1-D flat cassegrain sub-reflector using EBG structure with graded reflection phases

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1. Introduction

In recent years, electromagnetic band gap (EBG) structures have been investigated by focusing on the low profile, radiation pattern of the antenna since the mushroom-type EBG structure was introduced. EBG structures consist of periodic metal-dielectric composite textures on the ground plane. The phase range of the EBG structure is from 180˚ to -180˚ [1]. In addition, the phase of EBG structure can be realized at any range including 0˚ where is operated as artificial magnetic conductor.

Using the phase properties of EBG structures, a reflector antenna can be improved from the viewpoint of profile reduction. Reflector antenna has high gain but it is not efficient to handle because the structure is too big and curve. The phase properties of EBG structure enable it to change from reflector antenna's curve to flat type as remained reflector antenna's characteristic. Using graded reflection phases obtained by tuning the textures' sizes, the reflection phase characteristic of conventional cassegrain sub-reflector can be approximately as a physically flat type. Therefore, using EBG structure, a 1-D flat cassegrain sub-reflector with graded reflection phases at 12GHz is proposed.

2. The design of 1-D flat cassegrain sub-reflector

2.1 Curvature of conventional cassegrain sub-reflector

The configuration of the conventional cassegrain reflector is illustrated in Fig.1. It consists of three sections: a main-reflector, a sub-reflector, a feed horn antenna. The diameter of the main-reflector, D_m, is 400 mm and the diameter of the sub-reflector, D_s, is approximately 100 mm by matching at the -11dB beam width of feed horn. Other parameters related to determine the curvature of conventional cassegrain sub-reflector are also depicted in Fig. 1. θ_e is half of the -11dB beam width of feed horn and F and f is the focal point of the main and sub-reflector, respectively. D_f is a longitudinal length of the feed horn and D_{pc} is a phase center of feed horn [2], [3]. The value of these parameters is presented in Table 1. The curvature of conventional cassegrain sub-reflector can be expressed as in Eq. (1) which represents an equation of hyperbola and its graph is shown in Fig. 2.

$$\frac{z^2}{a^2} - \frac{x^2}{b^2} = 1 \qquad (1)$$

Where a, b are values for the asymptotic curve of hyperbola. By substituting the point Q_1, Q_2 in Eq. (1), the curvature of conventional cassegrain sub-reflector are expressed as in Eq. (2).

