The important parameters in polarimetric operation of Doppler weather radars are 'Differential reflectivity (Zdr)' and 'Differential phase (Φdp)'. The system will have inherent Zdr and Φdp values which are considered as bias values and are to be compensated when estimation is done using received echoes. The objective is to obtain a constant bias value for these parameters over the dynamic range

CONFIGURATION

The Receiver of Doppler Weather Radar consists of several sub-modules like Coherent signal Generator, RF & IF receivers and Simulator. It is a ***'Dual channel polarimetric receiver'***.

Fig.1 shows the block diagram of Receiver showing the interconnectivity between different sub-modules.

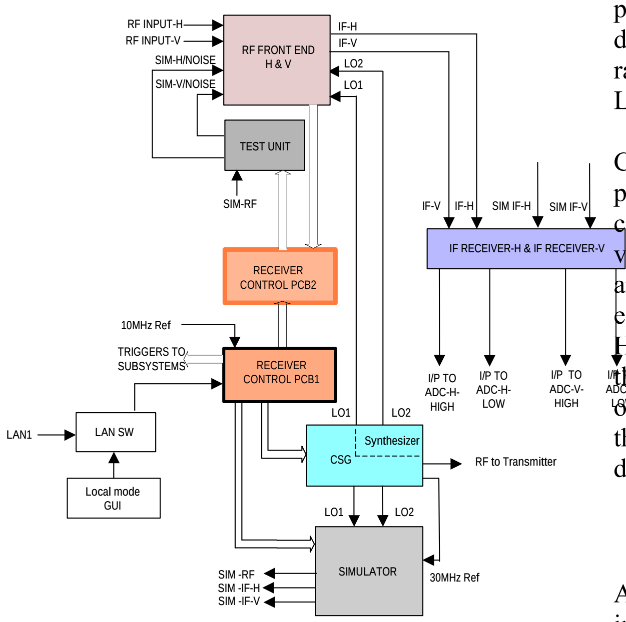

Fig1 Block diagram of Receiver

RF Front end receives the C-Band signal from the antenna. A directional coupler at the input facilitates the injection of RF test signal/Noise signal into the LNA for testing purpose. Simultaneous injection of received signal from antenna and simulation signal is possible. The received C-Band signal is down-converted using the same LOs that are used for transmission. Two RF Front end modules are used, one each for Horizontal and Vertical channel.

Fig6. RF frontend unit

In the Transmitter chain, the output is divided into two channels and brought to the feed as horizontal and vertical channels. Care is taken to maintain the channels physically same so that the phase difference and amplitude difference between both channels are minimized.

Calibration of the Receiver chain is done by injecting any specific power level at LNA input and comparing the output with the expected value. In CW calibration, input power is varied over the dynamic range of -10 to -110dBm. In dual polarization mode, other than the linearity and gain plots of both channels, Zdr and φdp plot over the dynamic range are also plotted. The usable dynamic range for polarimetric parameters is -10 to -80dBm LNA input.

C band DWR system has two channels of ADC processing for a single polarization which is further combined in the software to a single channel. For vertical channel also similarly two ADC channels are combined. The Zdr and Φdp values are estimated as a difference between the outputs of Horizontal and Vertical channel. For compensating the resultant Zdr bias and Φdp bias in order to obtain an error free estimation, it is important that the bias value remains constant over the usable dynamic range.

METHOD OF CALIBRATION

A RF input from a calibrated signal generator is injected at the input of Test Unit. The Test Unit Horizontal and Vertical outputs are injected to the RF front end Unit through the directional coupler. The downconverted IF output is connected to the IF receiver H and V channels. Each output of If Receiver is connected to the ADC inputs. The signals are processed and Zdr and Φdp values are computed and sent to the RT displays. The input power level is varied from -10 to -110 dBm corresponding to LNA input.

In the initial measurement it was found that the Zdr value is constant upto -30dBm only. The initial bias value from -30 to -10dBm is nonlinear and the bias is not constant. For φdp, it was observed that there is a difference between the constant phases of high channel and low channel ADCs. Refer Fig 2 for initial Zdr plot and Fig 3 for initial φdp plot.

