Ka-band Dual Gridded Antenna with Improved Intercostal Design

#Hiroyuki Ohmine, Michio Takikawa, Toru Takahashi and Yoshiyuki Ohkawa

Mitsubishi Electric Corporation

325 Kamimachiya, Kamakura-shi, Kanagawa, 247-8520 Japan

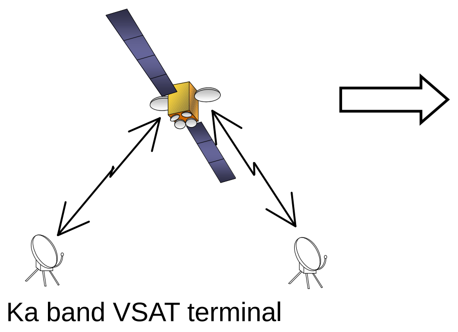
Omine.Hiroyuki@ct.MitsubishiElectric.co.jp

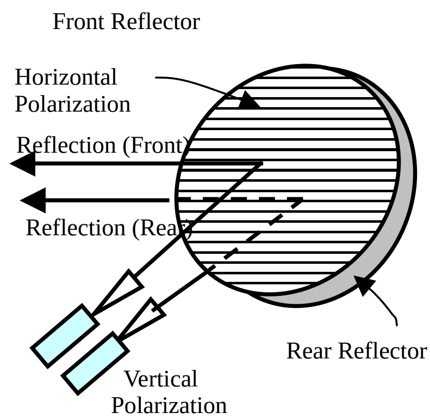
1. Introduction

New configuration and test results of ka-band dual gridded antenna with improved intercostals design that used for broadband satellite communication has been demonstrated. Although the dual gridded antenna has features of orthogonal purity of two polarizations [1]-[4], which consists of grid front reflector, rear reflector and intercostals that support both reflectors, the diffraction from the intercostals degrade radiation performance especially in ka-band. The specific improved intercostals design, which is thin thickness of the ring shaped intercostals surfaces compared traditional intercostals, has been introduced to reduce reflection and diffraction from the intercostals by decreasing intercostal occupation volume. Consequently, it can improve shaped beam performance even in ka-band. In order to estimate improved intercostals effectiveness, one meter-sized dual gridded antenna has been fabricated and tested in ka-band.

2. Configuration of improved intercostal design

Fig.1 (a) and (b) show the outline of dual gridded antenna and its application. The horizontal polarization wave is reflected on the front reflector that has horizontal direction grid, while the vertical polarization is reflected on the rear reflector that consists of solid without grid. The front and rear reflectors are supported by outer and inner intercostals, which hold reflectors firmly against severe vibration in launching. Since this combined reflector configuration suffers from difference of wide temperature range, large thermal deformation is arisen between front and rear reflector due to its substrate inherent coefficients of thermal expansion (CTE) difference. Therefore the intercostal is needed to minimize thermal deformation of combined different substrates. However, the reflection and diffraction from the intercostals make beam shaping and sidelobe reduction worse.

