In Orbit Antenna Pattern Tests and Service Coverage Measurements of COMS

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Abstract*—Communication, Ocean and Meteorological Satellite (COMS) is the multi-purposed Korean geostationary satellite funded by Korean government ministry, and is to supply communication services, ocean and weather observation for 7 years. COMS was launched by Ariane-5 on 26th June 2010 and arrived successfully to operational geo-stationary orbit 128.2E. It features a multi-beam Ka-band Communications package, a set of equipments to study Ocean Ecosystem to aid the fishing industry and a Metrological weather observation system. The multi beam Ka-band antenna in orbit test campaign was conducted by Electronics and Telecommunications Research Institute team. A brief outline on functional and operational capability including software and hardware used for in orbit test validation of Ka-Band antenna system is addressed. After successful in orbit test, service coverage measurement for COMS Ka-band antenna was performed. Methodology and results for service coverage measurement are addressed also. The antenna in orbit test results show COMS Ka-band antennas performance was not degraded by satellite launch and service coverage are formed as we designed over the south Korea peninsula.

Keywords-Communication, Ocean and Meteorological Satellite; Ka-band payload; In orbit test; Service coverage measurement.

I. INTRODUCTION

Communication, Ocean and Meteorological Satellite (COMS) is a multi-mission satellite and one of the key features of this satellite is the Electronics and Telecommunications Research Institute (ETRI) developed multi-beam Ka-band antenna system [1] that consists of two spot beams; South Korea and North Korea as shown in Figure 1. The antenna system consists of two reflectors installed on the east and west panel of the spacecraft. COMS is first of its kind that incorporates both earth observation and communications payloads from single geostationary satellite [2][3][4]. This paper describes field measurement of COMS antennas pattern and coverage of this unique satellite. Correlation between ground and field measurement shape for this multi beam Ka-band antenna pattern and coverage is presented.

In this paper, COMS Ka-band antenna configuration was reviewed at Section 2. In orbit test methodology for antenna pattern measurement was reviewed at Section 3 and in orbit test results was reviewed at Section 4. Section 5 and Section 6 describe filed measurement of COMS Ka-band payload service coverage and conclusion, respectively.

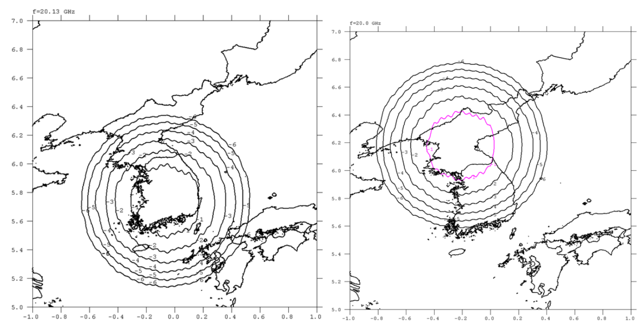

Figure 1. COMS service coverage for SK and NK beams

II. COMS ANTENNA AND GROUND TEST

The antenna system consists of two reflectors installed on the east and west panel of the spacecraft. Each reflector mounted on Antenna Deployment and Trim Mechanism (ADTM) comprised of offset reflector integrated with backing structure and sun shield, as illustrated in Figure 2. The ADTM provides on orbit capability to adjust beam pointing. The reflecting surface is graphite and support structures are honeycomb sandwich with graphite/epoxy face sheets and aluminum core. East reflector is illuminated by two feed horns generate South Korea and China Beams. West reflector is illuminated by single a feed horn to generate North Korea beam.

