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February 5, 2016

VIA IBFS

Marlene H. Dortch, Secretary
Federal Communications Commission
445 12th Street, S.W.
Washington, D.C. 20554

Re: DIRECTV Enterprises, LLC; Modification Application to Launch and Operate DIRECTV RB-79W, a Satellite in the 17/24 GHz Broadcasting Satellite Service at 79° W.L.; File Nos. SAT-MOD-20150428-00031 and SAT-AMD-20150818-00058; Call Sign S2861

Dear Ms. Dortch:

DIRECTV Enterprises, LLC ("DIRECTV"), by its counsel, herein submits a white paper intended to aid the International Bureau's review of the waiver request submitted in association with DIRECTV's pending modification application seeking authority to operate SKY Mexico-1 (also known as DIRECTV RB-79W), a geostationary satellite in the 17/24 GHz Broadcasting Satellite Service ("BSS"), at the nominal 79° W.L. orbital location.[1] The white paper by Orbital ATK is titled "SKYM-1 Satellite R-Band Off-Axis Performance: Analysis Methodology and Correlation to Test Results" and provides additional detail and rationale for the methods used to assess the far off-axis performance of the satellite transmit antenna. DIRECTV respectfully requests expeditious grant of this pending application.

Please do not hesitate to contact the undersigned with any questions.

Respectfully Submitted,

/s/ Jennifer D. Hindin

Jennifer D. Hindin
Counsel for DIRECTV Enterprises, LLC

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1 IBFS File No. SAT-MOD-20150428-00031.

SKYM-1 Satellite R-Band Off-Axis Performance: ***Analysis Methodology and Correlation to Test Results***
January 26th, 2016

Introduction:
This document serves as an overview to the methodology applied when assessing the SKYM-1 R-Band Off-Axis transmissions, and how this directly relates to the requirements stipulated in FCC Section 25.264 (critical sections summarized below). As part of this assessment, Orbital ATK concluded that a combination of analysis and test would be required. Firstly, analysis would be required to assess levels more than 35+ dB below the main transmit beam due to intrinsic noise floor limitations of near-field/compact ranges. Secondly, via test, to correlate main beam performance values to confirm the predictive quality of the analysis.

Synopsis of Required Angular Ranges: From Section 25.264a (1), (2), & (4)

- Transmitting antenna off-axis gain over a range of ±30º from the X axis in the X-Z plane (in 5° intervals), and over a range of ±60º in planes rotated about the Z axis (in 10° intervals).
- Off-axis antenna gain measurements be made at a minimum of three frequencies (5 MHz above the lower edge of the band; at the band center frequency; and 5 MHz below the upper edge of the band).

Synopsis of Submitting Predicted/Measured Off-Axis Gain Data: From Section 25.264c & 25.264d

- Submit predicted transmitting antenna off-axis gain information over the angular ranges described above. Provide pfd calculations on the basis of this predicted antenna gain data.
- Confirm the predicted data by submitting measured off-axis antenna gain information over the same angular ranges described above.
- To the extent practical, measurements should be made under conditions as close to flight configuration as possible. This could be done with the antenna mounted on the spacecraft or may include the use of simulated spacecraft components.

Section 1 will provide an overview of the analysis methodology used to generate our Off-Axis model which combines Feed Off-Axis transmissions beyond the reflector edges (i.e. spill-over) with main beam scattering effects from the spacecraft body.

Section 2 will cover analysis results from both the combined feed/scattering off-axis as well as performance from off-axis feed contributions only. The comparison of these results exhibit how the Off-Axis performance is driven by the feed spill-over, and that the scattering effects from the spacecraft body are negligible.

Section 3 provides a snapshot of measured (near-field range) data, and is used to confirm that the predicted analysis performed on the main beam (including scattering effects) correlates to the measured data. As a conclusion to this section, the analysis results for the SKYM-1 off-axis PFD value is supplied, showing sufficient margin to the -117 dBW/m^2 /100kHz.