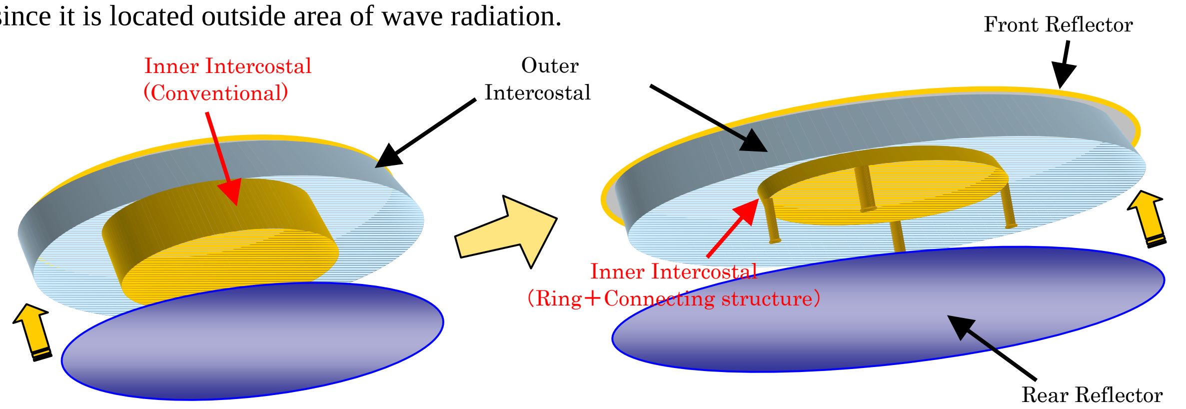




(a) Satellite communication application (b) Outline of dual gridded antenna

Fig.1 Configuration of dual gridded antenna

In order to overcome this problem, new inner intercostals configuration that has thin thickness of the ring shaped intercostal compared to conventional large thick intercostals and connecting structure is proposed as shown in Fig.2 (a) and (b). This configuration can reduce reflection and diffraction from the intercostal surfaces by removing intercostals volume. Further this thin ring is also effective to reduce thermal deformation of the front reflector as well as thick ring because ring shaped structure can inherent hold out of surface deformation even though the thickness is thin. Consequently improved thin ring shaped intercostals has advantage of not only reducing diffraction but also minimizing thermal deformation. Outer intercostal does not affect on the performance degradation since it is located outside area of wave radiation.



(a) Conventional (b) Improved

Fig.2 Improved intercostals configuration

3. Analysis of dual gridded antenna with intercostal

Antenna radiation performance is calculated by PO (Physical Optics) method [5] with taking into account the reflection and transmission coefficients of the grid on the front reflectors and inner intercostals as shown in Fig.3. The front reflector and inner intercostal consist of sandwich layered configuration, skin, core and skin. Fig.4 shows analysis model in which cylindrical shape inner intercostal is replaced by twelve plane intercostals easy for calculation.

Fig.5 shows analysis results of radiation contour pattern with/without inner intercostals in Japan area coverage for example. As for comparison, contour analysis of conventional full height intercostals is shown in Fig.5(a), and that of thin 1/4 height is shown in Fig.(b). It is notice that gain variation between with and without inner intercostal on Edge of Coverage (EOC) in Fig.5(a), the difference is large and around one to three dB and side lobe level raised 10dB up in worst point. On the other hand, the difference between with and without thin intercostals is small and gain variation is less than 0.5dB in Fig.5(b).

Thermal deformation analysis is performed in cases of half sun and cold condition, which represents worst case of thermal conditions obtained from thermal analysis on orbit. Fig.6 shows temperature distribution on the reflector in case of half sun and the temperature difference reaches around 150 degree. In cold case the temperature is assumed as –140 degree uniform. Analysis results of thermal deformations are indicated in Fig.7 and found that it in case of thin 1/4 height inner intercostals is almost half of that of no intercostals case. And also the difference of full height and 1/4 height is small, and which means that ring shaped ring can is effective for thermal deformation mitigation even thickness is thin.