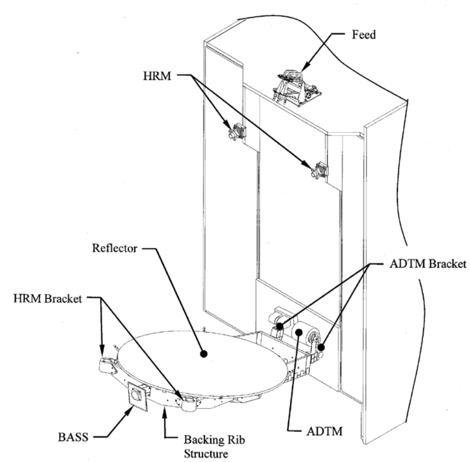

Figure 2. Illustration of Antenna Configuration (East Panel)

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At unit level, pattern tests were performed at ETRI (Daejeon, Korea) Near Field Range before and after environmental tests for various parameters, such as gain, side-lobe, cross-polarization, co-polarization isolation, alignment information between reflector and feed. At the system level, these tests were independently performed by MDA (Montreal, Canada) in Compact Antenna Test Range (CATR). The two sets of test results are summarized in literature [5].

III. In Orbit test methodology

After successful launch of a satellite and bus In Orbit Test (IOT), a series of measurements are performed to verify and identify if any mechanical or RF parameters of satellite antennas are degraded or changed. The satellite antenna IOT is essentially Power Flux Density (PFD) and Effective Isotropic Radiated Power (EIRP) measurements over selected points of the coverage pattern carried out by accurately measuring at an earth station. One of the most important tasks is thus earth station and test equipment calibration. ETRI did this calibration on the earth station located at Daejeon, South Korea, prior to IOT commencement using operating KOREASAT satellites. Antenna pattern tests involve a number of single (E- or H-) plane radiation pattern cut measurements [6][7]. The measurement can be done point by point (direct measurement, no processing required). In modern satellites, a antenna pattern cut can also be performed much faster by slewing the satellite at known speed and recording in a computer the earth station power level measurements time stamped that need complex data processing

A. *Antenna IOT Objectives*

The Antenna IOT, also known as antenna mapping, is not a replacement of range test because IOT tests are subject to many uncertainties and is not as detailed as CATR. IOT is a confirmation test with following objectives:

- Confirm that no RF or mechanical or damage due to harsh launch environment
- Ascertain correct reflector pointing and recommend if ADTM adjustment required
- Confirm pattern shape integrity and identify if there is any RF performance degradation
- Validation of TED model

B. *Special Test Considerations*

At Ka-Band IOT, weather impact is significant and antenna IOT was carried out only during dry periods. Antenna pattern cuts are relative measurements and error will be minimized if the variations of measurement uncertainties attributed by weather and equipment drift can be minimal during each of the pattern cuts. In consideration of above, for COMS Ka-band antenna pattern cut measurements, spacecraft slewing method [8] has been selected that implies measuring the SFD and EIRP at Daejeon earth station while the satellite with antenna is moved at known speed that results a pattern cut. An antenna pattern cut was completed within 15~20 minutes instead of couple of hours with point by point method [8].

C. *IOT Data Processing*

Astrium (Toulouse, France), the satellite manufacturer using their restitution software processed the satellite positional time stamped data and ETRI, Korea processed the ground measured data also time stamped. ETRI/Telesat software was used to synchronize the two data sets that enabled to extract each pattern cut plots. The IOT measured pattern cut plot is then compared with ground based measurements to evaluate in orbit performance. Antenna IOT, also known as antenna mapping, is not a replacement of range test because IOT tests are subject to many uncertainties and is not as detailed as in CATR.

IV. IOT test result summary

Astrium, using their restitution software processed the satellite positional time stamped data. ETRI extracted satellite position to measured signal strength data for each cuts. Because the beams are unshaped circular, it was considered to have only two pattern cuts (E- and H) for each beam instead of multiple cuts [9] for shaped beam antennas. This philosophy was adopted primarily to save antenna IOT time. ETRI/Telesat software was used to compare each pattern cut with ground based CATR measurements to validate beam shape integrity and identify precisely the desired bore-sight adjustment. In simple terms the software did try to match each pattern cut by shifting incrementally in both azimuth and elevation until best match is achieved for both E- and H-plane cuts.

