SCATSAT-1 Performance Assessment and Quality Monitoring using Level-0 data

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***Abstract* - Quality of the wind vector over sea derived from the Scatterometer data depends on the on board sensor performance, platform stability, ground processor and the used GMF. This primarily requires regular assessment and monitoring of system behaviour in terms of sensor parameters. Orbit and attitude data is also observed to check the stability of the platform. This paper discusses the performance evaluation of SCATSAT-1 sensor, based on the quality metrics generated from the Level-0 data. This quality metric consists of calibration power, PRF, echo window start time, scan rate of antenna and target dependent variable parameters such as noise and echo data. Further, using the same quality metrics, alerts are generated in near real time in case if any deviation is observed with respect to the specifications. Time series of each parameter is observed to monitor the temporal behaviour and trend.**

Results from data analysis shows consistency in the parameters and found to be within specified limits. Loopback calibration power for HH and VV beam is observed as 50.3 and 50.6 dB respectively which matched with lab measurement done during pre-launch phase. Alternate calibration power also shows consistent behaviour throughout and observed as 51.3dB. Temperature of system at various junction is quite stable within the range of 10^o to 16^{o}C showing a temporal pattern. Results from trend analysis confirms the stable behaviour and consistency of the system.

***Index Terms* - Beam, Incidence angle, Doppler, Noise, Echo Data, Transmitted Power**

I. INTRODUCTION

SCATSAT-1, a continuity mission of OSCAT was launched on 26 Sep 2016 from Sriharikota and has completed more than a year on board aims to derive the ocean wind vector at global scale. SCATSAT -1 carries a pencil beam conical scanning Ku band real aperture radar, which collects backscatter power in horizontal and vertical polarization at incidence angles of 48.90 and 57.60 respectively [1]. It operates day and night and covers the entire globe in two days. SCATSAT-1 mission is a global science mission and its data is used by international agencies such as NASA, NOAA, KNMI, EuMETSAT etc. to generate wind over the ocean and forecasting of various phenomenon over the ocean such as storms, cyclones etc. which requires accurate sigma-0 data over the sea [2]. Derived sigma naught accuracy depends on the ground processor as well as raw data (Level -0) provided by the sensor. Level- 0 data contains echo data and ancillary information for both the polarization. Level-0 data is basic input which is used to generate higher level of data products viz. Level-1B, Level-2A and Level-3. Quality assessment of input data(Level-0) or data products at each level is main concern so that poor quality of data is eliminated while performing weather or climate analysis [4-7].

Data Quality Evaluation (DQE) is an independent system which assesses the sensor performance on regular basis in Near Real Time. Level-0 raw data from each acquisition of SCATSAT-1 passes through DQE chain for the conformance of data quality and if required, system raises the alarm so that immediate action can be taken before disseminating the data products to user [3]. The key objective of DQE system is to ensure the dissemination of best quality of data to the end user.

This paper discusses the results and analysis to depict the SCATSAT-1 Scatterometer performance and platform stability using more than a year of data. Section 2 describes the working principle of Scatterometer and details of data sets are discussed in Section 3. Section 4 tells about quality parameters and brief approach for metric generation followed by results and analysis in section 5.

II. SCATSAT-1 Scatterometer Working Principle

SCATSAT-1 Scatterometer is an active pulse radar which transmits chirp modulated pulses in two polarization HH beam(Inner) and VV beam (Outer) alternatively through the antenna. It uses pencil beam antenna which rotates at the speed of 20.5 RPM, covering swath of 1800 Km for outer beam and 1400 km for Inner beam. Derived Product from sensor are qualified on 1400 Km swath. From the experience of OSCAT - 2 qualified wind products specifications are 25 Km X 25 Km wind vector cell.