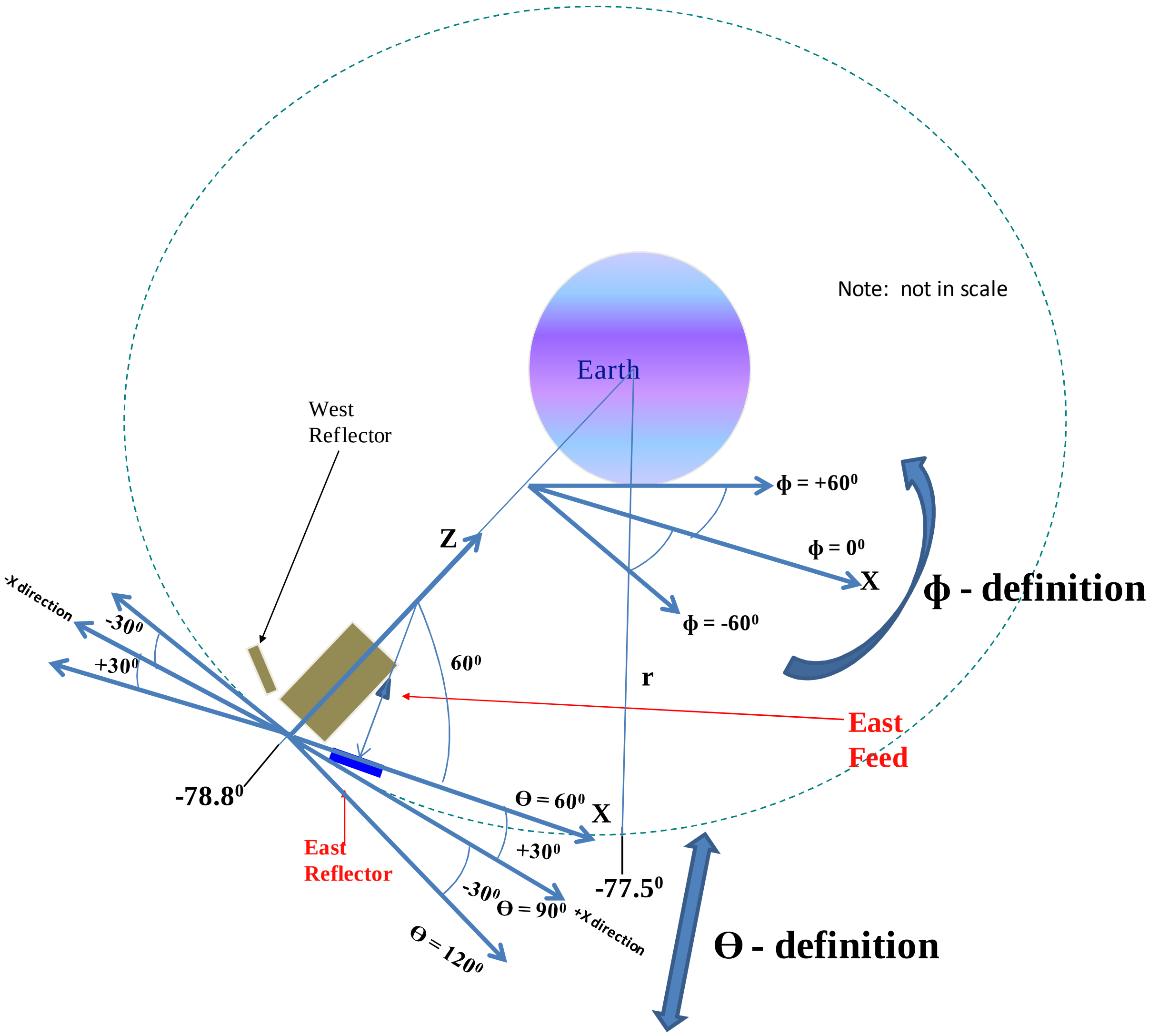

Figure 1 – Definition of Spacecraft Coordinates

Section 1: Analysis Methodology for Off-Axis Performance

As mentioned in the overview, Orbital ATK recognized that actual scattering levels generated by R-Band Feed interaction with the Spacecraft (and other contributors) would result in energy field levels far below the intended transmission beam. Therefore, performing measurements at the spacecraft level would be insufficient to accurately quantify these negligible field levels. Accuracy of near field ranges incur increasing levels of error as they drop below 35 dB of dynamic range, and while this may be sufficient for feed spill-over measurements it would not be capable of measuring scattering only effects. This limitation in addition to the inability to mechanically accommodate a fully deployed satellite on a rotating compact range pedestal, precluding Orbital ATK from verifying compliance to field levels solely through measurement.

In order to properly quantify the potential co-satellite interference, Orbital concluded that a combination of spacecraft level analysis supported by unit level measurements would be required. This would then be correlated through spacecraft level testing down to its dynamic range limitation. Specifically, Orbital would utilize “as-measured” reflector surface shapes combined with “as-measured” feed horn performance and place these into a spacecraft level scattering analysis using modeled panel surfaces. For these analyses, a worst case “non-randomized” (flat) surface was assumed for the East face of the spacecraft and modeled using Orbital ATK’s standard TICRA Grasp software.

The modeling itself was constructed to combine (4) contributing elements (paths). These are described in detail below:

Contributor # 1: Feed → Reflector → Far Field

Related field from the feed horn is incident upon the reflector which reflects RF radiation to the far-field. Most of the RF radiation is concentrated into the coverage region. Some very low level radiation will be scattered or diffracted towards off-axis regions.

