Design of Experiment to Quantify and Rectify Field Measurement Anomaly in Vicarious Calibration

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Abstract

The use of Design of Experiments (DOE), a Total Quality Management (TQM) tool to achieve continuous improvement, has been demonstrated to improve product and process in manufacturing sector. This research brings a new dimension to the word "product" as being the data collected in field and thus showcases the applicability of DOE tool to improve the data in a scientific endeavor. This multi-disciplinary paper encompassing management tool in the field of satellite remote sensing demonstrates the use of Design Of Experiment (DOE)- an Analytical TQM method- in salvaging anomalous ground measured data through quantifying and rectifying the anomaly introduced during field measurement carried out as a part of vicarious calibration of Resourcesat-2 LiSS3 sensor. The experiment is designed to quantify the deviation in ground measured data through determining an anomaly-factor *alpha*and re-processing anomalous data to rectify the error. The imprecision in calibration of LiSS3 data in the range of ±10% using impacted ground measured data reduced to half, using the post-corrected data. The meticulously designed experiment could be used to optimize the ground measured data to derive useful outcome. Thus it demonstrates the use of carefully designed experiment in salvaging resourceful data acquired through field measurements to arrive at meaningful result and establishes the usefulness of total quality management tool even to scientific study.

Key Words: Vicarious Calibration, Design of Experiment, TQM, Radiance, Reflectance

1.0 Introduction:

The optical remote sensing is a process of collecting information about an object or ground feature without getting into physical contact (Lillesand, Kiefer, & Chipman, 2004). The separation between object and remote sensing system in space-based optical remote sensing (ORS) can be as much as few hundred kilometers from which the satellite-borne sensor senses the sunlight reflected from the object being viewed and records as sensor measured data. The data thus collected is converted to physical units viz. sensor measured Radiance (SMR) or Reflectance using pre-determined coefficients called calibration coefficients which relates the signal strength recorded by the sensor and the physical unit.

After the satellite is launched, the calibration coefficients need periodic monitoring and at times, updating. One such approach to re-calibrate the sensor during post-launch phase is called Vicarious calibration (Thome, 2004)

This paper showcases the process involved in vicarious calibration and demonstrates how a carefully designed experiment can be used to convert an erroneously measured ground dataset to useful dataset for attaining the intended goal of data collection without having to repeat the field measurement.

The second section describes process of vicarious calibration in a nutshell followed by an introduction to an analytical Total Quality Management tool calledTaguchi Method (Kanji & Asher, 1996) or Design of Experiment (DOE) which is largely used for improving product and process in manufacturing sector. The third section shows the anomaly found in the ground measurement followed by the detail of experiment designed to quantify the error in order to rectify and reuse ground measured data (GMD) for deriving useful inference about the status of sensor's calibration discussed in section 6. The last section summarizes the findings of this experiment.

2.0 Vicarious Calibration in a Nutshell

The "vicarious", or secondary, calibration is a post-launch calibration process (Zhengchao, Bing, Hao, & Wenjuan, 2014) for Earth Observation (EO) sensors to ensure consistent result throughout the life time of EO mission. *'Calibration' is defined as an operation, that under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication*(JCGM-WG2, 2006).

The pre-launch lab calibration of an Earth Observation System (EOS) is carried out to establish a relationship between sensor-recorded data and the physical unit of light source-the radiance. This calibration is accomplished under controlled environmental conditions of temperature, humidity and cleanliness.

Over a period of time, and even during the launch, due to the harsh outer-space conditions and normal wear and tear of the system, the laboratory derived coefficients may require monitoring and correction (Trishchenkoa, Cihlara, & Zhanging, 2002).This alteration in relationship between the input energy and system response to this incident energy needs to be constantly monitored and restored, to ensure consistent performance throughout the life of the mission.

The reflectance-based vicarious calibration procedure (Gilead & Karnieli, 2004)involves extensive in situ measurements of the surface spectral reflectance of ground and measurement of atmospheric parameters, synchronous to satellite overflight using calibrated ground-measuring as well as atmospheric-parameter-measuring instruments. Using the radiative transfer code (Chandrasekhar, 1960)to model the interaction of radiation with atmosphere, the ground measured reflectance is converted to modeled top-of-atmosphere (TOA) radiance (MTR). Coefficients are derived as a relationship between the modeled TOA radiance (MTR) and the top-of-atmosphere (TOA) target radiance measured by the sensor (SMR). These computed coefficients can be used in place of, or in addition to, those derived during the pre-flight laboratory calibration exercise. The vicarious calibration process is depicted in a nutshell in Figure 1.

The ground measuring instruments consist of hyper spectral (SVC, 2010)radiance/reflectance

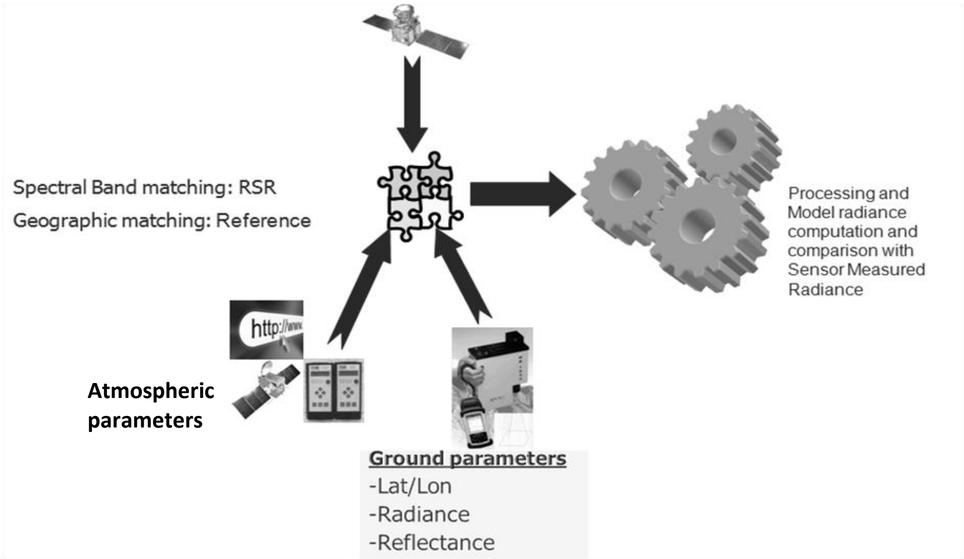


Figure 1 Vicarious Calibration process in a nutshell

Source: (Desai & Panchal, 2014)

measurement capability. These measurements are required to be integrated for the respective spectral bands(Pandya, Singh, Murali, Babu, Kirankumar, & Dadhwal, 2002) of the sensor being calibrated using sensor's spectral response function (also called Relative spectral response-RSR) to get band integrated radiance (BIR) which is input for deriving ground measured reflectance required by RTC to convert to modelled TOA radiance (MTR).