$$\frac{z^2}{2.5^2} - \frac{x^2}{7.51^2} = 1 \qquad (2)$$

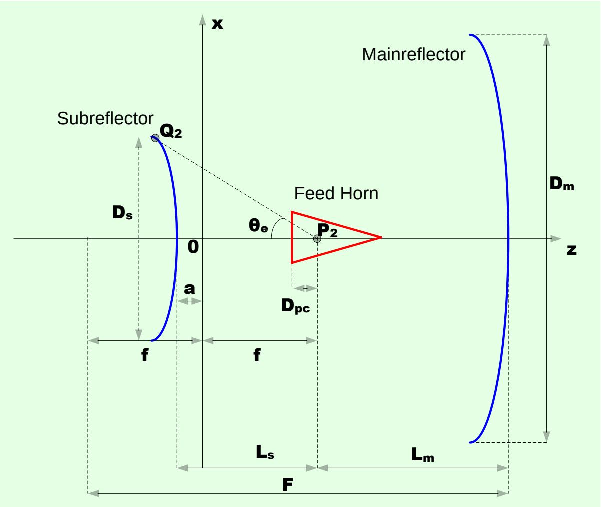


Figure 1: Geometry of conventional cassegrain reflector

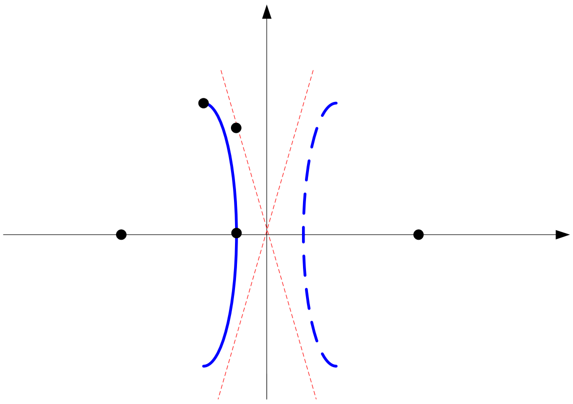


Figure 2: Graph of hyperbola

Table 1: Parameter values of conventional cassegrain reflector

Parameters	Values	Parameters	values
θ_e	22.7˚	F	424.685mm
D_{pc}	5mm	f	102.7mm
D_f	47mm	L_m	219.3mm
D_m	400mm	L_s	105.2mm
D_s	100mm	a	2.5mm

2.2 The reflection phase of 1-D flat cassegrain sub-reflector

The conventional cassegrain sub-reflector can be realized as a physically flat but electromagnetically curved type if an equiphase plane of the conventional cassegrain sub-reflector is obtained. As the length of unit cells which are continuously arranged in EBG structure varies, the capacitances and inductances of the unit cells are changed and then surface resonant frequency is also altered. This result leads the variance of reflection phases of EBG structure. The size of each cell can be determined by reflection phases of EBG structure and the 1-D flat cassegrain sub-reflector can be designed. The reflection phase across the proposed surface is expressed as in Fig. 3 and it is shown that the reflection phases are approximately graded with Eq. (2).

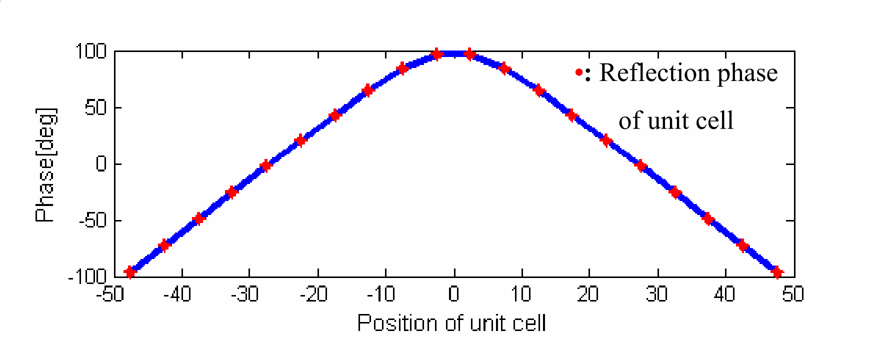


Figure 3: Reflection phase of 1-D flat cassegrain sub-reflector

3. The proposed 1-D flat cassegrain sub-reflector

The geometry of proposed 1-D flat cassegrain sub-reflector is illustrated in Fig. 4. The total dimension is 100 mm × 100 mm and FR4 substrate with a thickness of 1.6mm is used for fabrication. The distance between the unit cells is 5mm and X band horn antenna is used as a feed antenna.

