X-, Ku- and Ka-Band Compact Global-Earth Coverage Feed Horns

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Abstract: Four compact global-earth coverage horns have been designed to meet specifications similar to that required for the Optus C1 satellite. These horns have high gain, low sidelobes, good return loss and compact geometries

1. Introduction

An earth coverage antenna pattern is often required for transmitting and receiving telemetry and command signals from a geostationary satellite. As well as efficient earth coverage, the pattern should minimize interference with other satellites. To achieve this, the amount of sidelobe energy should be as low as possible, both for co- and cross-polarised signals while illuminating the earth efficiently at the required power level over the 17.4° angle subtended by the earth (see Fig. 1). Horns are commonly used for global-earth coverage, and therefore, the geometry of the horn has to be compact to keep the weight as low as possible [1]. Usually there is a trade-off between performance and size/weight of the horn. However, recently, CSIRO designed and built a global-earth coverage corrugated horn with very low sidelobes (≤-36 dB) that is also very compact [2].

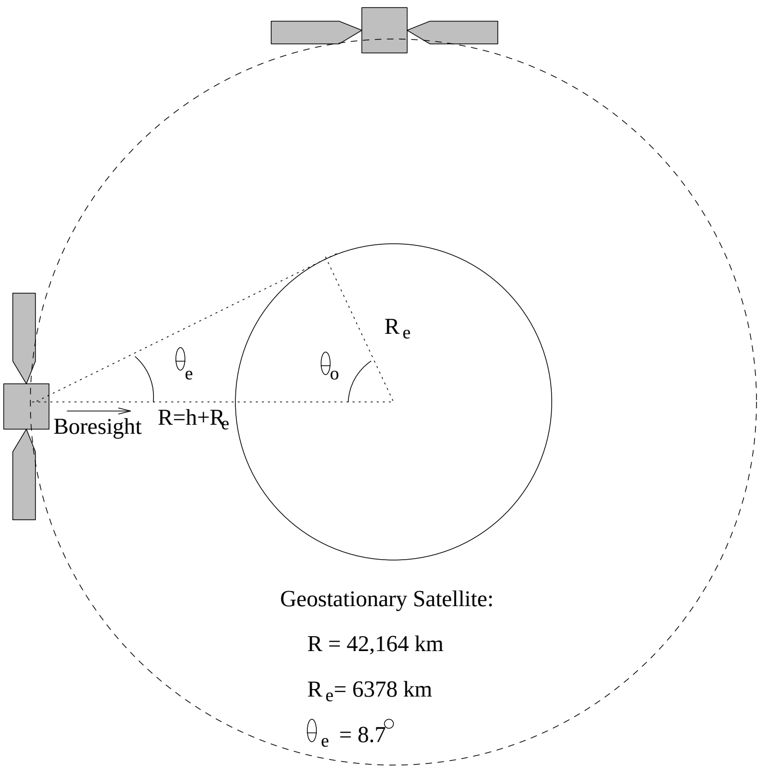

Figure 1: Satellite in a geostationary orbit.

2. Design of X-, Ku- and Ka- bands global-earth coverage horns

Following an approach similar to [2][3], we designed a further four horns to cover the X-, Ku- (2 options) and Ka- bands for possible future satellite applications, such as the Optus C1 satellite, which will be launched by 2002. The performance required of these horns is summarised in Table 1. The horns have different requirements on bandwidth and gain (G) in each frequency band. Because of the intended satellite use, these horns were optimized to be as compact as possible while meeting the specifications of Table 1. The horn-profiles are shown in Figs 2 to 5 while the gain on boresight and at the edge-of-coverage (EOC = 8.7° for a geostationary orbit) is shown in Fig. 6, where it can be seen that the specifications summarized in Table 1 are met. Typical radiation patterns from the X-, Ku- and Ka- band horns are shown in Figs 7 to 12. The return loss of the three corrugated horns is of the order of 30 dB or better in their respective frequency bands. Although the return loss of the Potter-type Ku-band horn (Option 1) is only about 13 dB, this can easily be fixed by designing an appropriate matching section.