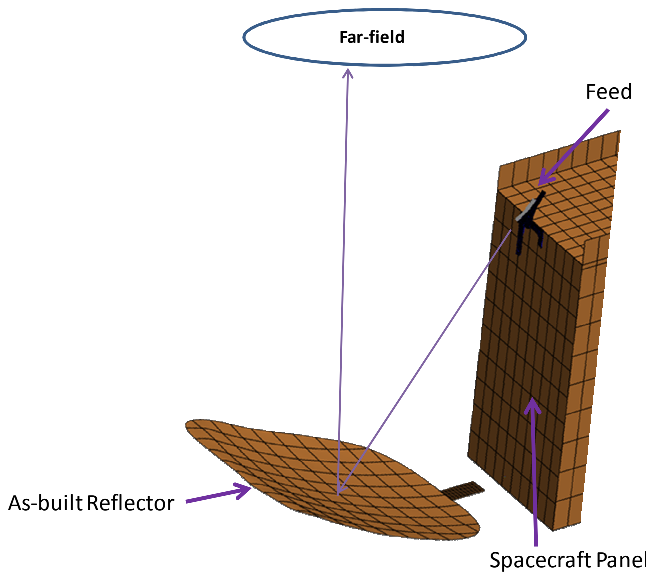

Figure 2 – Feed to Reflector to Far Field Contribution

Contributor # 2: Feed → Far Field

This contributing element accounts for off-axis radiation sourced directly from the feed, but not captured within the main beam due to its gradual directivity roll-off. Low level radiation is transmitted beyond the edges of the reflector (i.e. spill-over).

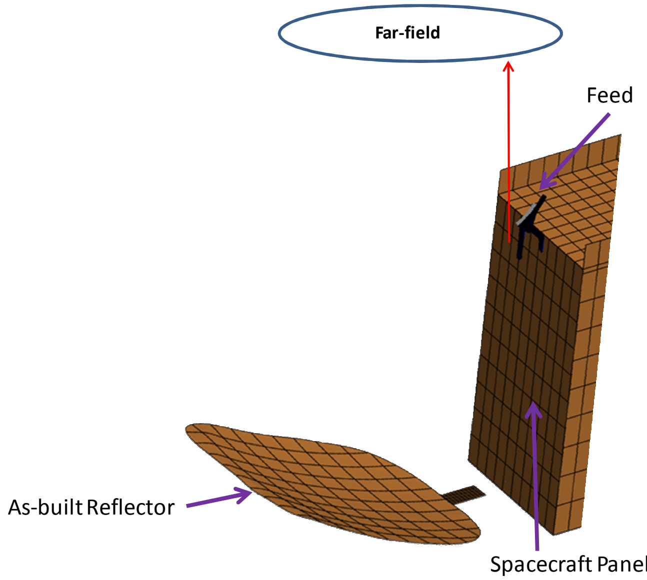

Figure 3 – Direct Feed Contribution to Off-Axis (i.e. Spill-Over)

Contributor # 3: Feed → Panel → Reflector → Far Field

Due to its close proximity to the Spacecraft East Panel, the R-Band feed's transmitted field will incur reflections away from the spacecraft panel, subsequently followed by reflecting off the reflector surface towards the off-axis direction.

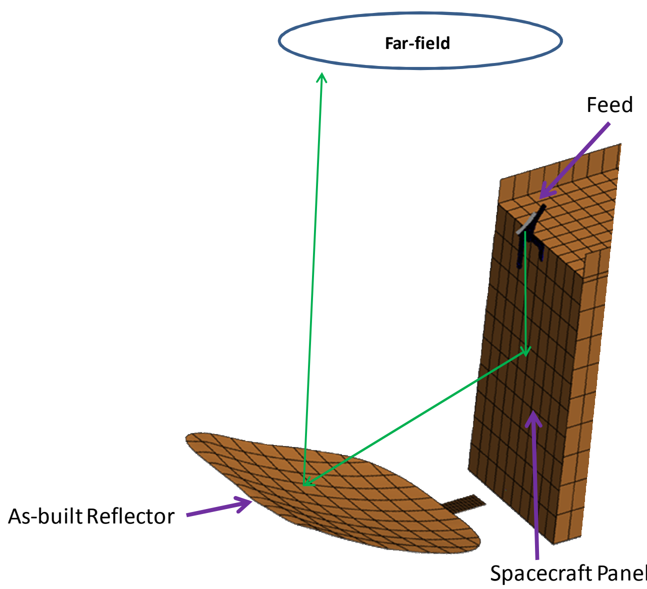

Figure 4 – Multiple Reflection Condition Feed to Panel to Reflector

Contributor # 4: Feed → Reflector → Panel → Far Field

Similar to the condition noted in Contributor #3, close proximity of the reflector to the Spacecraft East Panel as well as the angle and shape of the reflector facilitates a portion of the main beam to be directed back towards the East spacecraft panel which then reflects into the far field.