The MTR is related to ground measured reflectance by the equation:

$$\boldsymbol{MTR} = \frac{\rho TE}{\pi} + Lp \text{-- (1)}$$

Where ρ is ground measured reflectance

E is the incedent solar irradiance

T is the atmospheric transmittance

Lp, the path radiance,a parameter added by atmospheric scattering

The MTR is compared with sensor measured radiance (SMR) which,in turn, is related to sensor measured digital number (DN) by the equation:

$$\text{SMR} = \frac{\text{Lmax} * \text{DN}}{\text{DNmax}} + \text{Lmin} \text{--(2)}$$

where Lmax and Lmin are lab measured pre-launch calibration coefficients,DN_{max} is the maximum count which the sensor can generate and is given by 2^n where n is the radiometric .lexip rep stib ni noitazitnauq

rednU .RTM lauqe tsum RMS ,deretlanu si esnopser esohw rosnes a roFoperational gnimussa ,secnatsmucric :sa detauqe eb nac RTM dna RMS ,ti no tnedecni ygrene eht ot raenil si esnopser s'rosnes eht taht

$$SMR = c1 * MTR + c0 \text{--(3)}$$

where c1 and c0 are post-launch calibration coefficients.

3.0 Design of Experiment and Vicarious Calibration Process

Design of experiment (DOE), also termed as Taguchi method, is a statistical technique to

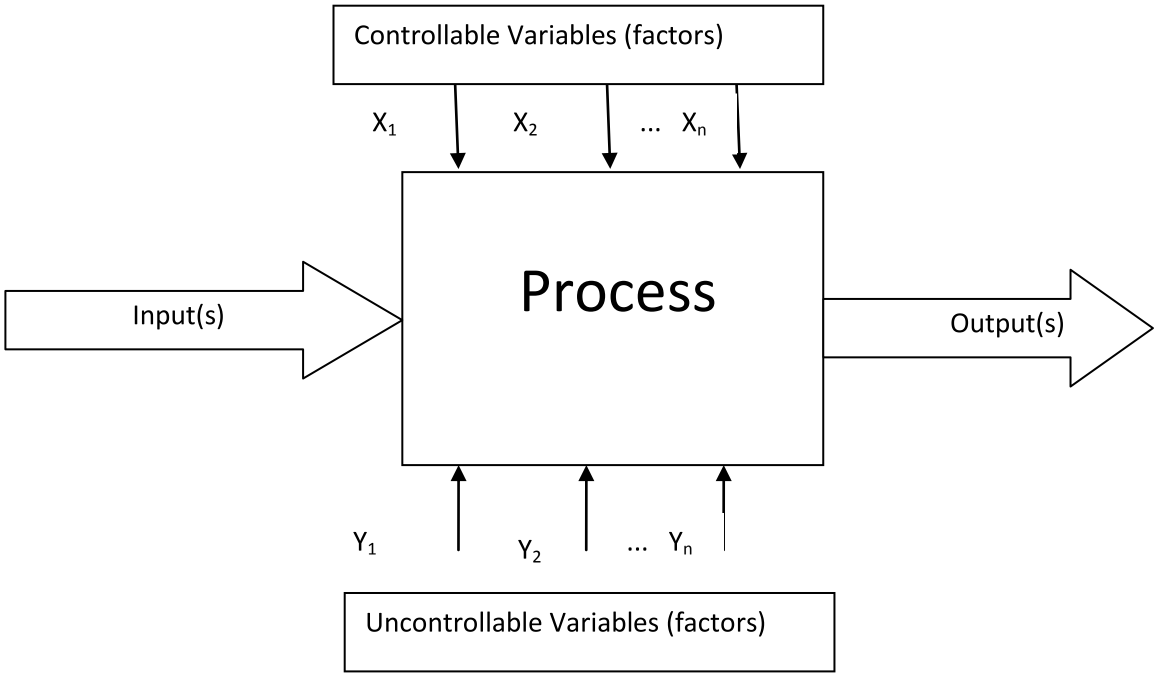


Figure 2 Generalized form of Process

Source : (Antony, 2014)

study the effect of multiple variables on a process or product simultaneously (Roy, 2001). Although the use of statistics is important in DOE it is not absolutely necessary (Lye, 2005).In order to designan experiment comprehensively, it is essential to have a good understanding of the process involved. A generalized form of a process (Figure 2) is the transformation of inputs to outputs through various controllable and uncontrollable variables. The variables, which are unique to the system under investigation, are called *factors*.

An experiment is designed by intentional changes (Lye, 2005) to the input process or machine variables (or factors) in order to observe corresponding changes in the process output. The information gained from properly planned, executed and analyzed experiments can be used to improve functional performance of products, to reduce the scrap rate or rework rate, to reduce product development cycle time, to reduce excessive variability in production processes, to improve throughput yield of processes, to improve the capability of processes, etc. (Antony, 2014).By studying the effect of individual factors on the results, the best factor combination can be determined (Fatoba, Akanji, & Aasa, 2014). One-Factor-at-a-time (OFAT) technique of DOE, which is regarded as outdated, also continues to be the chosen approach which consists of varying one variable at a time, with all other variables held constant.(Tanco, Viles, & Pozueta, 2008)

Hence, of the hundred Total Quality Management methods listedby (Kanji & Asher, 1996)under four categories viz Management, Analytical, Idea Generation and Data Collection Analysis & Display, this technique which is used for product or process optimization is put under the category of Analytical Method which can be used during or post-commissioning of process or product.

Taguchi's approach, although used almost synonymous to DOE, is not free from criticism. The trade mark holder of Shainin System™ , Dorian Shain in strongly objected to the use of the Fractional Factorial technique and established the DOE principle on reducing the number of factors through the use of techniques like Pareto Analysis (Tanco, Viles, & Pozueta, 2008). Thus Shainin System™, which, at times is simple version of OFAT method is suited for high quality processes.
The Taguchi experimental design is carried out in five phases (Roy, 2001) shown in Figure 3
Blending the steps of vicarious calibration procedure depicted in Figure 1and the generalized