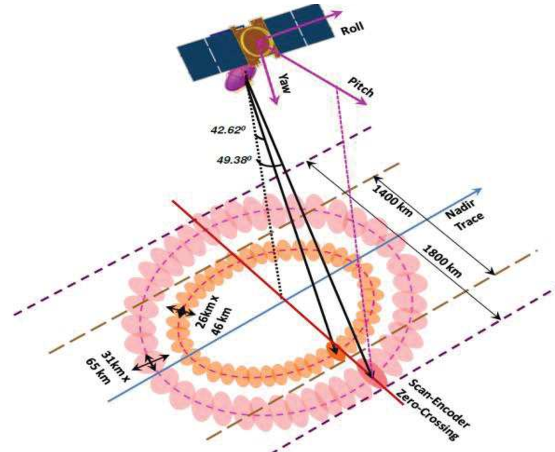

Figure 1 A schematic view of the SCATSAT-1 scanning geometry

Returned signal received through antenna experiences doppler shift due to spacecraft motion. The Doppler shift experienced by the signal consists of shift due to azimuth position of antenna, earth rotation and attitude. During on board processing the Doppler compensation due to azimuth position is being corrected, however no correction being done for earth rotation and attitude but sufficient receiver bandwidth is provided to receive the returned signal. Doppler compensated signal is then de-ramped using on board generated replica. De-ramped spectrum is then portioned in to the signal plus noise and noise compartments. Samples in noise bandwidth are integrated to generate noise samples. Signal plus noise bandwidth is frequency binned to generate slices of selectable resolution. Thus there are signal plus noise and noise measurement available in each PRI (Pulse Repetition Frequency). Number of data samples will vary depending on slice bandwidth chosen. Estimate of signal power is done by subtracting measured noise power from the measured signal plus noise power. This Estimated power is converted to sigma naught from radar equation. The description of data used for this analysis is given in next section.

III. Data used

The data used for this work is Level-0 sensor data. The data is taken of each acquisition from operations generated through Level-0 Chain at National Remote Sensing Centre (NRSC) Hyderabad. It consists of data from DACS/PLC inserted AUX where both static and dynamic information are stored. Dump wise Level-0 data is first extracted for both inner (HH) and outer (VV) beam carrying 281 and 282 footprints respectively. There are few programmable critical parameters in SCATSAT-1 related to Total S+N Band Bandwidth in the spectrum, Total Noise bandwidth of each of the Noise Samples (N1 & N2), Location of each of the Bands in the spectrum, Bandwidth of the slices generated by Integrating the basic samples, Precision of the processed data samples based on the requirement. These parameters are useful to pick up the correct record from data format. Using this information, Ancillary data and dynamic data (echo data and noise) is separated and processed to generate quality metrics which is stored into database [3]. In this work nominal mode data is taken for analysis [2]. The data used in this work is from October 2016 to December 2017.

IV. Quality Metric Generation

In order to keep an eye on sensor performance, DQE system generates and monitors the quality metrics using sensor and meta data. A set of crucial parameter is identified for metrics generation and observed with respect to its defined specifications [2]. On observing any deviation this system issue alerts for corrective measures. The sensor and platform parameters analysed in this work are- (i) Loopback Calibration Power (ii) Noise (iii) Junction Temperature (iv) Telemetry Data (v) Azimuth Angle (vi) PRF (vii) Echo Window Start Time (viii) Orbit and Attitude data

The transmitted power is looped back to the receiver through 100 dB isolator and fed to DACS (Data Acquisition and Compression Subsystem), known as calibration power. DACS digitizes this cal power fed from the receiver and integrate samples to compute 16/32-bit value, which is formatted in the auxiliary data frame. There is another source of cal power from FESA (Front End Switch Assembly) telemetry. The pulsed power from TWTA (Travelling Wave Tube Amplifier) is sent to the FESA output port towards rotary joint and is asynchronously monitored by a diode detector. This power termed as FESA Calibration power is telemetered to PLC and received on ground as a part of LBT (Low Bit Transfer) data. FESA Transmit Power Telemetry is poorly sampled at the rate of once in 16 seconds whereas loopback calibration power sample is available at every PRI.

Any of these two alternative is used as transmit power reference during data processing to produce the corresponding sigma-0 values. Any variation in loopback calibration power may affect the estimation of sigma-0 hence monitoring consistency of transmit power and comparison of the power from both the sources is an important activity.