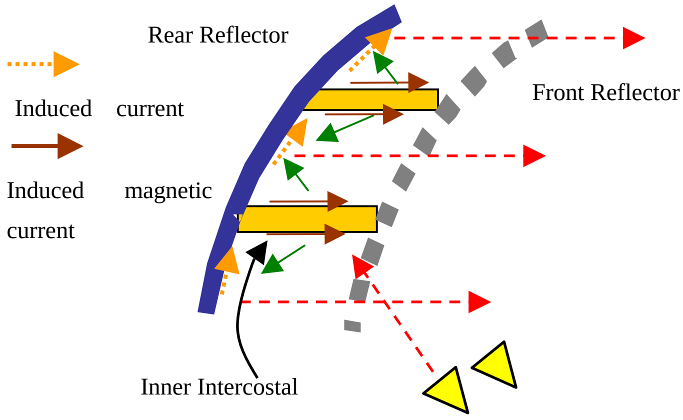


Fig. 3 PO analysis method

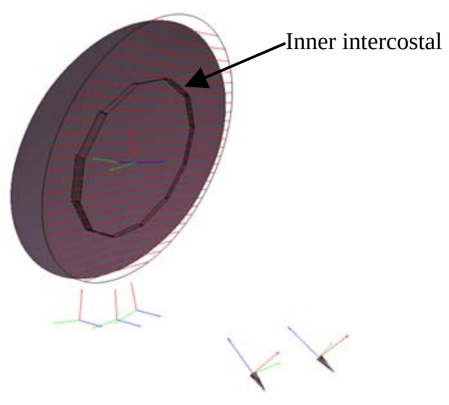
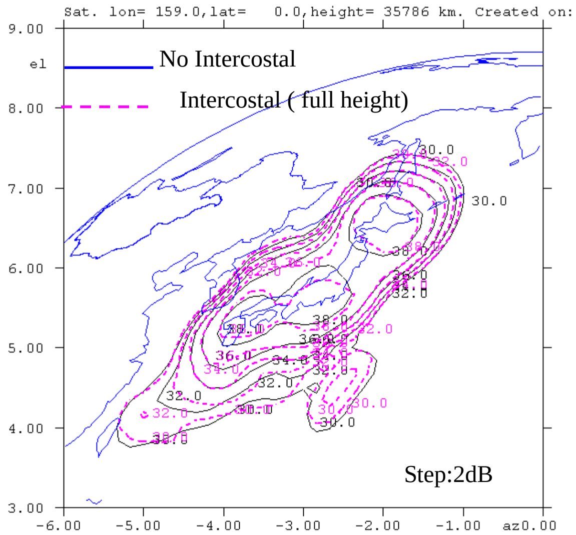
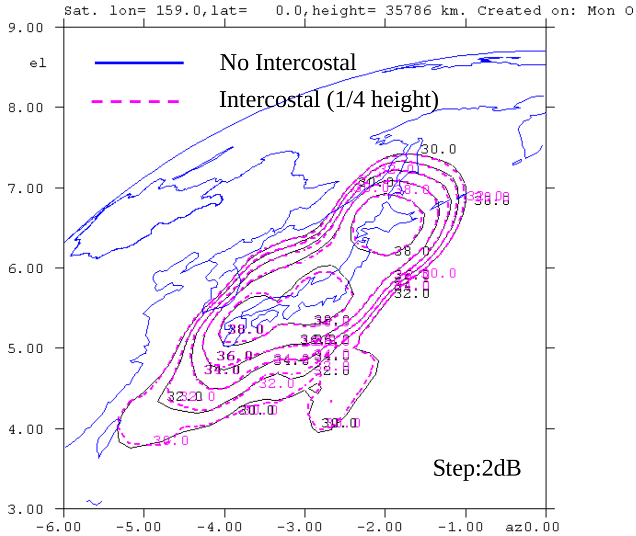


Fig. 4 Analysis model



(a) Full height intercostals (conventional)



(b) 1/4 height intercostal

Fig.5 Comparison of radiation contour pattern

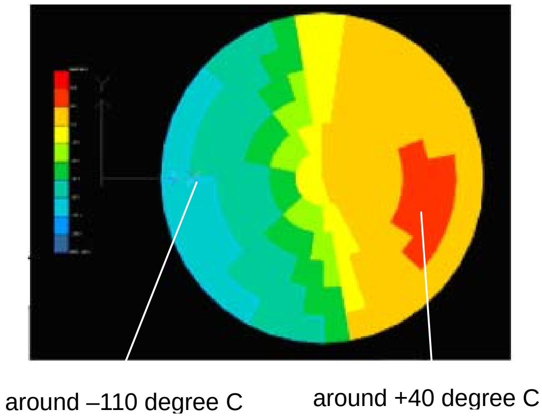


Fig.6 Temperature distribution
on the front reflector (half sun)