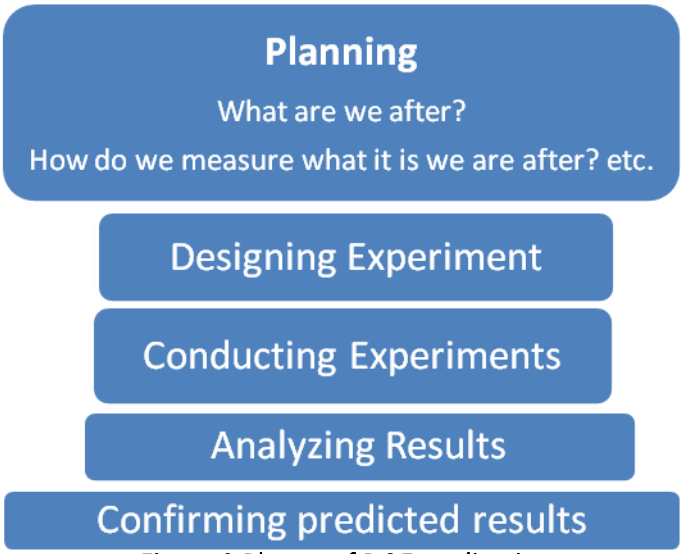


Figure 3 Phases of DOE application

Source: (Roy, 2001)

form of a process (Figure 2) , the vicarious calibration can be regarded as a process whose inputs are:a) ground measured radiance/reflectance values and b) atmospheric parameters with controllable factors like instrument calibration and pointing accuracy during measurements, the uncontrollable parameter being sky condition, wind speed and direction etc. The output of this process is the calibration coefficients interrelating the sensor measured radiance (SMR) and modeled top-of-atmosphere radiance (MTR).
The experiment designed in this study aims at quantifying a suspected anomaly in measuring ground reflectance data and use the quantification to re-process the archived data without having to repeat the pricey field experiments.

4.0 Ground measured data and anomaly

Thepost launch vicarious calibration of Linear Imaging Self Scanning Sensor-3 (LiSS-3) sensor (Figure4 Linear Imaging Self Scanning Sensor-III)onboard Resourcesat-2 Earth Observation (EO) system (NRSC, 2011) was proposed as an operational activity through identification of calibration sites(Desai Y. , Srivastava, Gupta, Bhavsar, & Kartikeyan, 2011). The procedure involved characterization (Desai, Bhavsar, Srivastava, Gupta, & Kartikeyan, 2012)of site through field measurements.
It is well established fact, that, the ground measured surface radiance (GMR) and reflectance are the most important inputs in vicarious calibration(Boucher, et al., 2011). The method requires measurement of reflected light over a white reference plate with nearly 100% reflecting lambertian surface property and that from the surface of the target-site, alternately, under identical solar illumination and viewing conditions in selected field of view (FOV) of the objective aperture. To ensure that the solar illumination angle during two measurements-one

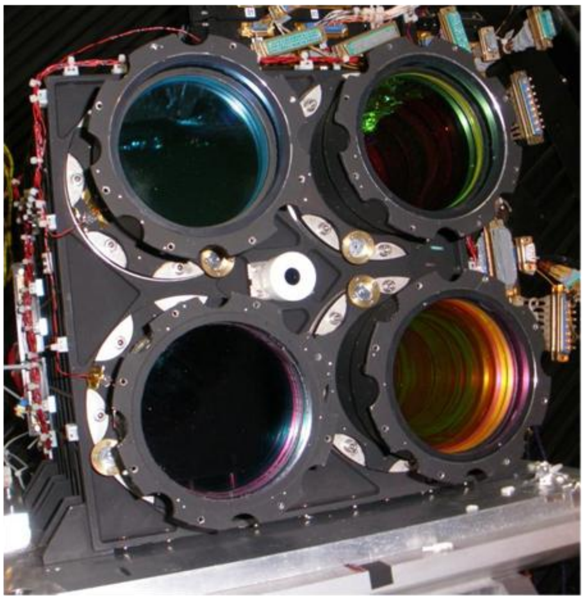


Figure4 Linear Imaging Self Scanning Sensor-III
Source: (NRSC, 2011)

on reference plate and other on the ground- do not change, both measurements need to be taken within shortest possible time- not more than the time taken to record the data and re-pointing the fore optics. The target reflectance with respect to the reference white plate is then given by (Boucher, et al., 2011):

$$\rho_{tar} = \frac{\rho_{ref} * L_{tar}(t_1)}{L_{ref}(t_2)} \text{--(4)}$$

where ρ_{ref} is reflectance factor (≈1) of reference plate, L_{tar} is the radiance of target measured at time t_1 and L_{ref} is reference radiance measured at time t_2 such that

$$\Delta t = t_1 - t_2 \approx 0 \text{--(5)}$$

These reflectance values, in conjunction with synchronously measured atmospheric parameters, are fed to Radiative Transfer Code (RTC) to derive Modeled Top-of-the-atmosphere (TOA) Radiance (MTR). These MTRs are then compared with sensor measured radiance (SMR).
During the initial operational phase of vicarious calibration, field measurements were carried out synchronous to satellite over pass on the dates listed in Table1

Table1Dates of field visits

Site:Bap	
1	30-Sep-11
2	19-Oct-11
3	20-Oct-11
4	16-Nov-11
5	17-Nov-11
6	6-Dec-11
7	19-Jan-12
Site:Lanela	
1	20-Sep-11
2	13-Oct-11
3	14-Oct-11
4	15-Nov-11
5	8-Dec-11
6	18-Jan-12
7	6-Mar-11

The software utility developed for data processing (Desai & Panchal, 2014) was used to compute Sensor measured radiance (SMR) with modeled Top of Atmosphere radiance (MTR). The post-processing analysis of these measurements indicated anomaly between groundmeasuredradiance/reflectance values, SMR and modeled TOA radiances (MTRs).

The post processing analysis showed two effects:

i) **S**ensor **M**easured apparent **Refl**ectance (SMRfl) was less than **G**round **M**easured **Refl**ectance (GMRfl)

ii) Sensor measured radiance was also less than modeled TOA radiance (SMR<MTR)(Figure 5)