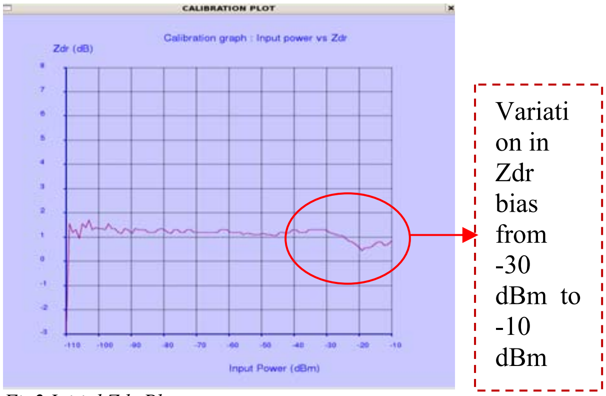

Fig2 Initial Zdr Plot

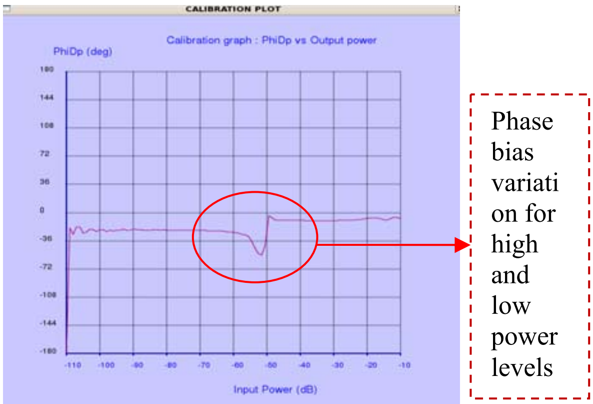

Fig3 Initial Φ_{dp} Plot

IMPROVEMENTS CARRIED OUT

On further analysis, it was found out that the RF Front end was saturating for more levels at the higher ends of input dynamic range. Since both units were into Saturation, the Zdr value is differing till the linear region starts and hence the variation in Zdr bias.

Modifications were done in both RF Front end units to improve linearity. Both Vertical channel and Horizontal channel gains were kept as similar as possible and measured and verified over the full dynamic range. As a result, constant Zdr bias was obtained up to -17dBm LNA input. Refer Fig 4 for modified Zdr plot.

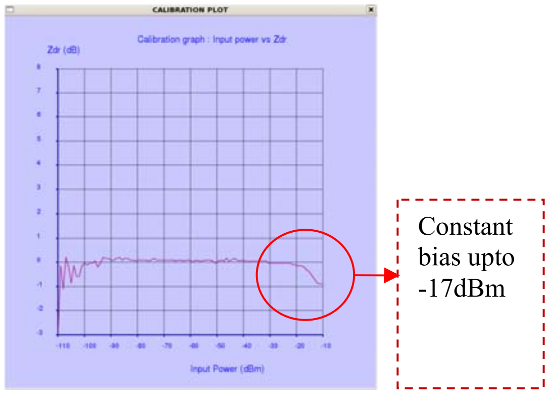

Fig4 Modified Zdr Plot

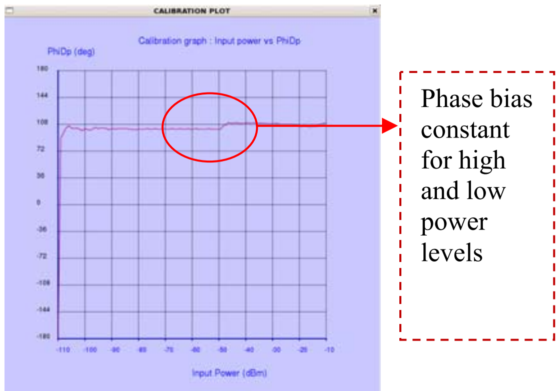

Fig5 Modified Φ_{dp} Plot

For φdp, it was observed that the phase differences between the four outputs of IF Receiver are different. The input phases of all 4 ADC inputs were kept same by adding additional cables in the channels to get same resultant phase. As a result, a constant φdp. Bias value was observed over the dynamic range. Refer Fig 5 for modified φdp plot.

CONCLUSION

A constant bias was achieved for differential reflectivity and differential phase over the dynamic range. This enables correction of bias value in software and proper estimation in real time operation.

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