The horns were designed using the well-proven mode-matching method [4]. Each horn is represented as a series of uniform waveguide sections and the horn profile by a sine-to-power "p" (for the Ku-band horns) or a polynomial-to-power "p" function (for the X- and Ka-band horns), where "p" is a variable [3]. For each horn profile, the radiation pattern is calculated and compared to the specification. This process continues until an acceptable design is obtained.

3. Conclusions

Four compact global-earth coverage horns have been designed to meet specifications similar to that required for the Optus C1 satellite. These horns have high gain, low sidelobes, good return loss and have compact geometries. Different performance objectives are achieved mainly by varying parameters of the profile [3]. New horns can be designed using the same approach for other applications, and this has resulted in compact Potter-type horns [5] and compact wide-band dielectrically-loaded feed horns [6][7].

4. References

[1] T. Kitsuregawa, "Advanced technology in satellite communication antennas", Artech House, Boston, 1990.

[2] C. Granet, T.S. Bird, G.L. James, "Compact low-sidelobe corrugated horn for global-earth coverage", IEEE APS'99, pp 712-715.

[3] C. Granet, "Profile options for feed horn design", submitted to the Asia Pacific Microwave Conference 2000, Sydney, Australia, December 2000.

[4] G.L. James, "Analysis and design of TE11-to-HE11 corrugated cylindrical waveguide mode-converters", IEEE Trans. on Micr. Theory and Tech., Vol. MTT-29, No 10, Oct. 1981, pp 1059-1066.

[5] C. Granet, V. Dyadyuk, "Compact Potter-type horns for a Traffic Management Radar", AP2000 Conference, Davos, Switzerland, April 2000.

[6] C. Granet, G.L. James, K.J. Greene, "Multi-band feed horns", JINA'98, pp 635-638.

[7] K.J. Greene, C. Granet, "Dielectrically-loaded horns used as antenna measurement range illuminators", AP2000 Conference, Davos, Switzerland, April 2000.

Table 1: Design specifications.

Horn	Dual-band X-Band	Ku-Band	Dual-band Ka-Band
Frequency Bands	Receive: 7.9-8.4 GHz Transmit: 7.25-7.75 GHz	12.25-12.75 GHz	Receive: 30-30.5 GHz Transmit: 20.2-20.7 GHz
Gain (dBi) (Specifications)	Receive: $16.8 \leq G \leq 23.3$ Transmit: $17.1 \leq G \leq 22.4$	$18.5 \leq G$	Receive: $17.0 \leq G \leq 22.7$ Transmit: $16.8 \leq G \leq 19.4$
Length	6λ (at 7.8 GHz) ($\approx$ 230 mm)	Option 1: 8.8λ (at 12.5 GHz) ($\approx$ 210 mm) Option 2: 6.2λ (at 12.5 GHz) ($\approx$ 149 mm)	7.5λ (at 25 GHz) ($\approx$ 90 mm)
Aperture Diameter	4.3λ (at 7.8 GHz) ($\approx$ 166 mm)	Option 1: 5.1λ (at 12.5 GHz) ($\approx$ 122 mm) Option 2: 5.2λ (at 12.5 GHz) ($\approx$ 126 mm)	4.1λ (at 25 GHz) ($\approx$ 49 mm)
Profile (see [3])	Polynomial "Bowl-shaped" (Corrugated) (see Fig. 1)	Option 1: "Bowl-shaped" (Smooth-wall) (see Fig. 2) Option 2: "Bowl-shaped" (corrugated) (see Fig. 3)	Polynomial (Corrugated) (see Fig. 4)