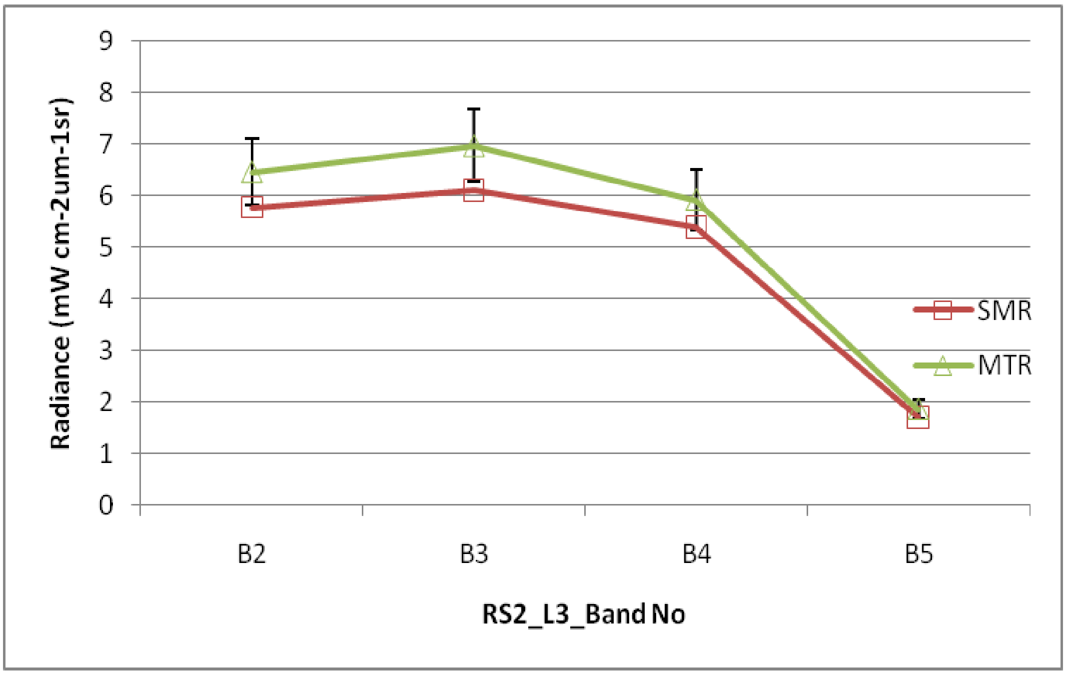


Figure 5 Comparison of average MTR and SMR

The cause of this "effect" needed to be identified through brainstorming exercise- the first phase of DOE application (Roy, 2001)

Fishbone diagram- named so due to its shape- also called Ishikawa diagram, commemorating its inventor Kuoro Ishikawa, is used to carry out cause-and-effect (CE) (Kanji & Asher,

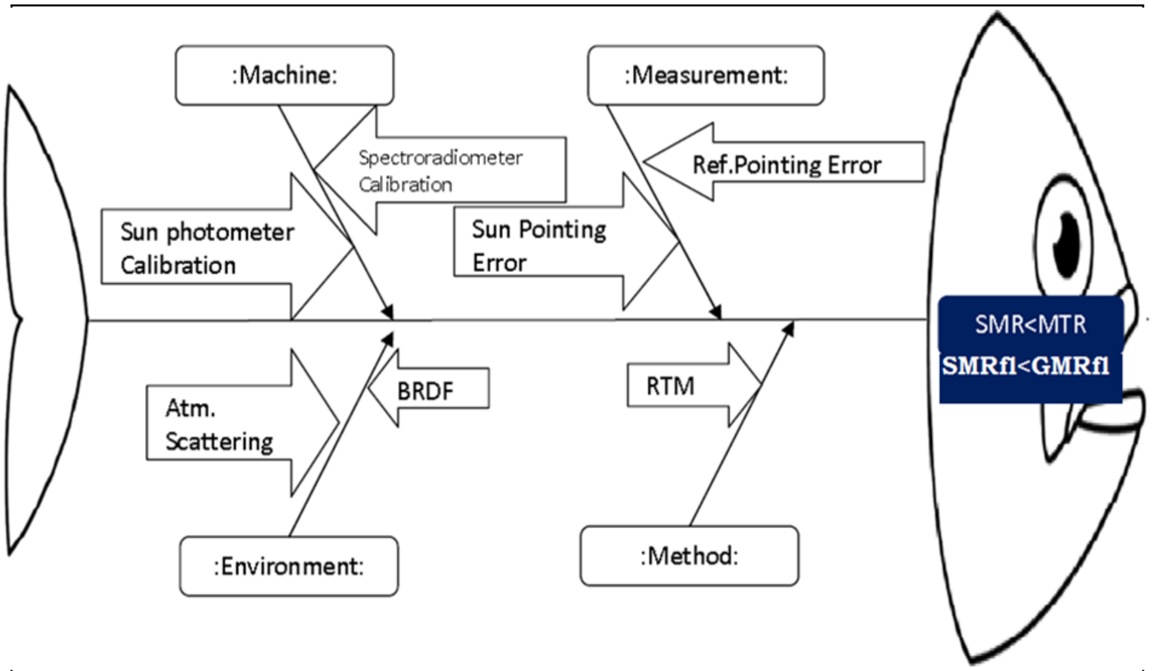


Figure 6 Fishbone diagram showing cause of sensor measured radiance being less than modelled target radiance

1996)analysis between various factors and observed outcome. The various factors form the skeleton of fish and the outcome is placed at the head of fish. The brain-storming session led to an Ishikawa diagram as shown in **Error! Reference source not found.**

Once the causes of an event (here, SMR<GMR and SMR<MTR) were identified, the analysis was directed towards distinguishing the role of each variable and verify any connection with

observed effect. This analysis is expected to give the answer to the question "What are we after?", raised in Figure 3.

The following criteria was considered for the selection of data for investigation to reduce the uncertainty in some of the causes from CE analysis.
1. Ground measurement carried out on the day of pass: This ensured that the condition of atmosphere is accurately modeled and corrected for, while computing the MTR.
2. The measurement time coincides with satellite pass time: This ensures that the solar illumination angles and hence uncertainty due to the bi-directional reflectance function (BRDF) is minimum.
3. The Aerosol optical depth (AOD) is low: Low aerosol loading reduces errors associated with atmosphere scattering (Thome, 2004)
The summary of conclusion for each causative parameter and its supporting argument is given in Table 2

Table 2 Cause and Effect analysis

Sr. No	Factor	Conclusion	Remarks (if any)
1	Instrument Calibration	The calibration of spectroradiometer and sunphotometer/ozonometer were verified	
2	BRDF	For the synchronous ground measurement for a nadir looking sensor , the BRDF factor will have common effect and cancels out	
3	RTM (Radiative Transfer Model)	The 6S RTM gives better than 1% accuracy(Vermote&Kotchenova, 2008)	
4	Atmospheric Scattering and sun angle errors	The synchronous measurement ensures similar solar zenith angles and subsequent correction using RTM will absorb this factor	
5	Reference pointing error	The size of field is large enough to cover the entire Field of View of instrument's fore-optics whereas the reference plate is 30cm x 30cm against the ground coverage of 24cm in 14deg FOV(SVC, 2010)	An incorrect pointing on reference plate can cause the denominator of reflectance formula to shrink and zest up the ground measured target reflectance

5.0 Design of Experiment to quantify and rectify anomaly

From the brainstorming exercise resulting into a CE diagram, one cause which evidently needed to be studied was that of error in pointing on the Reference plate with 14deg FOV fore optics of spectroradiometer. Once the answer to "What we are after" has been reached, the next phase i.e. designing of experiment began to answer "How do we measure what it is we are after?"
The field-of-view (FOV) covered by three available objective apertures is shown in FOV-map (**Error! Reference source not found.**)