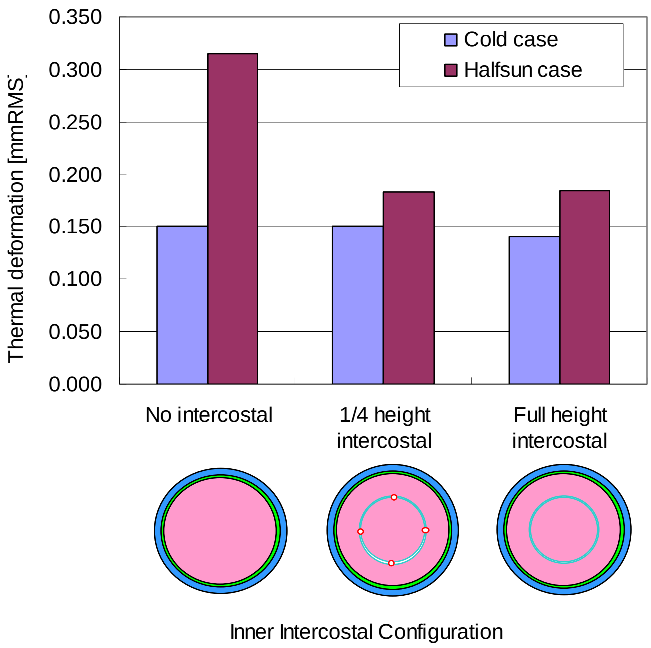


Fig. 7 Comparison of temperature deformation

4. Fabrication and test results

One meter-sized dual gridded antenna with a cirlularly symmetric parabolodal surface has been designed and fabricated in ka-band. The front reflector is composed of sandwich honeycomb panel made by aramid fiber reinforced plastic and polarization grid is patterned on the surface. The rear reflector is composed of honeycomb sandwich panel made by carbon fiber reinforced plastic (CFRP), which does not have grid patterns. Rear and front reflectors are connected by improved inner and outer intercostals which are the part of circular cylinder whose axis is along the antenna axis. For the substrate, cyanate resin which has low hygroscopic properties and is resistant to micro-crack, and ultra high modulous pitch graphite fiber were applied. Simple grid patterning method, transcribing a grid pattern etched on a plane onto a curved reflector surface, is applied [6]. In this method, only plane shaped grid pattern are used to obtain a desired pattern on a curved reflector surface, which is easily etched by conventional photo-etching technique and equipments.

Fig.7 shows comparison of calculated and measured radiation pattern of front reflector. Low cross polarization under -40dB was obtained as shown in the figure, and cross polarization of discrimination was confirmed in ka-band. The antenna gain was also measured and 0.4dB high gain at peak gain was obtained in case of improved thin intercostals compared to full height conventional intercotal. Fig.8 shows photo of fabricated dual gridded antenna when radiation pattern was measured.

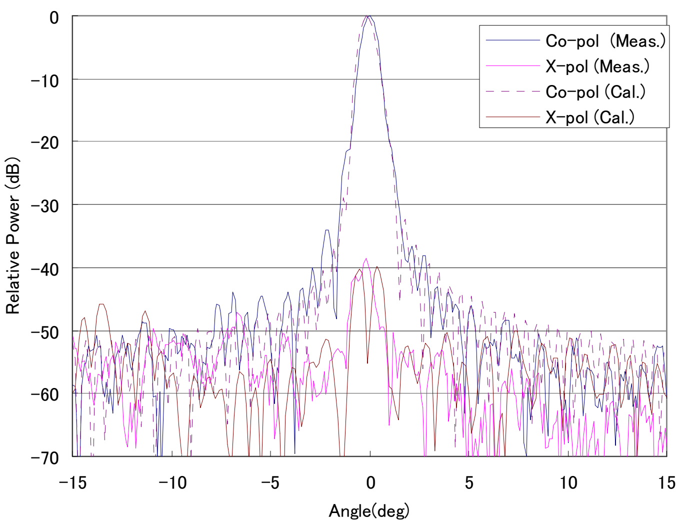


Fig.8 Comparison of calculated and measured radiation patterns of improved intercostals design

Fig.9 Photograph of fabricated reflector (one meter size)

5. Conclusions

New configuration and test results of ka-band dual gridded antenna with improved intercostals has been demonstrated. The improved thin intercostal design has been introduced not only reducing diffraction from the intercostal but also minimizing thermal deformation. One meter-sized dual gridded antenna has been fabricated and tested in ka-band. The result of the measurement showed cross-polarization level was obtained. The validity of the dual gridded reflector antenna in ka-band has been shown and advantage of thin intercostals has been confirmed. Thermal test will be done in future.

Acknowledgments

This work has been carried out under a contract awarded by MIC of Japan under R&D program for expansion of radio resources.

References

[1] K.K.Chan and Hyjazie, “Design of Overlapped gridded reflectors for frequency reuse”, 1985 IEEE International Symposium Digest, AP-S-5-2, pp.149-152, 1985.

[2] J.Poncy, P.Pass and H.Guenat, “Development and Qualification of the Shaped Contoured Dual Reflector of the ARABSAT2 Satellite”,46th International Astronautical Congress, IAF95-I.1.02, Oct. 1995.

[3] Masao Yamato, Izuru Naito, Hiroyuki Shigemasa and Tatsuhiro Noguchi, "Development of Dual Gridded Reflector Antenna for SUPERBIRD-C," AIAA Conference, 1997.

[4] N. Elie, L. Ravelli, A. Lacombe, B. Ollivier, ”Antenna Reflector for Telecommunication Satellite at EADS Astrium Space Transportation Les Mureaux, EuCAP2007, We1.2.2.

[5] Knud Pontoppidan, GRASP9 Technical Description.

[6] Izuru Naito, Masao Yamato, Shin-ichi Honma, Norio Miyahara and Shigeru Makino, "A Patterning Method of Polarization Grids on a Reflector Using Reflector Surface Developing Technique," Proceedings of ISAP’96, 1996.