In OSCAT, noise measurement (N1 and N2) shows scan dependent bias. Therefore, for SCATSAT-1, along with OSCAT noise measurement scheme, one more noise measurement scheme (N3 and N4) is adopted which bypasses the on board processing (i.e. doppler compensation and deramping). Any of these measured noises can be used in Scatterometer to precisely estimate the signal power which in turn affects the sigma naught. Also, this noise samples used for the estimation of brightness temperature thus the stability of these noise samples is very important.

DQE software coverts the count corresponding to Noise data into engineering units using the coefficients available and monitors the behaviour for each acquisition.

Temperature data of all packages of the Scat Payload is measured using thermistors mounted on them. Some signals are transmitted to PLC, which in turn sends the digitized data to BMU and received as telemetry data described in next sub-section. Following are the five junction's temperature obtained from Level-0 data in PLC inserted AUX data block:

a. FESARx_Protect_Switch_Temp gives Temperature Data of FESA Receiver Protected switch
b. FESA_VH_Select_Switch_Temp to get Temperature Data of FESAVH Select Switch
c. LNA Temp junction to monitor Temperature of FESA LNA
d. WG_LOC_H_TEMP to provide Temperature Data of WG - H
e. WG_LOC_V_TEMP to provide Temperature Data of WG - V

Operations range of system is expected between 5 to 30o C. DQE software is set to send alerts in case temperature goes beyond this range.

Digital Sub-System (DSS) processes most of the telemetry signals including some of the thermistor signals. All the telemetry data processed by DSS and system status data, are transmitted to BMU sequentially at an interval of 16 seconds. This data is being used for monitoring the payload health by DQE for each acquisition. Apart from health monitoring, some of the thermistor data would also be used by SCATSAT-1 processor so monitoring of this data is significant.

Following are the parameters available as a part of telemetry data which are being monitored by DQE:

a. FESA Transmitted Power
b. Bus Current (Current drawn by overall system)
c. Helix Current (TWTA current)
d. Temperature
   1) FESAR_Detector_Location2 Temperature [Junction-1]
   2) TWTAM_EPC_Internal Temperature [Junction-2]
   3) TWTAM_Temperature_Internal Temperature [Junction-3]

For a given scan, azimuth angle is the antenna position with respect to the orbit positive pitch axis which is supposed to vary from 0°to 360°in one scan. Along track variation of azimuth angle for a given footprint number shows linear variation due to inclination of orbit from true north. There are total 563 pulses transmitted in one scan with alternate polarization in next pulse (VV in one pulse followed by HH), alternatively in one scan in both the polarization. So the across track footprint to footprint difference of azimuth angle remains constant at equator i.e. 1.277°. It is essential to monitor the consistency in the measurement of azimuth angle as it is the core input in the generation of wind vector. In ScatSat-1 Scatterometer, this angle can be measured either by optical angle encoder or hall sensor. During nominal mode of operation optical encoder is used for measuring this angle. If required as contingency option, PLC can also generate angle with the help of Hall sensor.

In the case of pulsed system like Scatterometer, the number of pulses radiated by the radar per second is called the pulse repetition frequency (PRF). The energy in a pulse characterizes the capability of the pulse to detect a target, and a high pulse energy is usually desired. This can be achieved by increasing the peak power. However, the maximum power is limited by the sensor hardware, particularly in the case of spaceborne sensors. In Scatsat-1 PRF is based on spacecraft altitude and non-interference of transmit pulse with returned echo. In nominal mode of operations PRF is set to be 193Hz.

The echo-window position for both the beams is dynamically tuned in discrete steps across latitudes as a definite echo-window width may be unable to accommodate the target returns from near and far range positions at all latitudes. It is also necessary to maintain the sufficient margin with the succeeding pulse to avoid any conflict or data loss. Echo-window start time is available for every footprint and follows a pattern as we move from lower latitudes to higher latitudes or vice versa.