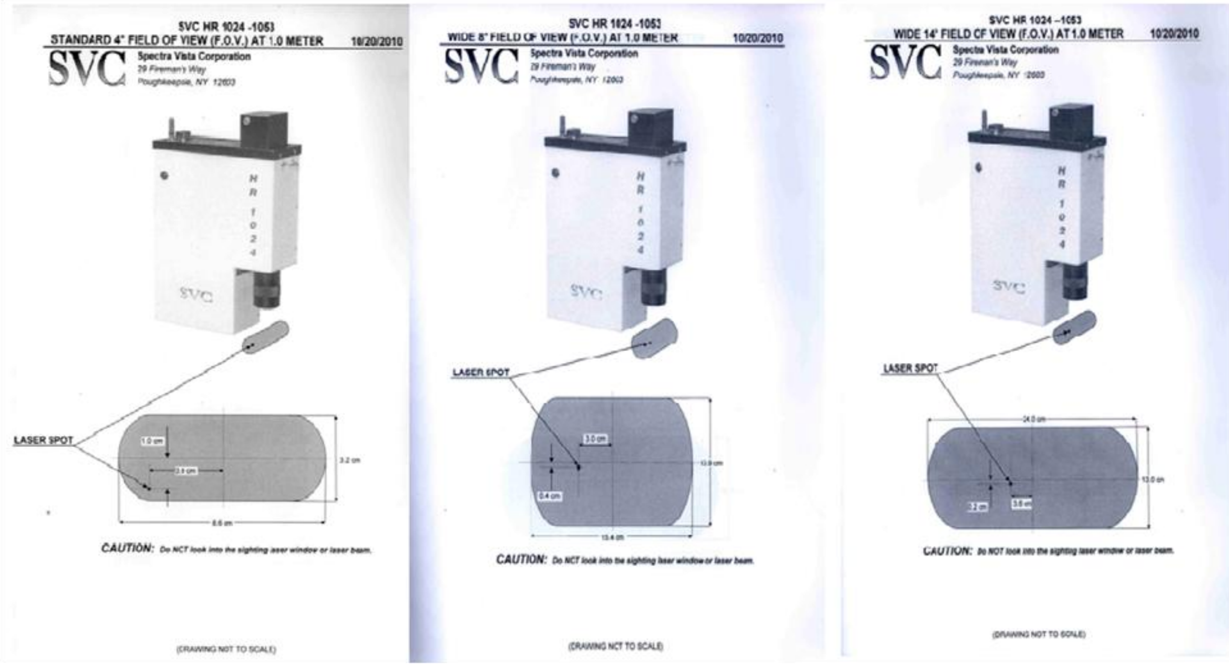


Figure 7FOV-map showing ground area coverage for selected fore-optics
Source: (SVC, 2010)

The sampling of ground measurement should be such that it covers one pixel of sensor being calibrated. The sampling is a function of FOV of fore-optics and height from where measurement is taken. As the measurement is taken by human standing on the ground the selection of FOV is then dictated by the size of reference plate (Boucher, et al., 2011).
The size of white spectralon reference plate being one square feet, the largest FOV which could be taken was 14deg with longer dimension of foot-print being 24cms (**Error! Reference source not found.**). Any "contamination" from background due to mis-pointing on reference plate will cause error in target reflectance which will be a function of reflectance of contaminating background.
Thus the experiment was designed with followingsequential objectives:
1) Verify the cross-calibration between apertures of three FOVs
2) Simulate the anomaly to re-affirm the outcome of brainstorming session
3) Quantify the anomaly with an aim to correct the same

6.0 The experiment:

The meticulously designed experiment requires equally punctilious execution to ascertain substantive outcome. The execution of experiment needs to keep focus on the listed objectives.

Re-iterated below are the objectives identified during this study:
1) Verify the cross-calibration between apertures of three FOVs
2) Simulate the anomaly to re-affirm the outcome of brainstorming session
3) Quantify the anomaly with an aim to correct the same
The sub-sections below details the method of execution in tune with corresponding objectives.

6.1 Verify the cross-calibration between apertures of three FOVs:

First thing first, was to ensure that the three FOVs being compared are cross-calibrated. This would ensure that all subsequent measurements are devoid of any inter-calibration effects.
Measurement of reflectance parameter over a target, however large, requires measurement over relatively small reference plate, giving rise to cause of uncertainty. Hence the measurement of radiance, as against reflectance, was taken to compare the response of instrument for the three FOVs to ascertain that it is only the effect of calibration, and not the size of target being measured, plays any role.
The configurations in which measurements were planned included three field-of-views and targets with three respective reflectance properties as shown in Table 3

Table 3 Selected targets to cover dynamic range

FOV	Target with varied reflectance
4	Black (ρ<5%)
8	Soil (ρ<30%)
14	White(ρ>75%)

6.2Simulate the anomaly to re-affirm the outcome of brainstorming session:

Once the inter-calibration of instrument in all three FOVs is established, the next objective would be to simulate the observed anomaly, which indicated mis-pointing of fore-optics while measuring the reference plate using 14deg FOV. The experiment to simulate the anomaly was conducted, this time by taking target *reflectance*measurements with three configurations viz 14/14,14/4 and 4/4 where the numerator showing the FOV selected while measuring target and denominator denoting FOV selected while measuring reference plate. Assuming with reasonable grounds that the pointing will be most accurate in 4deg FOV, the readings taken in 4deg FOV were taken as standard and the data measured in 14deg FOV was compared against this standard.
Targets of different hues viz. Red, Green, Black and White were selected so as to cover large part of sensor's dynamic range.

6.3 Quantify the anomaly with an aim to correct the same:

After simulating the anomaly, the last and most crucial step was to quantify the anomaly and apply the correction factor, *alpha (a)*, and reprocess all anomalous datasets.
Contemplating the fact that the erroneous reflectance is the result of anomaly in Reference radiance and is unrelated to the target radiance, approach to derive *alpha* coefficient, which is the measure of contribution from background to reference radiance, was undertaken.The experiment involved measuring reflectance of each feature through measurement of reference plate placed in background of three different reflectance properties viz Black, White and Soil (**Error! Reference source not found.**).
The field of view for reference as well as target was to be kept same i.e. the objective aperture to be kept same while taking measurements on the reference plate and corresponding measurement on the target. Additional scenario for validation of result was planned where the reference plate is measured with 4deg FOV and the target is measured in 14deg FOV. Thus generating four sets of measurement settings (shown by √ in

Table 4).

