Comparison Study Between Photogrammetry & Laser Radar

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1.0 Abstract

At the Harris Corporation (Government Communications Systems Division – GCSD) solid carbon fiber and aluminum shaped reflectors are manufactured to support military ground, sea, & air communications. These reflectors range in size from 1 to 13 meters. To meet performance requirements, the surface profile of these reflector dishes are held to rigid tolerances. For 25 years, Photogrammetry (PG) has been the Harris standard for characterizing the surface profile of these reflectors due to its high accuracy, portability and ability to work in unstable conditions. This technique has been "Tried and True" and is familiar to both the engineering and the quality organization.
Over the past year, Laser Radar (LR) has been evolving into a robust inspection technique that reduces materials used and automates the measurement process. In a cost competitive market of reflector fabrication, Laser Radar offers a promising solution in reducing the re-occurring labor cost during significant production efforts. For the implementation of this technology it was necessary for the LR to be compared to what Harris recognizes to be the standard of surface characterization. To be accepted, the surface profile characterization (i.e. RMS) for reflectors must be ≤ 10% when compared to Photogrammetry.
This technical paper discusses the LR evaluation techniques used for determining the surface profile of reflectors and if LR will be a suitable alternative to PG during significant production efforts at Harris.

On a variety of reflector sizes, the surface profile (i.e. RMS) was calculated with both LR and PG. The percent differences between RMS values ranged from 2% to 6%. Additionally, the labor hours required to determine the RMS value was reduced by 90% when an automated program was used. For this application of determining the surface profile of reflectors, LR was a suitable alternative to PG in the reduction of recurring costs associated with production efforts.

Future investigation will be performed to utilize a target projection system in conjunction with PG. If successful, the target projector would eliminate the need to apply and remove PG targets and greatly reduce measurement time.

2.0 Surface Profile Characterization

Please note the process and technique used to generate the RMS values for the different methods are Harris specific, other applications may result differently.
A symmetrical point grid is determined so that the surface profile (RMS) of the reflector can be calculated. This grid is very labor intensive and must be applied accurately as it will be used as an alignment feature during the surface characterization. The grid is applied in a repeatable sequence and correlates the datum reference points of the production tool. The grid is typically transferred to the surface of the reflector during production. This repeatability is maintained throughout production to achieve an "apples to apples" comparison among the reflectors. After measurement, the data is compared to the theoretical surface and new Z values are generated for the measured X and Y values. Next the theoretical Z values are used to generate a deviation or delta between the measured and the intended surface. This data is then used for reporting RMS and characterizing the surface profile of the reflector. A requirement of ≤ 10% was determined as the threshold needed to be met for the RMS comparisons.

3.0 PG and LR Comparison Process

To ensure that the study comparison was not jeopardized it was decided that the reflector would be put into alignment and measured with the LR first. A LR RMS value was then calculated using the predetermined measurement grid. The LR was used immediately afterwards to project the point grid onto the surface which allowed for easy application of PG targets. This method ensured that the same point locations are

consistent between both measurement methods. A PG RMS value was then calculated using this applied target grid. Since divulging RMS values is competition sensitive, the LR and PG RMS will be expressed as a % difference. The formula below is used:

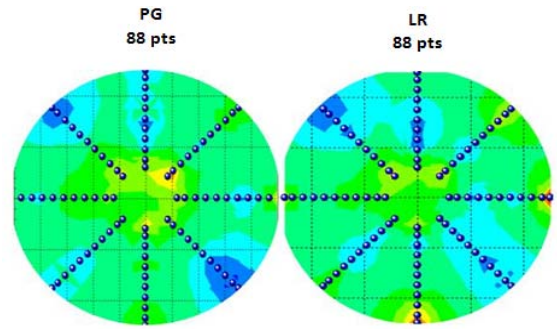
$$\text{Percent Difference} = \left| 1 - \frac{\text{LR RMS}}{\text{PG RMS}} \right| \text{ X } 100\%$$

It is important to note that comparing the calculated PG and LR RMS is inadequate for determining the relative accuracy of the two technologies since the surface of the reflector is less accurate than either method. It is however, sufficient for determining whether LR is accurate enough for production process.