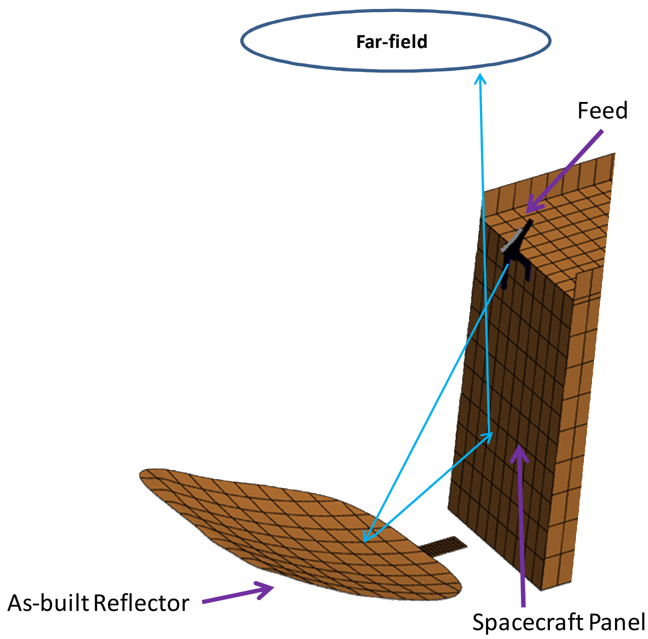

Figure 5 – Mulitiple Reflection Condition Feed to Reflector to Panel

Section 2: Comparison of Predicted versus Measured Off-Axis Performance

Prior to reviewing the predicted performance levels, it is important to understand the reference frame to which the field strength are being analyzed. As shown in Figure 7 below, the ±30º Theta Range and ±60º Phi range are located just above the edge of the reflector body, as this provides a worst case region of field strength. It should be noted that closest co-satellite location is likely much closer to the +X-axis direction (shown by red arrow), however, Orbital ATK applied conservatism by shifting this range downward.