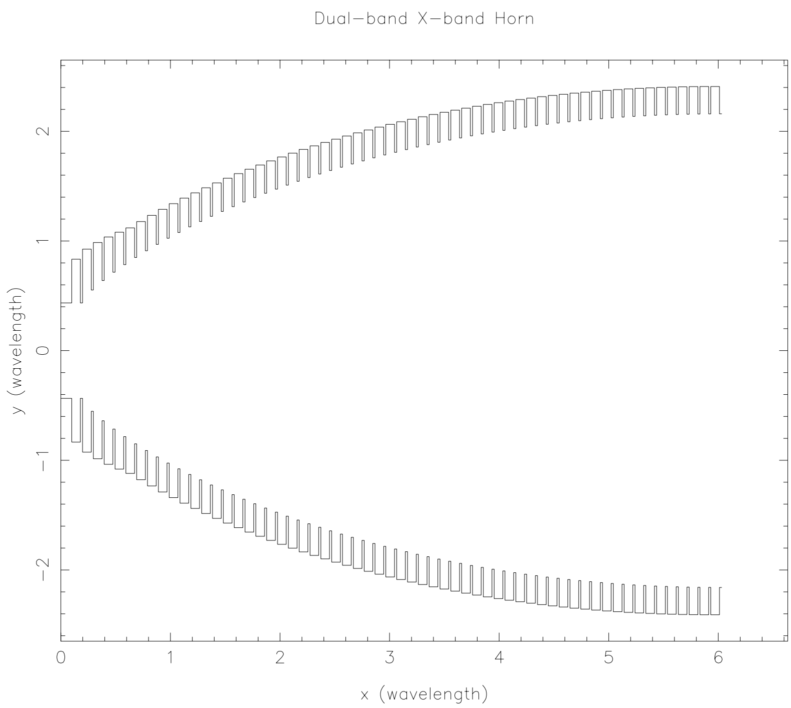

Figure 2: Geometry of the dual-band X-band horn.

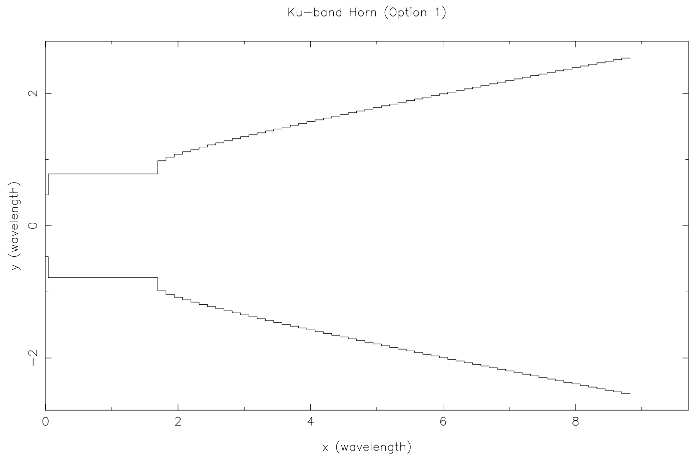

Figure 3: Geometry of the Ku-band horn (Option 1) (Note that there is an abrupt step between the input waveguide and the start of the horn to create, as in [5], a compact Potter-type horn).

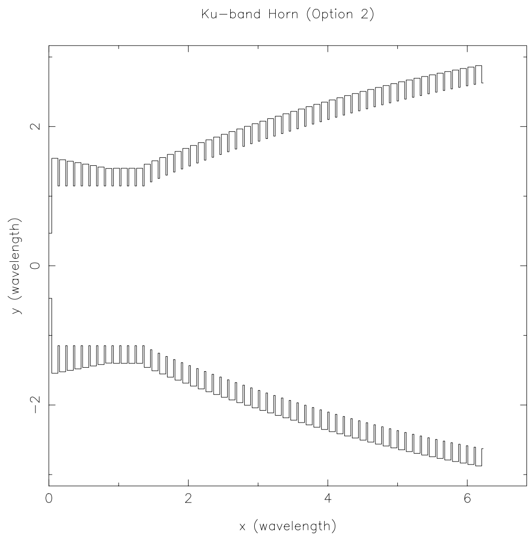

Figure 4: Geometry of the Ku-band horn (Option 2) (Note that there is an abrupt step between the input waveguide and the start of the horn to create, as in [2], a multi-hybrid mode horn).