3.1 (1.3 Meter Reflector)

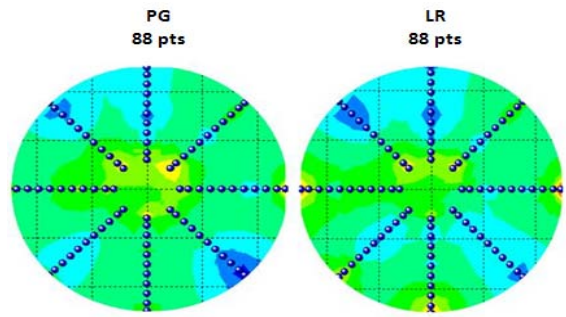
For a 1.3 meter reflector, (Figure 1) comparison data was captured on serial numbers 16, 17 and 18 during a recent manufacturing build. The comparison study mimicked the 88 point grid used by PG to verify reflector RMS throughout the manufacturing process. Plots were generated from the Z deviations to aid in graphically monitoring the surface of the reflectors. The tracking of Peak to Peak Z values between the two methods was consistent, (see Figures 2, 3, 4). For serial numbers 16, 17and 18 the percent difference in RMS values were 5.8%, 5.9% and 6.2% respectively.

Figure 1 – 1.3 Meter



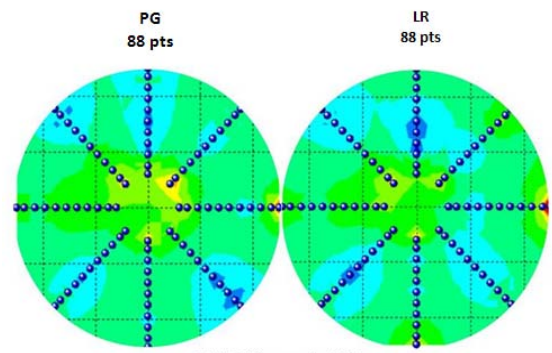
5.8 % Difference in RMS

Figure 2 – 1.3 Meter, SN 16



5.9 % Difference in RMS

Figure 3 – 1.3 Meter, SN 17

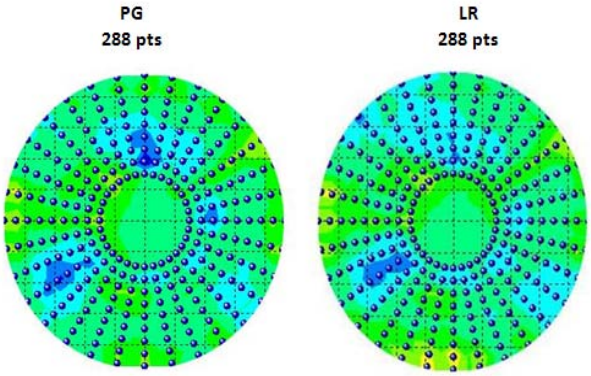


6.2% Difference in RMS

Figure 4 – 1.3 Meter, SN 18

3.2 (1.3 Meter, 288 Grid)

To evaluate the LR sensitivity of a denser point grid (288 pts), another 1.3 meter reflector was used. The denser grid increased the resolution and helped minimize the deviations for RMS and Peak-to-Peak values. The tracking of Peak-to-Peak Z values between the two methods was consistent, (see Figure 5). For this particular reflector, the difference between LR and PG RMS values was 5.6%.



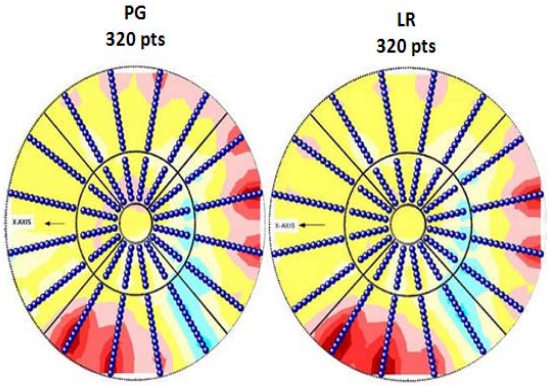
5.6% Difference in RMS

Figure 5 – 1.3 Meter, Denser Grid

3.3 (2.5 Meter Reflector)

The second size chosen for comparison was a 2.5 meter panelized reflector, (see Figure 6). This particular reflector is larger and deeper than the smaller 1.3 meter. This reflector would be characterized using 320 data points which represents the current PG process. The same measurement technique, alignment process, and analysis used in the 1.3 meter tests were applied to ensure consistency between data sets. The tracking of Peak to Peak Z values between the two methods was consistent, (see Figure 7). For this particular reflector, the difference between LR and PG RMS values was 1.6%.