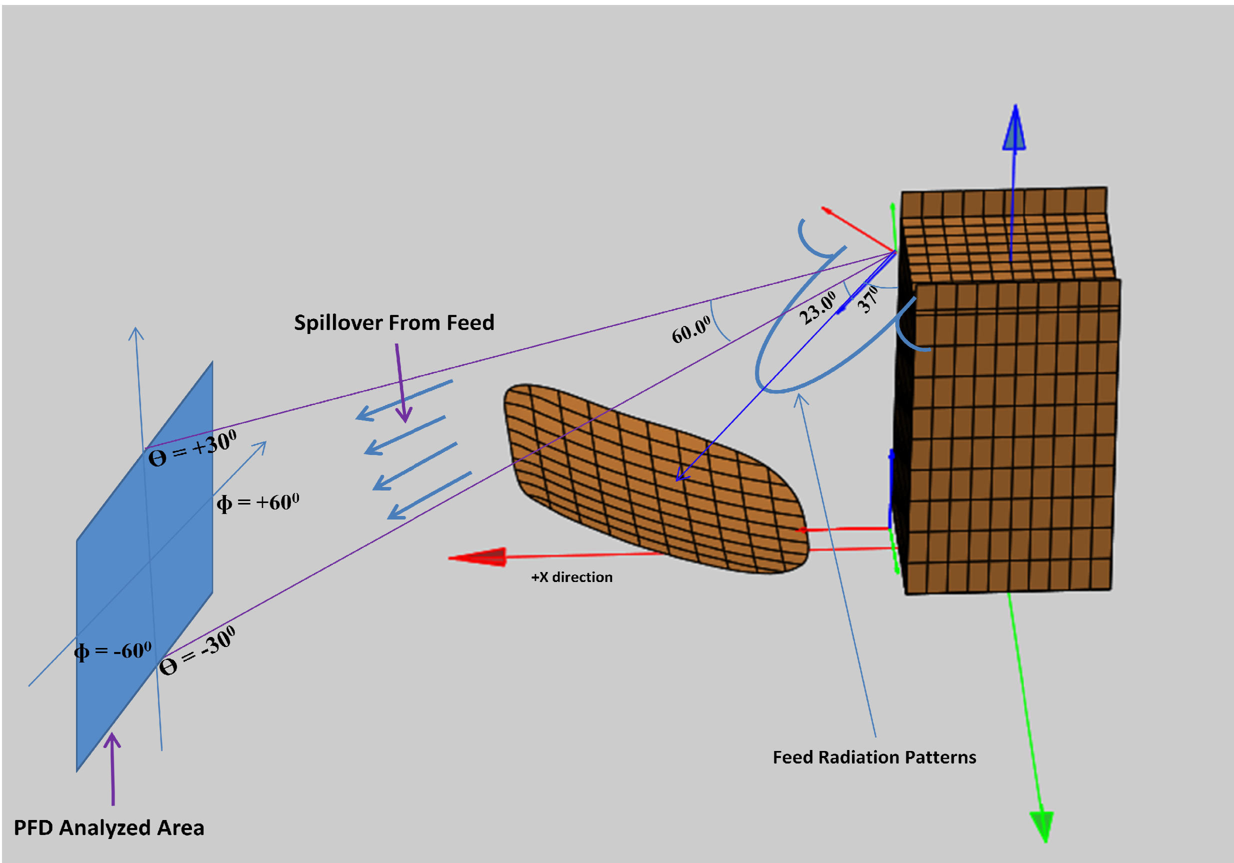

Figure 6 – Visualization of Analyzed Angular Ranges

The analysis results exhibited in Figure 7 and Figure 8 below provide two plots each. The first plot (left) exhibits a fully predicted performance, while the second plot (right) replaces the R-Band Feed horn predicted pattern with the "As Measured" pattern. As can be seen in this plot, the measured feed horn performance exhibited high correlation to the predicted pattern.

As expected, the highest field strength level is observed on the East side, in the region closest to the edge of the reflector. This is where the highest "spill-over" occurs, due to being closest to the boresight of the feed horn but not obstructed by the reflector surface itself. It can also be seen by looking at the top of these plots how the field strength drops off underneath the edge of the reflector surface (colors drops to lighter red than orange at very top).

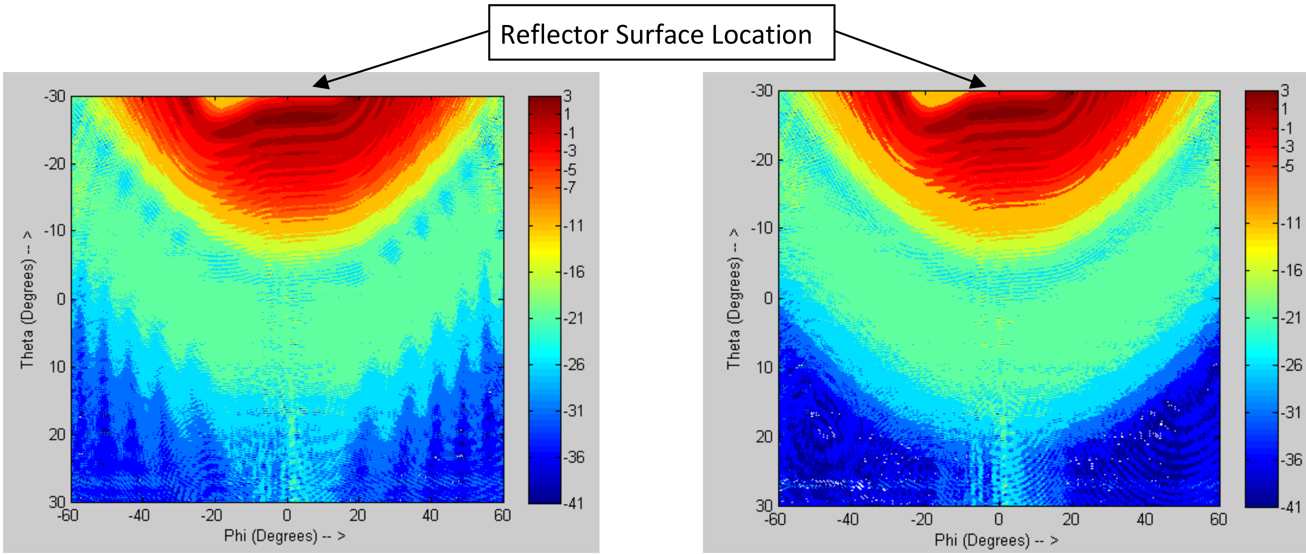

Figure 7 – East Side Prediction (Left) Off-Axis Performance versus Predicted w/Measured Feed (Right)