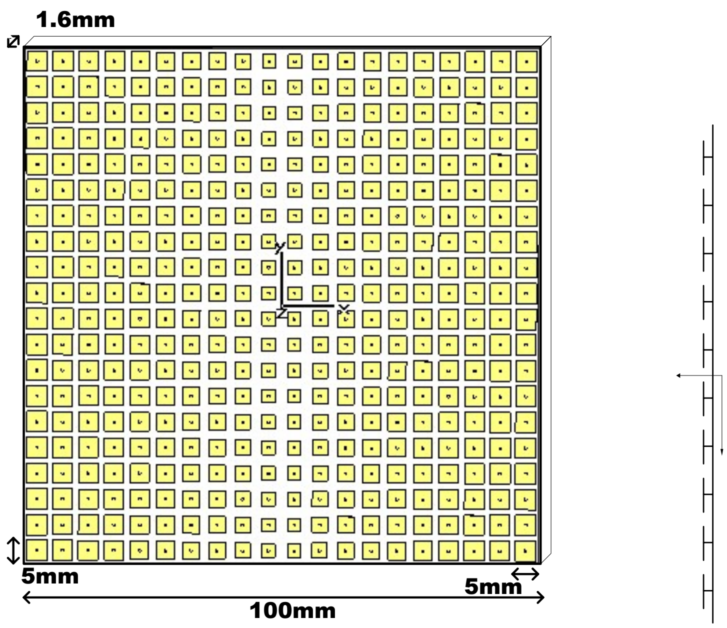
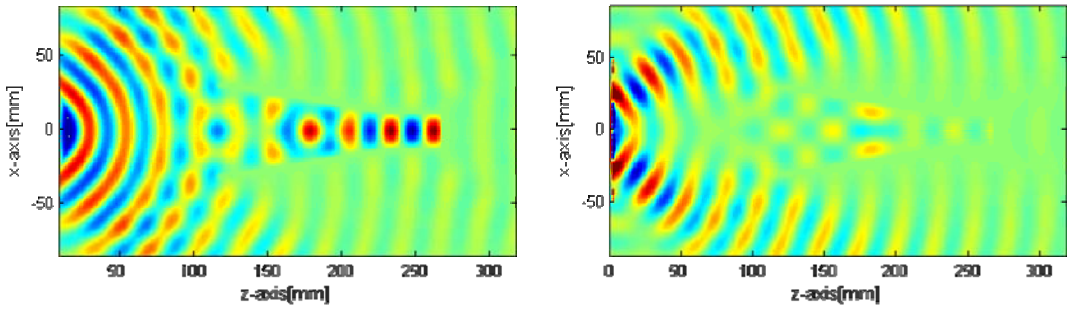


Figure 4: Geometry of 1-D flat cassegrain sub-reflector

The Fig. 5 is shown the reflected E-field of conventional cassegrain sub-reflector and 1-D flat cassegrain sub-reflector. From the Fig. 5, it is demonstrated that the beam pattern of proposed 1-D flat cassegrain sub-reflector is nearly the same as the conventional cassegrain sub-reflector. However, amplitude tapering is observed at the 1-D flat cassegrain sub-reflector. This can provide an advantage of preventing the feeder blockage.

The Fig. 6 is shown the reflection phase at the front of main-reflector. The position of main-reflector is about 324mm [L_s+ L_m] and the reflection phase of the two cases is nearly the same. Therefore, conventional cassegrain sub-reflector can be alternated by 1-D flat cassegrain sub-reflector.



(a) Conventional cassegrain sub-reflector (b) 1-D flat cassegrain sub-reflector

Figure 5: Reflected E-field distribution at 12GHz

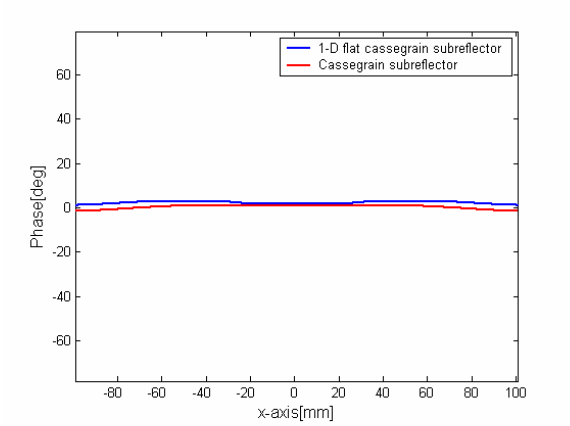


Figure 6: Reflection phase in front of the main-reflector [324mm]

4. Conclusion

In this paper, 1-D flat cassegrain sub-reflector using EBG structure with graded phase is proposed. From the curvature of conventional cassegrain sub-reflector, the graded reflection phase of 1-D flat cassegrain sub-reflector is determined and then the unit cell's size of the EBG structure is also determined. It is revealed that proposed 1-D flat cassegrain sub-reflector has nearly the same pattern as the conventional cassegrain sub-reflector and has an advantage of preventing the feeder blockage. Therefore, proposed 1-D flat cassegrain sub-reflector is a good alternative for the conventional cassegrain sub-reflector.

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Reference

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