Level-0 data is first extracted for each scan line and foot print. For nominal mode of operations with 20.4 r.p.m each scan of inner beam contains 281 foot prints and outer beam contains 282 foot prints. Ancillary data and dynamic data (echo data and noise) is separated and processed to generate quality metrics which is stored into database for further trend analysis. Orbit and attitude parameters are obtained at the frequency of one record per second. DQE matches the time of OAT data with scan acquisition time to pick the corresponding OAT record. DQE monitors satellite position, satellite velocity and altitude as orbit parameters and roll, pitch and yaw values as attitude parameters.

V. Analysis, Results and Interpretation

Interpretation of the analysis results for the quality parameters defined in section 4 is discussed in this section.

A. DACS, PLC AUX data analysis

Figure 2 shows the stability in the calibration power from DACS. Power observed to be 50.6(dBm) and 50.3(dBm) for HH and VV beam respectively which is as measured at the time of Pre launch [3].

Noise N1 and N2 are shown in figure 3. Since launch 99.89% data shows stability as per specifications. For the rest 0.11%, alerts in near real time were observed. It was analysed that the data where noise was high is due to solar flares.

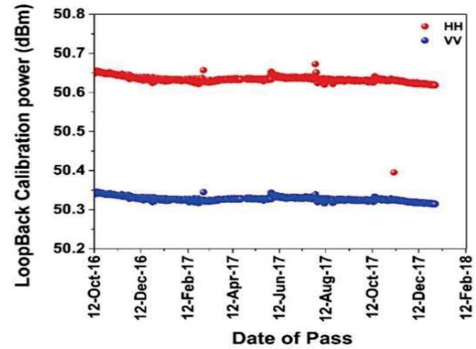

Fig. 2. Loopback calibration power (dBm)

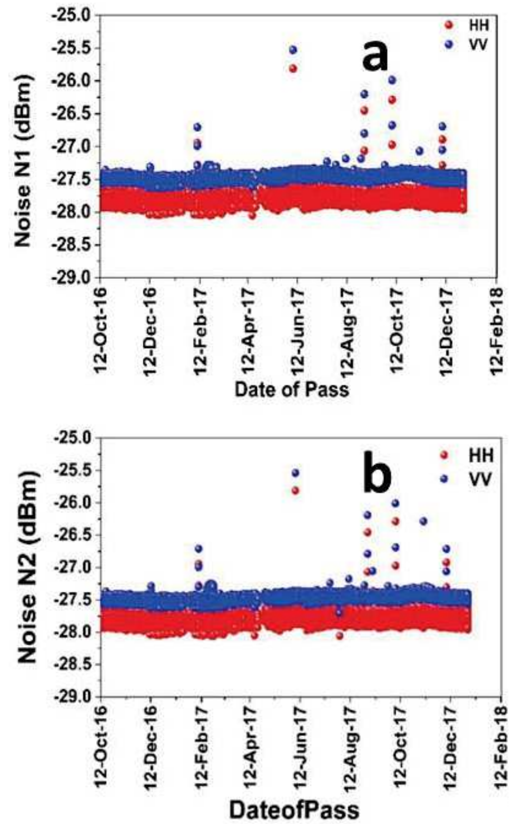

Fig. 3 Time series of Noise power (dBm) (a) N1 (b) N2

The five junction temperature observed to be consistent with time and is shown in figure 4. The pattern seen from the figure depicts a step pattern which is repeating temporally. Increment in temperature by one degree is observed for all the junction during last one year but no affect is observed in product quality. The statistical analysis at the five junctions is given in Table 1.