A. *Antenna Pattern Shape Integrity*

Figures 3 and 4 show typical E- and H-plane plots of antenna pattern cuts measurements respect to the CATR measurement for South Korea and North Korea Beam. The plots show that the antenna patterns measured during IOT are very similar with CATR measurement.

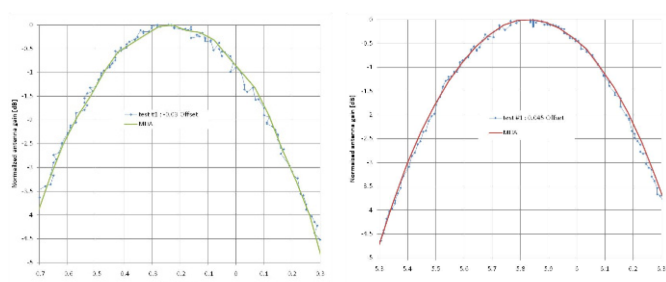

Figure 3. South Korea Beam Plot (East Reflector)

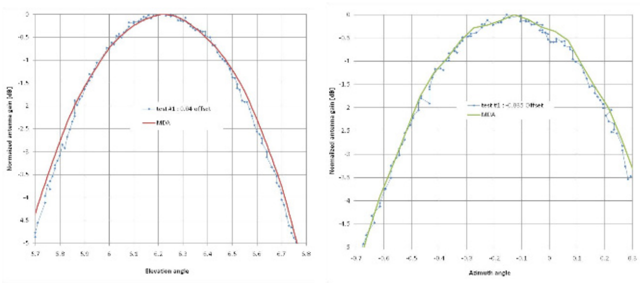

Figure 4. North Korea Beam Plot (West Reflector)

B. *Antenna Beam Pointing Adjustment*

The IOT data analysis predicted an average de-pointing of 0.045^0 for South Korea and 0.040^0 for North Korea Beam. This implies re-pointing of 0.025^0 for East reflector and 0.020^0 for West reflector considering that feeds are fixed and ration between mechanical and RF beam shift is 1+BDF (~1.9). But, antennas still meet the specified EIRP and G/T requirements with above de-pointing. Such a small de-pointing is within measurement tolerance, and therefore, it is considered that no ADTM adjustment is necessary for either reflector

C. *Antenna Thermo Elastic Distortion (TED) Validation*

An extensive thermal deformation analysis were carried out during design phase and maximum deformation is found to be 0.276mm for West reflector at begin of life for sun normal illumination, which corresponds to directivity loss of less than 0.2dB at edge of coverage. The thermal analysis also shows that maximum de-pointing due to TED is less than 0.02^0 and occurs around equinox. The IOT was performed around summer solstice when the deformation is minimal and gain loss is below measurement tolerance and therefore no useful thermal distortion tests could be conducted.

D. *Cross-polarization and pointing Confirmation Tests*

Antenna IOT had been performed at a single frequency and it is industrial standard to perform IOT based on co-polarization measurements. This is because cross-polarization measurements are not accurate enough to get a meaningful result. Both co- and cross-polarization performances were measured at three selected locations for each beam at low, mid and high frequency transponder. These results were compared to ground based predicted EIRP and SFD. The measured values were within measurement uncertainties (0.5dB for co-polarization and 2dB for cross-polarization) and thus confirms both pointing and cross-polarization.

V. SERVICE COVERAGE MEASUREMENT OVERVIEW

The purpose of service coverage measurement is to check how much EIRP contour map of COMS in orbit is similar with contour map gathered from the ground test in CATR facility. For the service coverage measurement, it needs to measure COMS Ka-band signal power over the South Korea area. The service coverage measurements need two system supports, master ground station and mobile station. The master ground station located in ETRI transmits un-modulated RF signal and experimental 3DTV broadcasting signal to COMS. The master ground station receives measure returned un-modulated RF signal from the COMS and it also receives Ka-band beacon signal from the COMS. The measured un-modulated RF signal levels in the master ground station were used for reference values for mobile station measurements. The measured beacon signal was used for signal compensation attenuated by atmosphere.