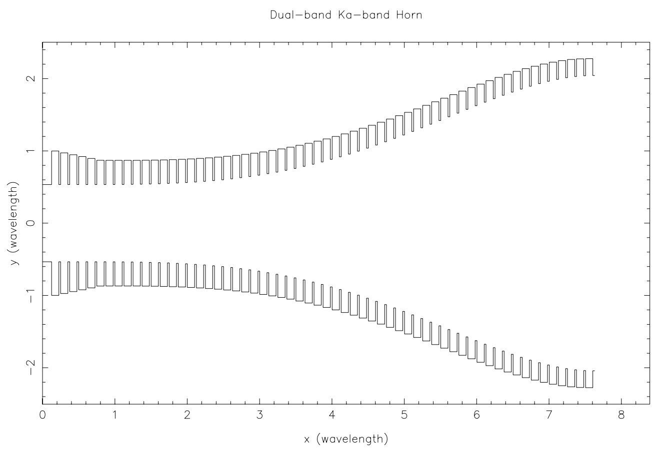

Figure 5: Geometry of the dual-band Ka-band horn.

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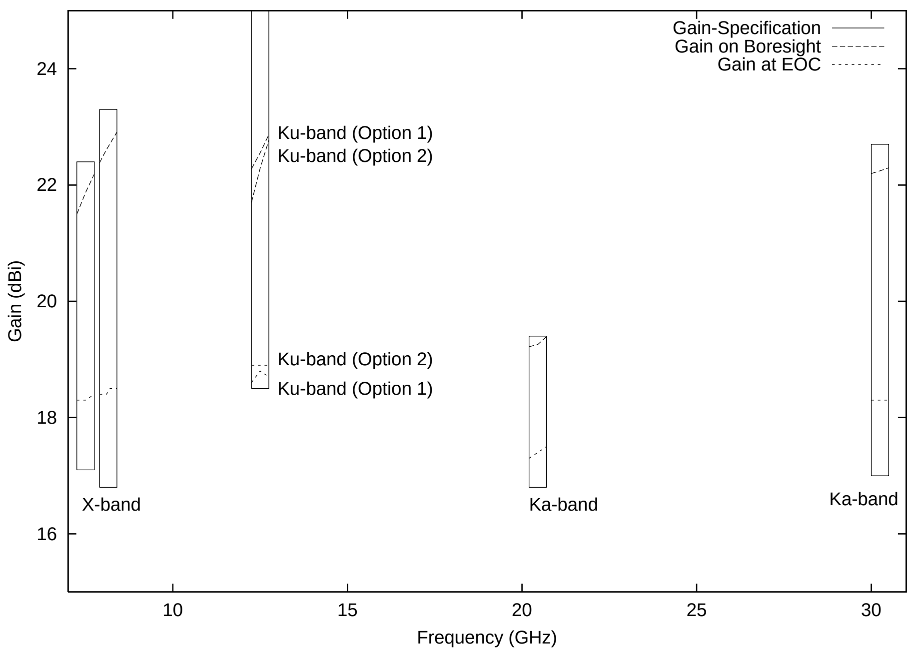

Figure 6: Gain on boresight and at the EOC for the X-, Ku- and Ka-band horns.

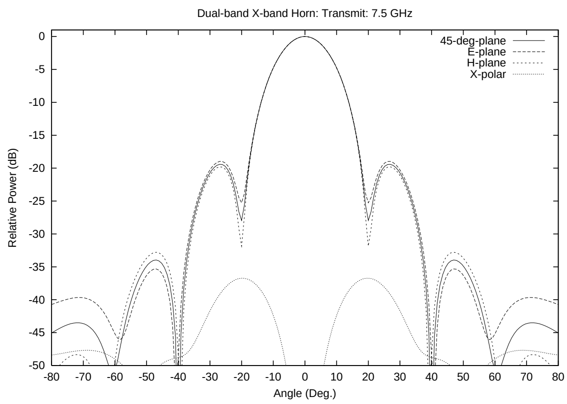

Figure 7: Dual-band X-band horn: Radiation pattern at 7.5 GHz.