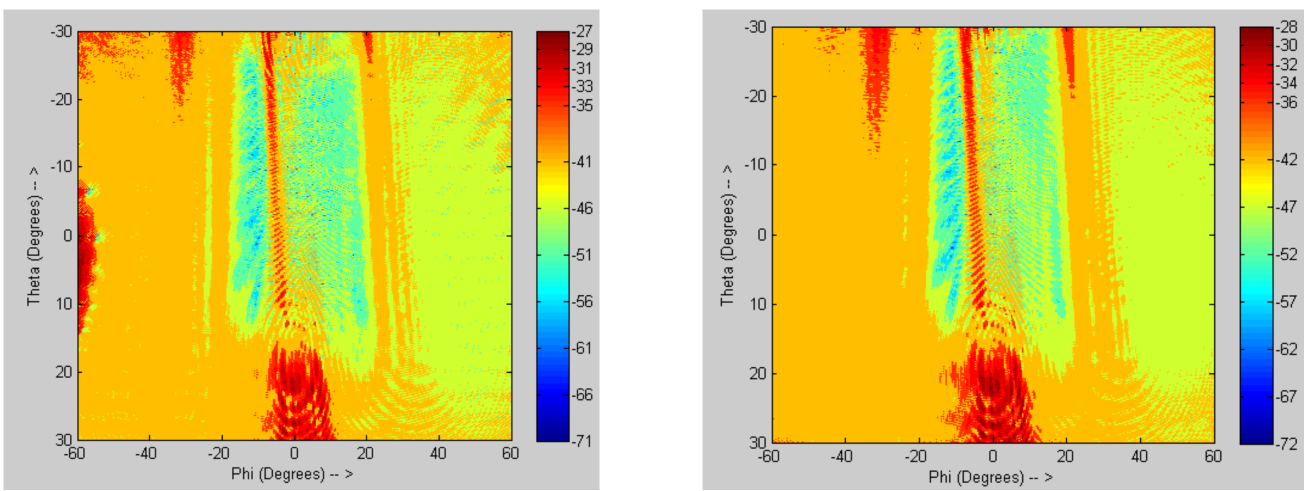

Figure 8 – West Side Prediction (Left) Off-Axis Performance versus Predicted w/Measured Feed (Right)

It becomes evident from the field strengths and gradients observed in Figure 7, that the primary driver for co-spacecraft interference will be driven by the East Feed itself, and the "spill-over" that occurs outside the edges of the reflectors. To verify this assumption, Orbital removed all scattering contributions from its TICRA Grasp model (i.e. only left in contributor #2). The results from this configuration are included below in Figure 9 and can be compared to those plots in Figure 7 showing that they are very consistent. Measured results from the R-Band feed are also exhibited below in Figure 10, and show how the gain value is consistent with expectations at an angular offset of 23 degrees (the angular distance to the edge of the reflector as shown in Figure 6).

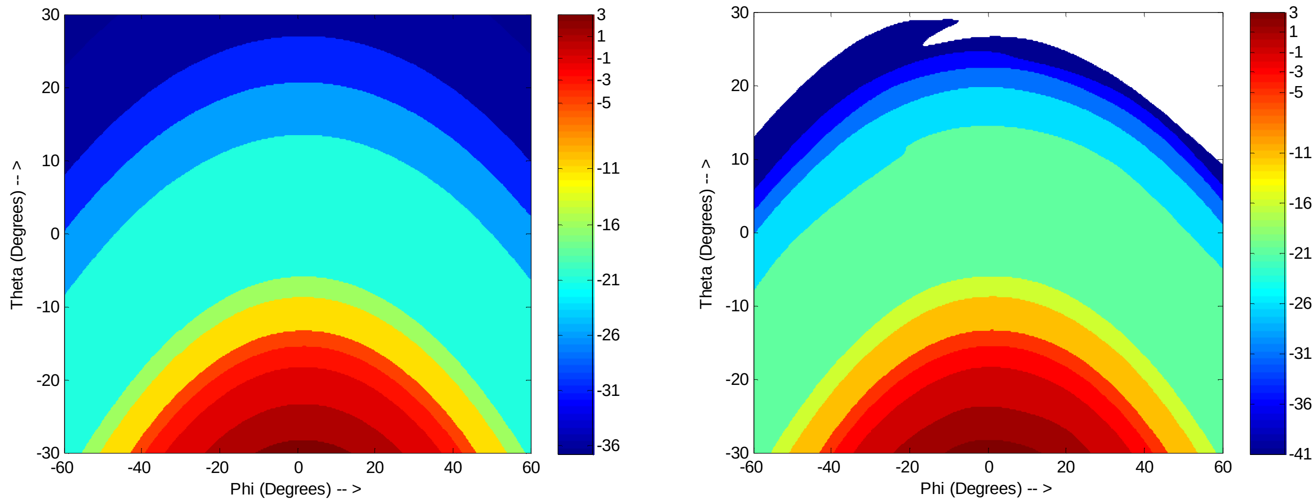

Figure 9 – R-Band Feed Off-Axis Performance Prediction (Left) versus Measured (Right)