The mobile station receives un-modulated RF signal generated by master ground station and repeated by COMS. Received beacon signal level was used for signal compensation attenuated by atmosphere to eliminate disturbance form the atmosphere condition changes. 3DTV broadcasting signal quality was measured by professional receiver to check Es/No and packet CRC errors. Figure 5 shows the simplified diagram for service coverage measurement [10].

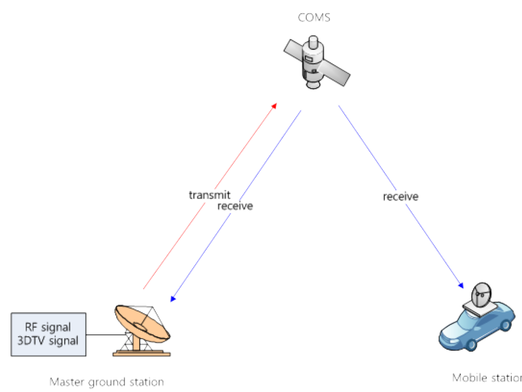

Figure 5. COMS service coverage measurement diagram

Master ground station has 7.2 meter size of diameter satellite antenna and 175W output power high power amplifier. Mobile station has 1.8 meter size of diameter antenna with auto tracking equipment. Figure 6 shows the master ground station and mobile station, respectively, used for COMS service coverage measurement.

Figure 6. Master ground station antenna and mobile station

The 17 measurement points over the South Korea peninsula are selected for mobile station measurement. Except reference point, all measurement points were selected on coast area because field measurements are to check

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service coverage of COMS Ka-band payload. Selected measurement points are shown in Figure 7.

- Reference point: ETRI in Daejeon(14)
- West coast area: Ganghwa(1), Taean(2), Byeonsan (3), Jindo(4)
- South coast area: Goheung(5), Geoje(6), Busan(7)
- East coast area: Pohang(8), Uljin(9), Sokcho(10), Goseong(11)
- North area: Chuncheon(12), Pochecon(13)
- Jeju island: Chagwido(15), Mosulpo(16), Sungsan (17)

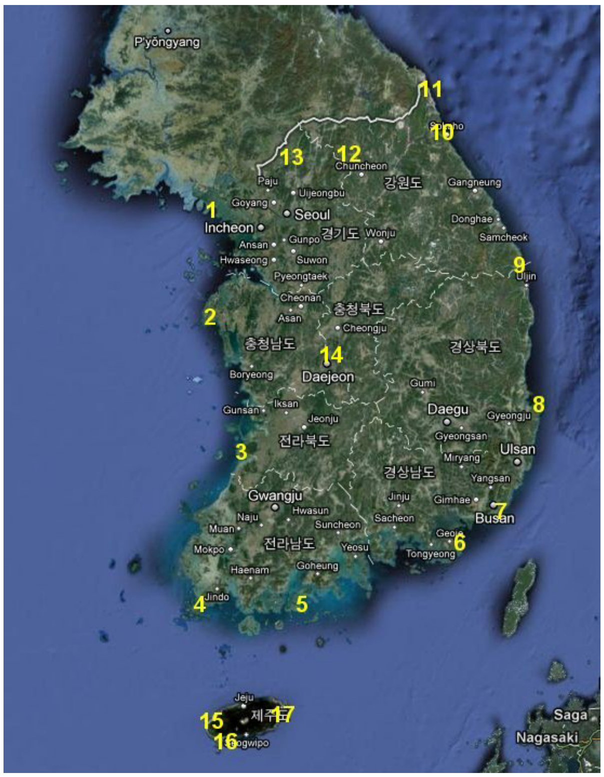

Figure 7. Measurement points for service coverage

VI. Service Coverage Measurement Results

Measurement data from the mobile station at 17 measurement point were normalized by the measurement data at the reference point. The signal variation due to the atmospheric condition was compensated by the beacon signal level data. Figure 8 shows the service coverage contour map for South Korea beam and Figure 9 shows the service coverage contour map for North Korea beam respectively.