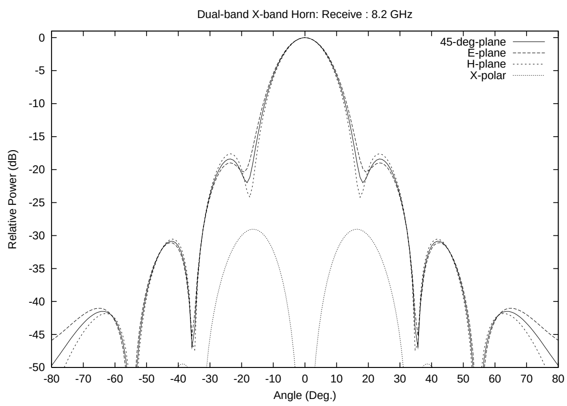

Figure 8: Dual-band X-band horn: Radiation pattern at 8.2 GHz.

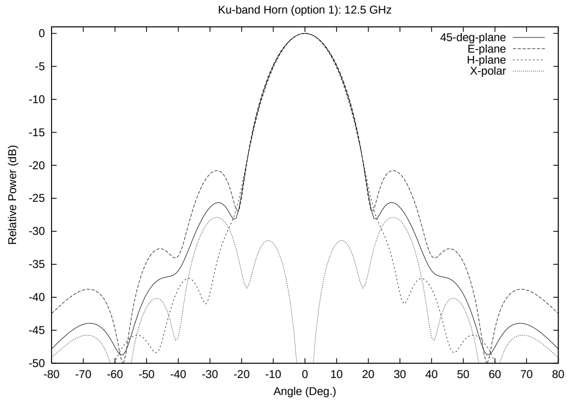

Figure 9: Ku-band horn (Option 1): Radiation pattern at 12.5 GHz.

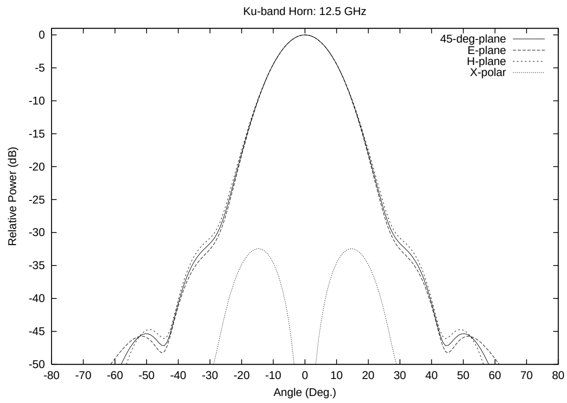

Figure 10: Ku-band horn (Option 2): Radiation pattern at 12.5 GHz.

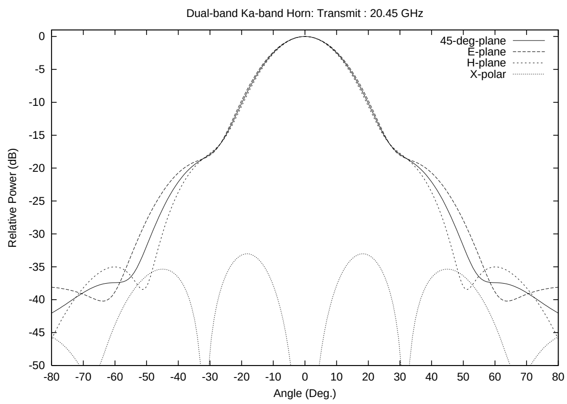

Figure 11: Dual-band Ka-band horn: Radiation pattern at 20.45 GHz.

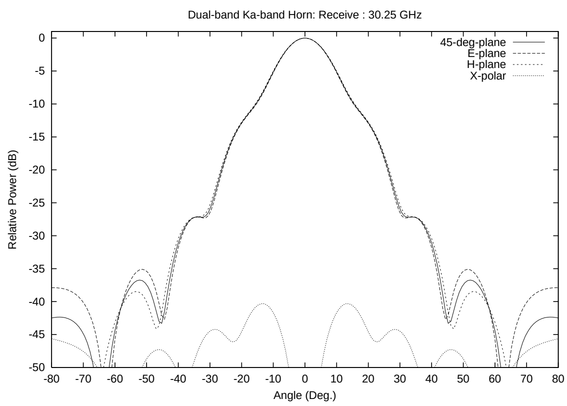

Figure 12: Dual-band Ka-band horn: Radiation pattern at 30.25 GHz.