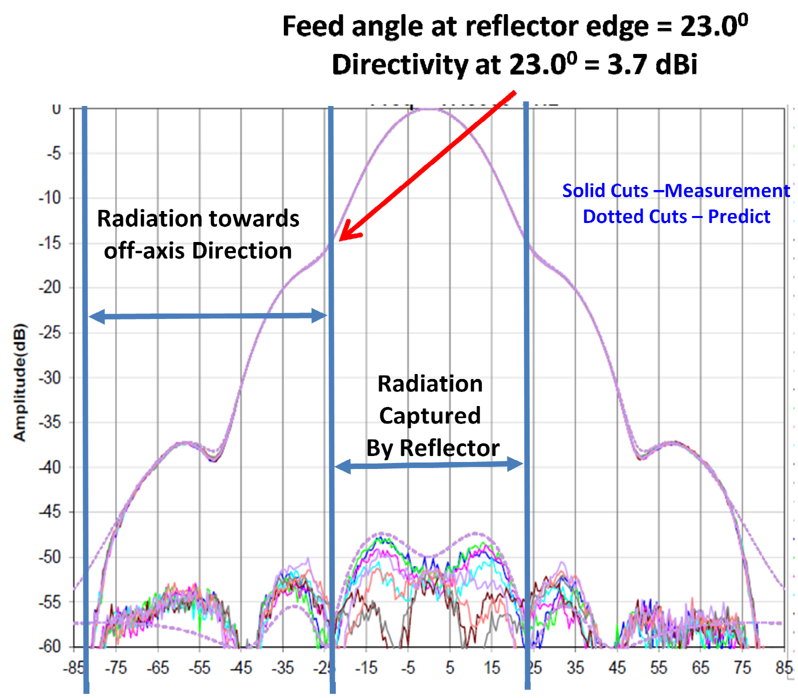

Figure 10 – R-Band Feed Measured Gain Roll-Off (Co-Pol & Cross-Pol)

Section 3: Spacecraft Measured Performance versus Predicted

The plot included below as Figure 11 exhibits an overlay of measured versus predicted performance. Measurements were performed as a fully integrated Spacecraft level, with reflectors deployed in their flight-like configuration. Solid lines in the plot represented as-measured patterns, and dotted lines represent predicted patterns. As can be see in this plot, all dotted and solid lines overlap extremely well, with divergence beginning to occur when the field strength is approximately 40 dB below the primary beam.

Based on these results, we can expect that any stray field strengths higher than this dynamic range should appear on this plot. Therefore, knowing that scattering performance is included within the prediction model, we can have comfort that the model accurately predicts all major sources of scattering performance.