Table 4 FOV selection on Reference and Target

FOV selected on reference plate	FOV selected on Target		
	14 deg	8 deg	4 deg
14 deg	√ (14/14)	X	X
8 deg	X	√ (8/8)	X
4 deg	√ (14/4) for validation	X	√ (4/4)

The pictorial representation of measurement settings is shown inFigure 8

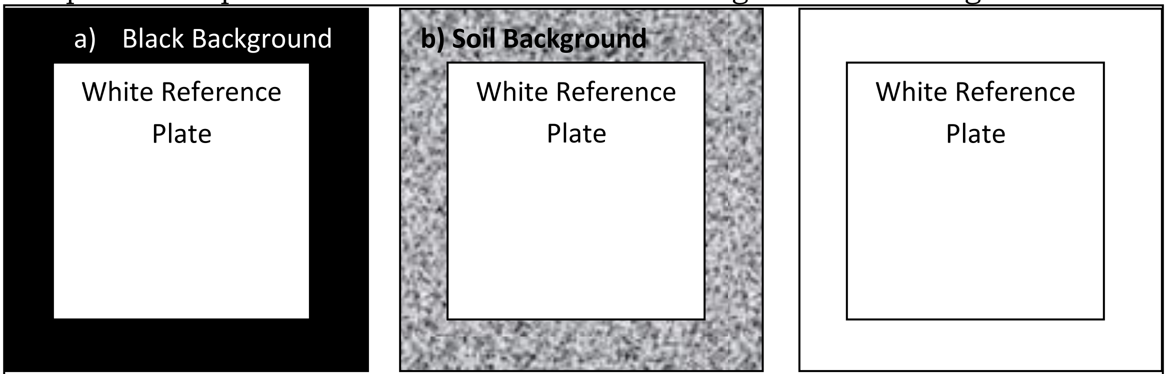


Figure 8 Reference plate in three different backgrounds a)Black b)Soil c)White
Source: sketched for this paper

The effect, in percentage, of a background 'i' on reference plate reading is computed as the difference between average of reference radiance in all three backgrounds and individual radiance of corresponding background target:

$$\%\mathbf{Effect} = \frac{\bar{L} - L_i}{\bar{L}} * \mathbf{100} \text{--(6)}$$

where L_i is the radiance of background 'i' and $\bar{L}$ is the mean of reference radiance in all three backgrounds.

The next section show the analysis from each experiment and the conclusion drawn.

7.0 Results, Analysis and anomaly removal:

This section analyzes the results against the objectives with which the experiments were conducted.

7.1 Verify the cross-calibration between apertures of three FOVs

To carryout cross comparison of measurement by all three FOVs,independent of white reference plate, measurements of radiance-rather than reflectance- values over large targets were taken. This ensured that the outcome is not influenced by the effect of measurement in any FOV due to target size limitation.

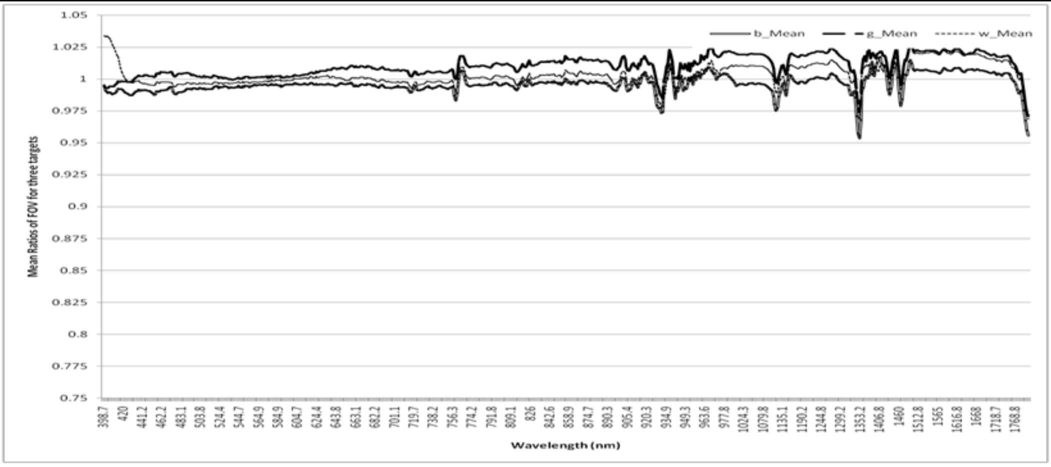


Figure 9Ratio of radiance measured in three FOVs for targets of three reflectance range

The comparison of target radiance in the formof their ratios(Figure 9)demonstrate that all three FOVs are cross-calibrated within±2.5% for targets of reflectance values ranging from Black (ρ=5%) to White (ρ=70%).

7.2 Simulate the anomaly to re-affirm the outcome of brainstorming session

After ensuring the cross calibration between three FOVs, the next step was to able to replicate the anomaly as inferred from the brainstorming session. This was to reconfirm that the cause of anomaly has been rightly identified.

The reflectance of targets was measured with three combinations in terms of FOV used for target and reference plate measurement as listed in Table 5.

Table 5 Configuration used for simulation of anomaly

FOV selected on reference plate	FOV selected on Target	
	14 deg	4 deg
14 deg	√ (14/14)	X
4 deg	√ (14/4)	√ (4/4)

- The target reflectance values obtained in three configurations for four different targets viz Black, Soil, Red and Green are shown inFigure

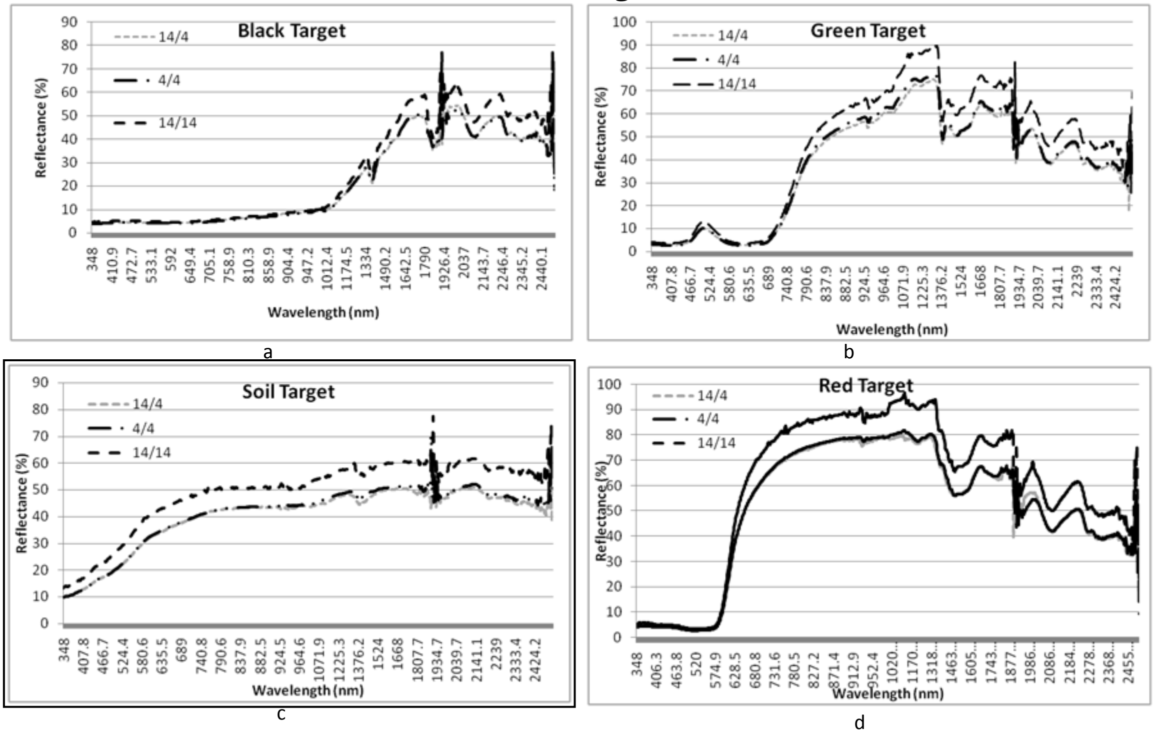


Figure 10Comparison of target reflectance in three measurement configurations

10.