TABLE I

Statistical observation of system Junctions Temperature

Junction Name	Minimum (0C)	Maximum (0C)	Mean (0C)
LNA	12.29	15.07	13.32
WGLOG_H	14.32	17.25	15.43
FESAV_H	13.41	16.16	14.66
WGLOG_V	14.52	17.25	15.53
FESAR_X	12.61	15.43	13.76

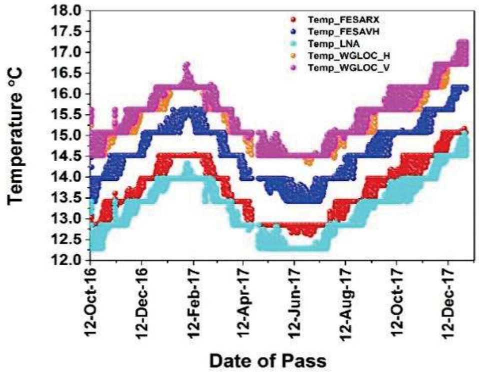

Fig. 4. System junction's temperature

Time series of footprint to footprint azimuth angle difference is found stable at around 1.270 as shown in figure 5. Quality metrics analysis shows that 99.97% data is stable and is within specifications. The remaining 0.03 % data shows variations where corruption in noise data is observed. Such data is flagged during Data Processing chain, so that user can ignore it.

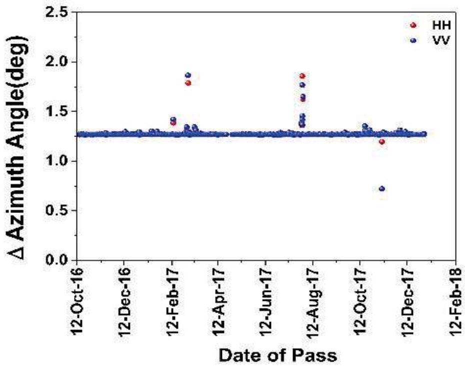

Figure 5 Delta Azimuth Angle

Pulse repetition frequency and echo window start time from the DACS data is observed to be stable. PRF is around 192.97 Hz and for both beams whereas echo window start time for HH is ~0.0068 seconds and for VV is ~0.0081 seconds. These are as per specifications [2]

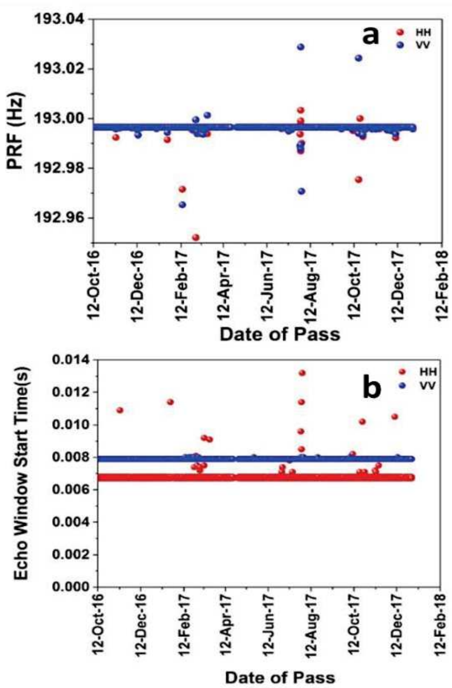

Figure 6 a) Pulse Repetition Frequency in Hz and b) Echo window start time in sec for HH and VV beams

B. Telemetry Data Analysis

Similar to Loopback Calibration Power from DACS, the Calibration power from FESA telemetry is also monitored by quality evaluation system so as to cross check the system stability. Observation from fig.7 shows calibration power from FESA around 51.2 dBm which is higher by the order of 0.6 to 0.7 dBm with respect to calibration power from DACS. On ground, data processor is using Loopback cal power because sampling of FESA cal power is coarser than Loopback Cal Power.

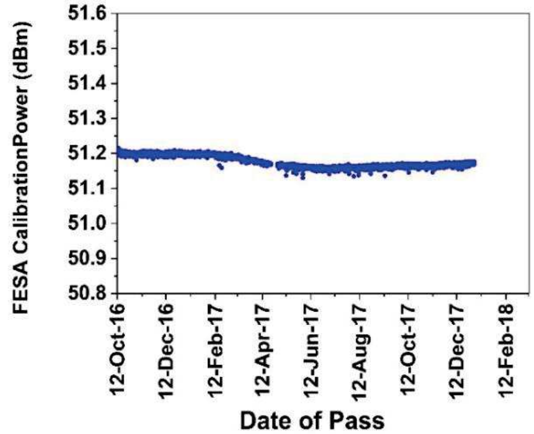

Figure 7. FESA Calibration Power (dBm)

Like Calibration Power, behaviour of temperature data from the telemetry at three different junctions is found similar to junction temperature data from the DACS as shown in fig. 4. Figure 8 shows the trend observed from the fourteen months of data.