Figure 6 – 2.5 Meter



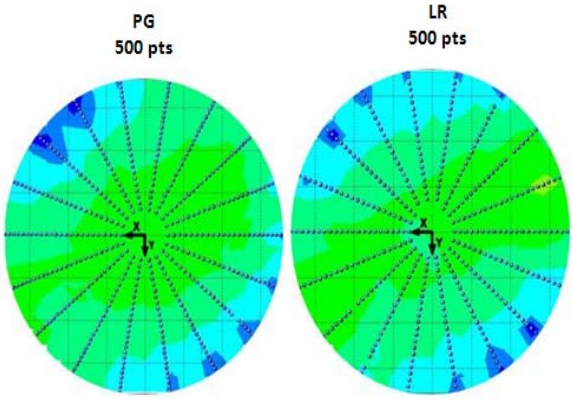
1.6 % Difference in RMS

Figure 7 – 2.5 meter

3.4 (3.8 Meter Reflector)

A third data point was a 3.8 meter trailer based, panelized antenna (see Figure 8). This larger reflector was characterized using 500 data points. Again the same measurement technique, alignment process, and analysis used in the 1.3 meter and the 2.5 meter tests were applied to ensure consistency between data sets. The tracking of Peak to Peak Z values between the two methods was consistent, (see Figure 9). For this particular reflector the difference between LR and PG RMS values was 2.6%.

Figure 8 – 3.8 Meter



2.6% Difference in RMS

Figure 9 – 3.8 Meter

4.0 Labor Savings

A labor savings analysis was performed on the 2.5 meter reflector. The results below are typical, but might vary depending on the size of the reflector. For both PG and LR, the following represented the four process steps that were compared:

Photogrammetry

- Setup – Target grid application
- Measurement – Perform photo shoot
- Process Data – Generate report & plot
- Cleanup – Remove targets & clean reflector surface

Laser Radar

- Setup – Position LR and perform reflector alignment
- Measurement – Perform scan
- Process Data – Generate report & plot
- Cleanup – Stow LR

The labor savings is displayed as a relative comparison between PG and LR. The formula below is used:

$$\%\ \text{Time Reduction} = 1 - \frac{\text{PG Process Time}}{\text{LR Process Time}}$$

In Figure 10 below, ~ 90% time reduction was realized with the use of the Laser Radar.

2.5 Meter Reflector (350 pts)	
Process Step	**% Time Reduction**
Setup	86%
Measurement	87%
Process Data	96%
Cleanup	88%
Total	89%

Figure 10 – Labor Comparison

Most of the PG time was spent applying target, removing targets, and processing data in accordance with Harris' standard procedures. But, data processing time for PG could be greatly reduced via the use of newly developed scripting techniques.

The findings showed that it is possible to perform 100% unit inspection with LR and reduce the recurring cost compared to the lower rate sampling approach used with PG. For this application of determining the surface profile of reflectors, Laser Radar was a suitable alternative to Photogrammetry in the reduction of recurring labor associated to a production environment.

5.0 Conclusion

For small to medium sized reflectors in a production environment, the use of the LR significantly reduced the reoccurring labor required to characterize the surface profile (i.e. RMS) of reflectors. This evaluation demonstrated that when compared to PG, LR met the requirement of ≤ 10% from a dimensional comparison standpoint. In addition to achieving parity in measurement performance to PG, LR achieved significant cycle time reduction with the use of automated programs. The difference in RMS was 6% maximum for small reflectors and substantially closer for the larger 2.5m and 3.8m reflectors. Peak-to-peak Z values measured by LR were consistent when compared to PG. The comparison study satisfied the requirements needed to implement the LR into areas of heavy production where cycle time and labor costs are driving factors. Further investigation is expected using PG and a newly developed target projector which may further reduce cycle time and labor costs.