The reflectance measured by taking reference plate readings in 14 deg FOV (configuration:14/14) show significantly high values for all targets whereas those taken with reference plate in 4deg FOV (configurations 4/4 and 14/4) coincide for all targets at all wavelengths.

This reasserts the outcome of brain storming session that the 14deg FOV overshoots the relatively small reference plate resulting in higher-than-actual target reflectance.

7.3 Quantify and rectify the anomaly

The systematic diagnosis of anomaly is only half work done. The qualitative information thus derived needs to be converted to quantitative figure so that the anomalous data can be put to use after suitable correction.

The overshooting of 14deg FOV Figure 11 beyond the reference plate will result in contribution

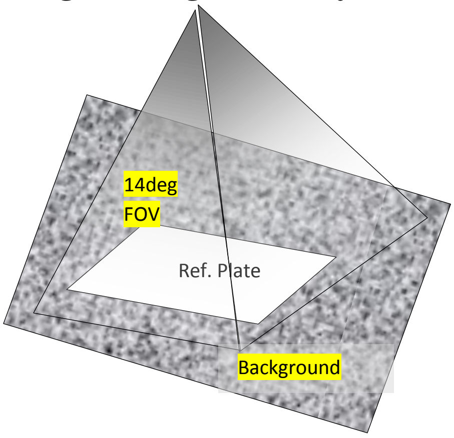


Figure 11Sketch showing 14 deg FOV overshooting the reference plate

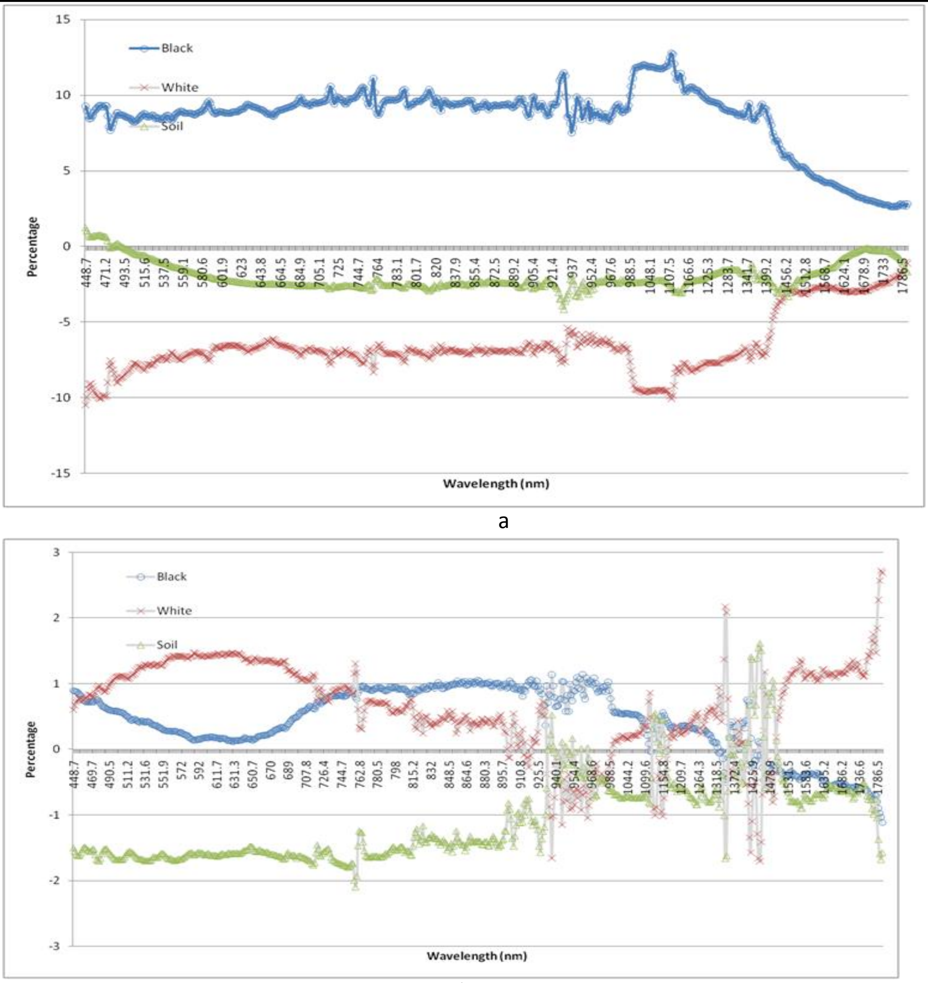
Source: Sketched for this paper

from relatively low reflecting background. This will "pull down" the reference value under the unity level resulting in jacking-up the target reflectance by the same factor.

Corollary: if the contribution of background can be modelled, the anomalous target reflectance can be corrected.

To analyze the trending of background contribution on reflectance measurements, the measurements were carried out in three distinctly different background conditions viz. Black, Soil and White.

The deviation in reflectance when measurements were carried out in three different background conditions for two FVOs (14deg and 4deg) is shown inFigure 12



b

Figure 12Comparison between effect of background on reflectance measured for a)14deg and b)4 deg FOV

The large deviation of >±10% in 14deg FOV as against <±2% in 4deg FOV indicate the subsistence of “leakage” from background in 14deg FOV owing to mis-pointing on reference plate.

Considering pure background target radiance as 'a', reference radiance contaminated by same background in 14deg FOV as 'b' and pure reference as measured by 4deg FOV as 'c' , the relationship between the three parameter can be given as:

$$\mathbf{b} = \boldsymbol{\alpha} * \mathbf{a} + (\mathbf{1} - \boldsymbol{\alpha}) * \mathbf{c} \text{------------------------------------(7)}$$

therefore, $$\boldsymbol{\alpha} = (\mathbf{b} - \mathbf{c})/(\mathbf{a} - \mathbf{c}) \text{--------------------------------------(8)}$$

The dependence of alpha-factor on background is shown Figure 13. Owing to the fact that the background of calibration site resembles the soil background used in the experiment, the alpha-factor corresponding to soil background, averaged over all wavelengths covering sensor being calibrated, was considered for re-processing the ground measured datasets.