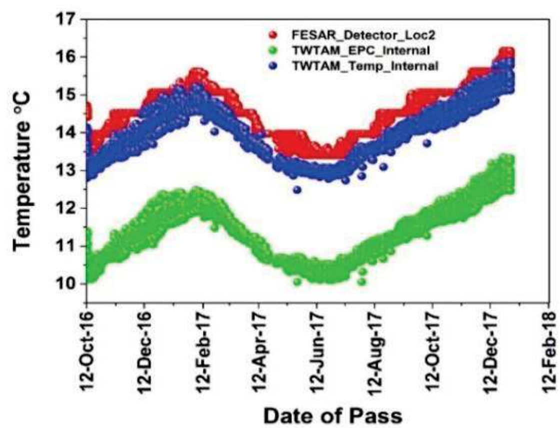

Figure 8. Temperature from Telemetry Data

Telemetry data provides overall system current as Bus current and TWTA current as Helix current. Bus current is around 1.9 Ampere. whereas the TWTA current shows step behaviour of less than 0.1 mA. which is in acceptable limits as per system specification.

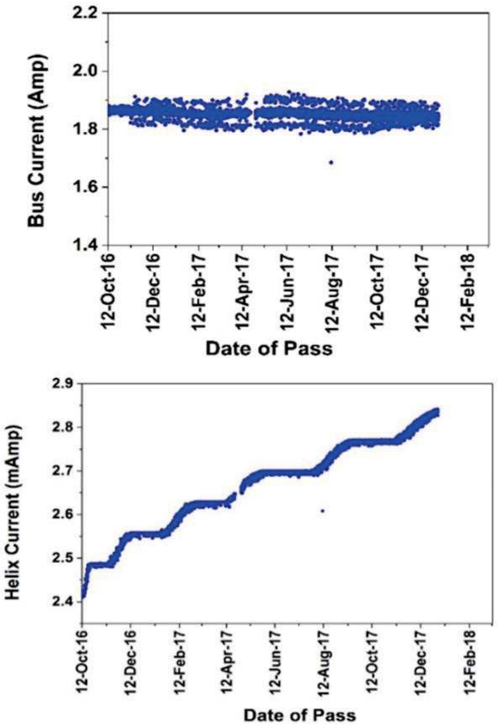

Figure 9 Time series of Bus Current (a) and Helix Current(b)

C. Orbit and Attitude parameters

Orbit parameter, satellite velocity found to be stable around 7.56 km/secs. During mid-February 2017 slight decrement in satellite velocity is observed (maximum up to 0.15 km/sec). Same trend is observed in satellite position and satellite altitude as shown in time series given below.

Attitude parameters Roll and Pitch observed for initial 15 months are found to be stable as shown in Fig. Yaw is found around 180^0 but for the occasions where decrement observed for the orbit parameters satellite position, velocity and altitude. Slight decrease of the order of 2-4 km observed in altitude after orbit manoeuvring performed in August 2017. Later mean altitude is found stable as shown in plot below.