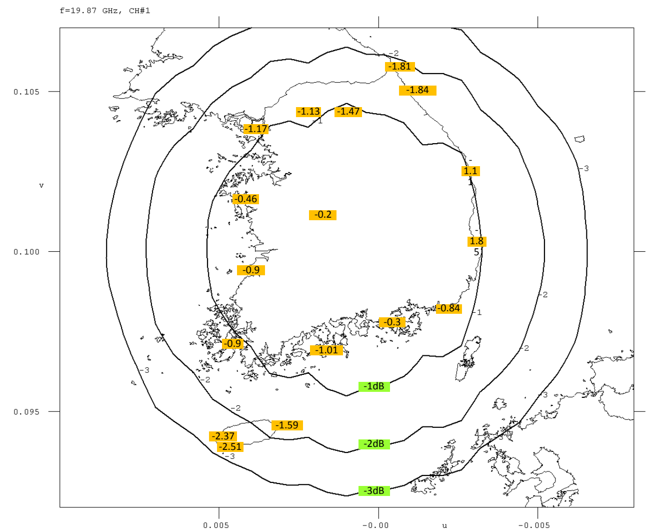

Figure 8. Service coverage map of South Korea beam

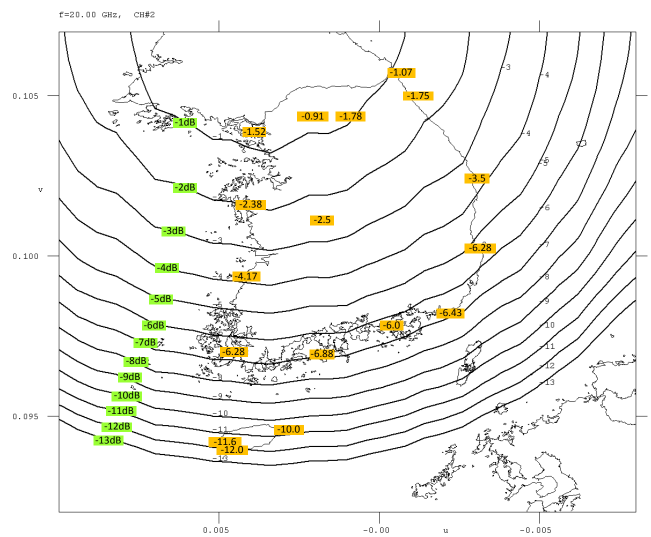

Figure 9. Service coverage map of North Korea beam

The above figures show that field measurement results over the South Korea at 17 points are similar with ground test results (solid line). The deviation between field measurement and ground test results are less than 1dB. This deviation value is acceptable when we consider measurement equipment stability of each ground stations and mobile station antenna pointing errors during field measurement. The reception of experimental 3DTV service was good for all measurement points. There were enough Es/No margins (3.5~8.5dB) and no packet CRC errors for 3DTV service over the South Korea. The field measurement results show that COMS Ka-band service coverage is formed well in orbit as we designed.

VII. Conclusion and Future Works

In this paper, we reviewed in orbit antenna pattern test results and service coverage measurement results of COMS.

The in orbit antenna pattern cuts have shown excellent agreement confirming beam shape integrity. The EIRP and SFD measurement at selected locations was well within measurement uncertainties when compared to that predicted from ground based measurements. The field measurement of COMS service coverage for South Korea beam and North Korea beam show similar results with ground measurement contour maps in CATR facility. The similarity between in-orbit test results and ground test results are confirms that Ka-band antenna was well withstands launch environments and also performances are not degraded in space environments. At this moment, 3D-HDTV broadcasting and broadband VSAT communications are in trial service through COMS Ka-band payload.

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