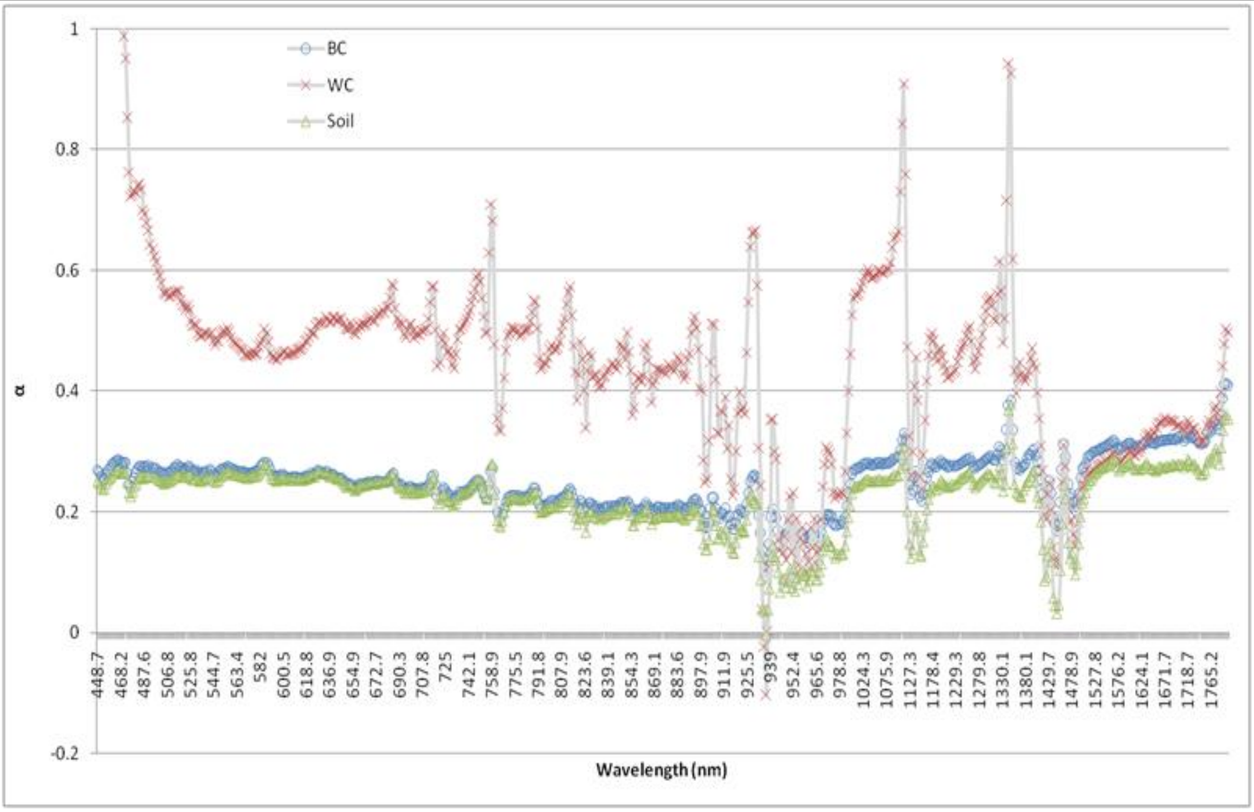


Figure 13The contribution of various background in the form of alpha-factor

7.4 Anomaly removal and validation:

The correction factor *alpha* thus obtained through scrupulously designed experiment was used to re-process ground measured data. Assuming a constant `α', we may think of recovering the reference-plate radiances as follows: For each corrupted plate radiance `b'(takenon the field in 14 degrees), let the correspondingbackground radiance be called `a'. The corrected plate reference radiance 'c'can be obtained as :

$$c = (b - \alpha * a)/(1 - \alpha) \text{--(9)}$$

The target radiance data were subjected to new reference values.After running the re-processed target reflectance values through radiative transfer code (RTC) it showed improved modelled TOA radiance (MTR) which was within ±5% of sensor measured radiance (SMR)

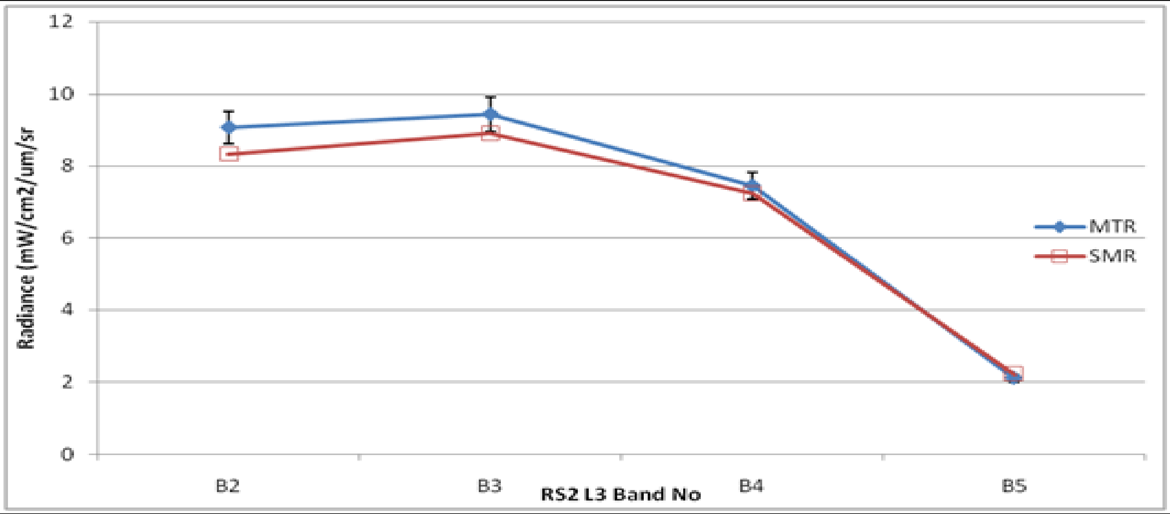


Figure 14 Comparison between Modelled TOA radiance (MTR) and Sensor measured radiance (SMR): Error Bar +/- 5%

8.0 Conclusion

This paper demonstrates the use of design of experiment (DOE)- an analytical TQM method- in quantifying an anomaly introduced circumstantially in a vicarious calibration exercise of an optical remote sensing sensor.
DOE has been widely used in improving the product accuracy in the manufacturing sector. This paper redefines the “product” to include ground measured data, which has been improved through an experiment which was methodologically devised and executed.
The significance of thorough knowledge of process and its components, in using DOE tool has also been demonstrated.
This study also brings out the paradox from the ground measurement perspective in selection of appropriate field of view, which is a tradeoff between using narrow field of view to increase precision and wider FOV for covering larger area through collecting more samples in less time.

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