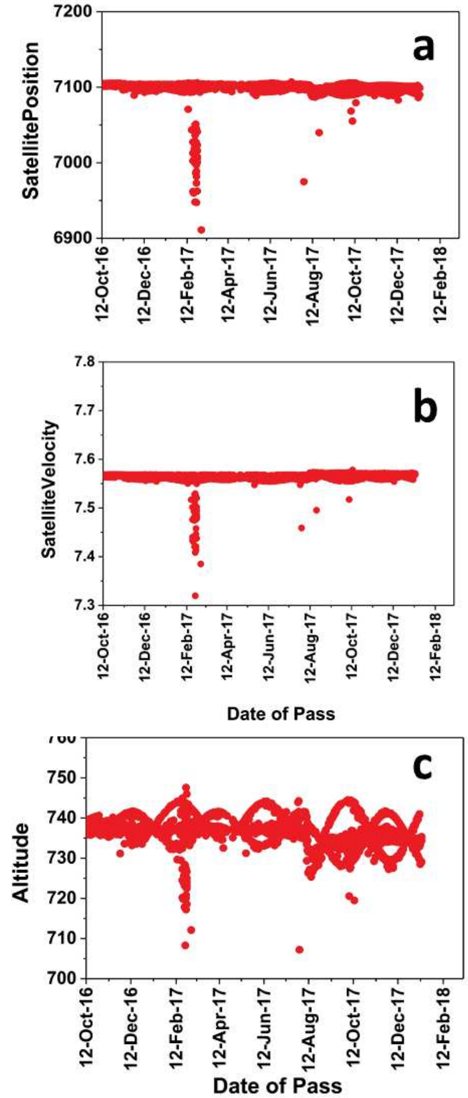

Figure 10 (a)Satellite Position, (b) Velocity and (c) Altitude Time Series

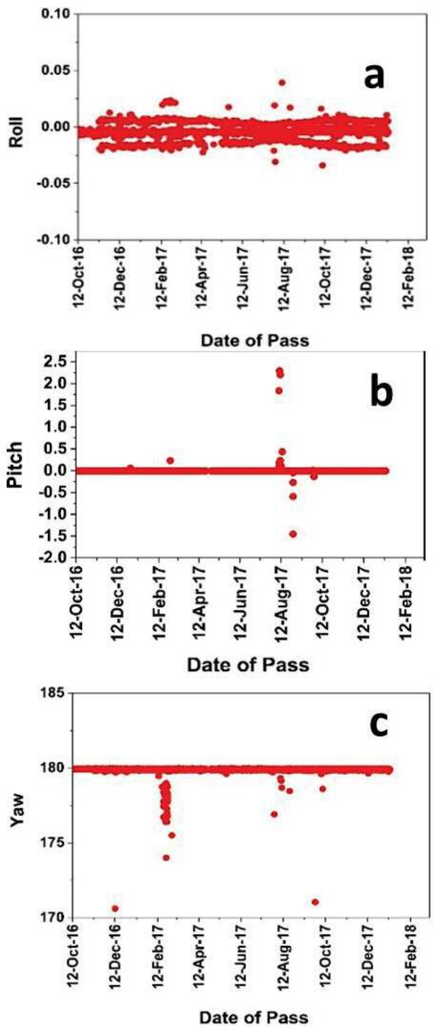

Figure 11 Mean value of a) Roll, b) Pitch and c) Yaw Time Series

VI. Conclusion

This work discusses about the SCATSAT-1 Scatterometer performance using Level-0 and auxiliary data as input. Results, shows consistency in static as well as dynamic parameters. It tells about the stable behaviour of SCATSAT-1 Scatterometer since launch. There are few cases for which alerts were given by data quality evaluation chain whenever deviations are observed but the percentage of such occurrences is very less of the order of 0.03% out of 15 months of sensor data (29 half orbits per day). Loopback calibration power as well as FESA telemetry power are found stable over this period. Junction Temperature shows that system is working well within the limit i.e. 10^0 to 17^0 C and following a temporal trend. Increment in temperature by one degree is observed for all the junction during last one year but no affect is observed in product quality. Bus current shows the stable trend and found to be 1.85 A whereas helix current shows increasing trend of the order of 0.0005 Ampere which is within acceptable range. Orbit and attitude parameters are behaving within the expected range. Slight decrement observed in orbit parameters and yaw for data sets in February 2017 but it has not given any adverse effect on data product quality on processing. Overall sensor and platform performance is found to be satisfactory from which high quality of data products are being generated.

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