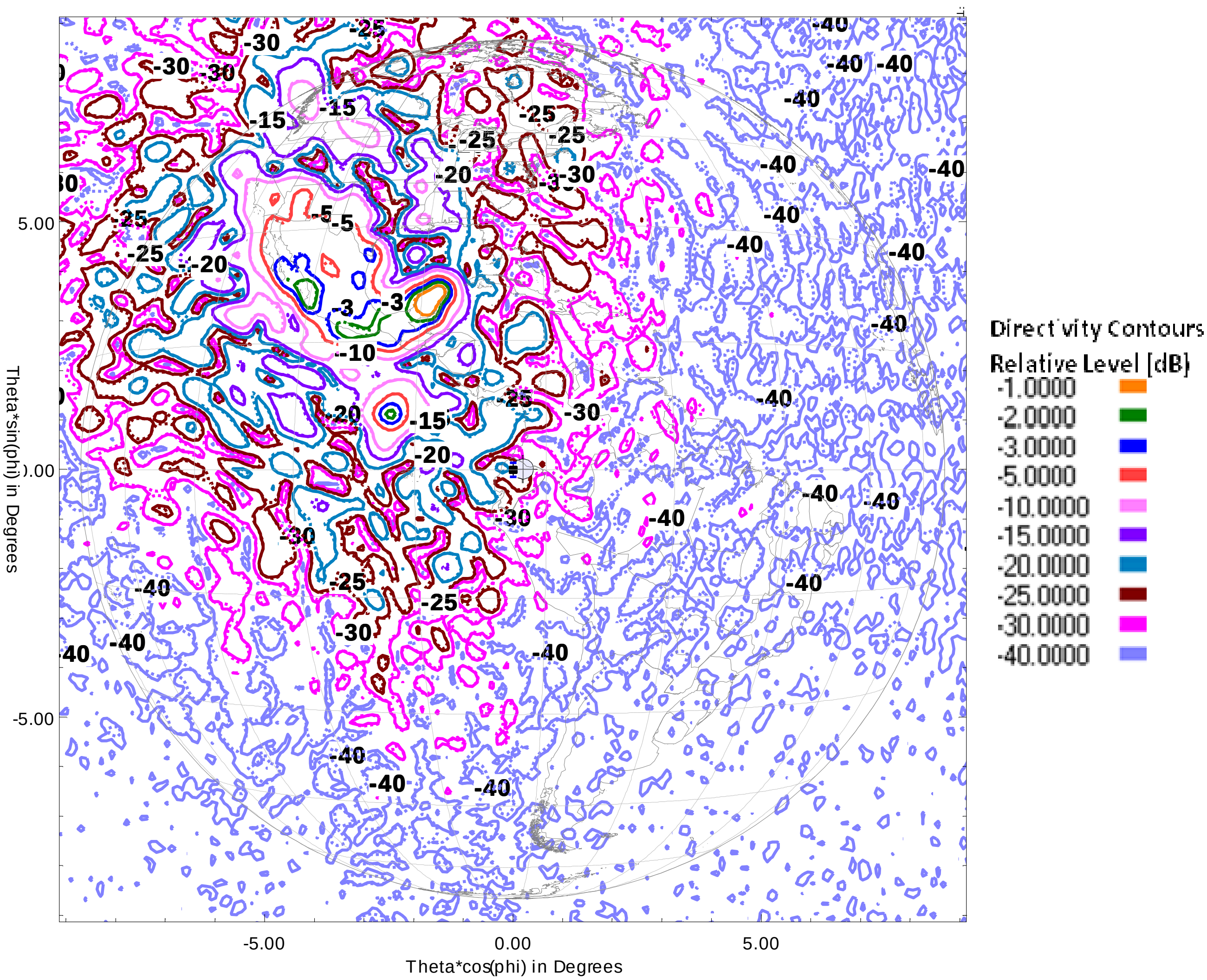

Figure 11 – As-Measured vs Predicted Spacecraft Transmitted Performance (Includes Scattering)

Co-Satellite interference calculations, as shown in Figure 12, use the highly conservative peak field value determined in the predictive analysis (Figure 7) which would correlate to a satellite within several meters of the source, instead of one that is nearly 100km away (at a 1.3º orbit location offset). However, using this values provides traceability to the as-measured system data due to being only 15 dB below the peak feed horn gain (see Figure 10) which places it approximately 35 dB below the reflected beam peak (note: ~20 dB gain in reflector).

- Orbital Location = -78.8^0
- Angular Separation = 1.3^0
- r = (6378 + 35,786) km = 42164 km
- Distance between orbital location
  - $d^2 = r^2 + r^2 - 2*r*r*\cos(1.3*pi/180)$
  - d = 956650.3 m
- Spreading Loss: $Loss = 10 \log\left(\frac{1}{4\Pi d^2}\right)$
  - Loss = 130.6 dB/m^2
- Peak radiation Level over all $\pm 60^0$ and $\pm 30^0$
  - 3.8 dBi (predicted peak)
- Conversion Factor = 15.24 dBW
- Peak EIRP Level = 3.8+15.24= 19.0 dBW
- Peak PFD = 19.0 -130.6 dBW/m^2 = -111.6 dBW/m^2
- For 100 KHz, PFD = -111.6 – 10*log(30X10^6 / 100X10^3) dBW/m^2 /100 KHz
- Peak PFD = -111.6- 24.7 dBW/m^2 /100 KHz
- **Peak PFD = -136.3 dBW/m^2 /100 KHz**
- **Spec Requirement is -117 dBW/m^2 /100 KHz**
- **Margin = 19.3 dB**

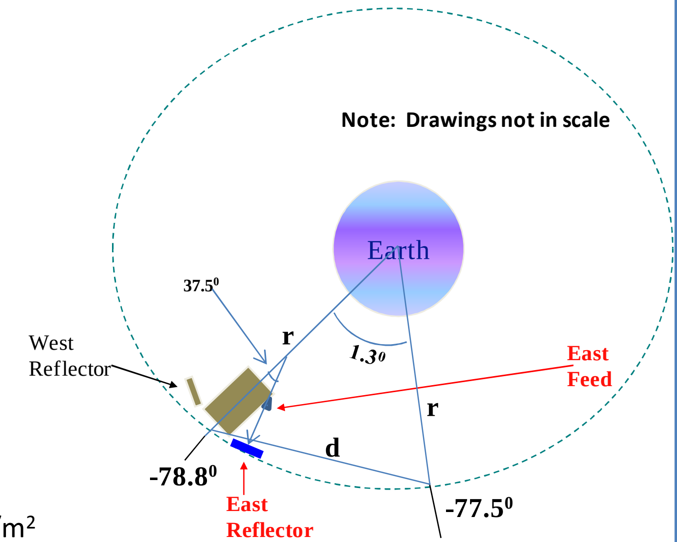

Figure 12 – Maximum Co-Satellite Interference @ 1.3º Offset

In summary, due to the lack of dynamic range in full satellite RF measurement facilities a combination of analysis, unit level measurements, and correlation to spacecraft level measurement sufficiently provides confirmation of what drives co-satellite interference. Once this is established, the calculation can then be performed (as shown in Figure 12) which confirms compliance performance to the field strength spectral requirements.