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# Analysis of slot coupling in a corrugated radial waveguide

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## 1. Introduction

A radial line slot antenna (RLSA) in Fig.1 is a high-gain, high-efficiency and low-cost planer antenna, which was originally proposed for satellite TV reception at 12GHz band [1]. Recently this antenna has been designed for a space solar power system (SSPS) [2],[3]. Figure 2 shows the relationship between the slow-wave factor and the aperture efficiency. The slow-wave factor $\xi$ is defined as $\xi=\lambda_g/\lambda_0$ where $\lambda_g$ is the guided wavelength and $\lambda_0$ is the free space wavelength. The slow-wave factor $\xi$ affects aperture efficiency of RLSAs. A dielectric material is generally filled in a radial waveguide to create a slow wave structure. The efficiency is degraded because of the grating lobes for too small dielectric constant while it is narrow banded because of the long line effect of a series fed array for too large constant [4]. The proper slow-wave factor is 0.8 to 0.9 in terms of the efficiency and the bandwidth [5]. Since antennas for SSPS are excited with high power energy and used in space, a hollow structure without a dielectric is desired. A corrugation structure was proposed as a slow-wave structure for a radial waveguide of RLSAs as shown in Fig.1 [6]. The slow-wave factor depends on the parameters of the corrugation height, corrugation space, corrugation width and waveguide height. In this paper, the

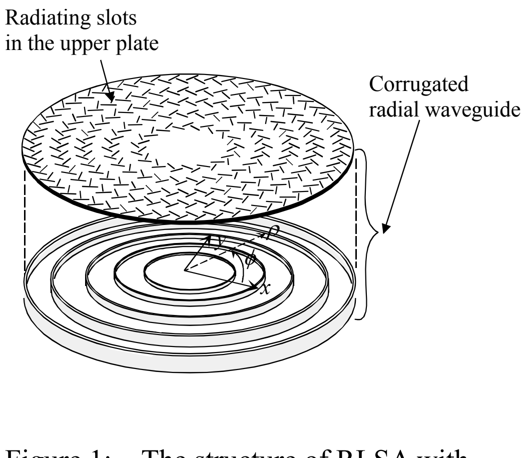


Figure 1: The structure of RLSA with corrugated radial waveguide

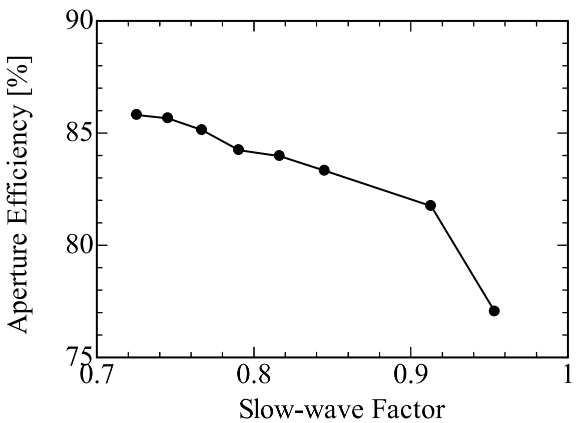


Figure 2: The relationship between the slow-wave factor $\xi$ and aperture efficiency

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corrugated structure without radiating slots is analyzed by the mode matching method. Next, an analysis method of slot coupling on the corrugated radial line by using the method of moments (MoM) with eigenmode expansions is proposed. In the both analyses, a radial waveguide is placed with a parallel plate waveguide by neglecting the curvature for simplification.

## 2. Slow wave factor in corrugated waveguide without slots

Figure 3 shows the analysis model of a corrugated waveguide without radiating slots by the mode matching method. This model has no variation with *x*-direction, and it has periodic in *z*-direction with a period *d*. Region 1 is the waveguide region. Region 2 is the corrugation region. The *b* is the waveguide height, and *c* is the corrugation height, *s* is the corrugation width. Figure 4 shows the slow-wave factor for various height *c* of the corrugation (*d*=5mm, *s*=2.5mm, *b*=7mm at 12GHz). The slow-wave factor ξ becomes lower for larger *c*. The proper slow-wave factor around 0.8 to 0.9 is obtained when *c* is about 2 mm. We check the slow-wave factor is not changed for *s* less than 2.5mm with keeping the ratio of *s*/*d* =1/2. However we cannot practically take a too small *s* normalized by *c* form fabrication point of view.

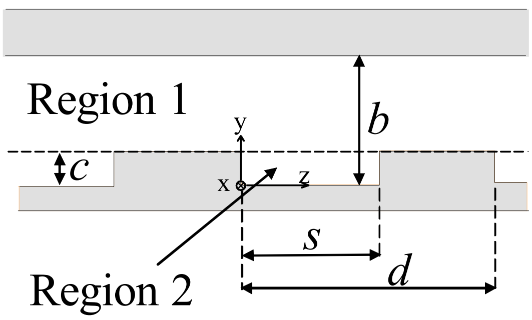



Figure 3: Analysis model for the mode matching method

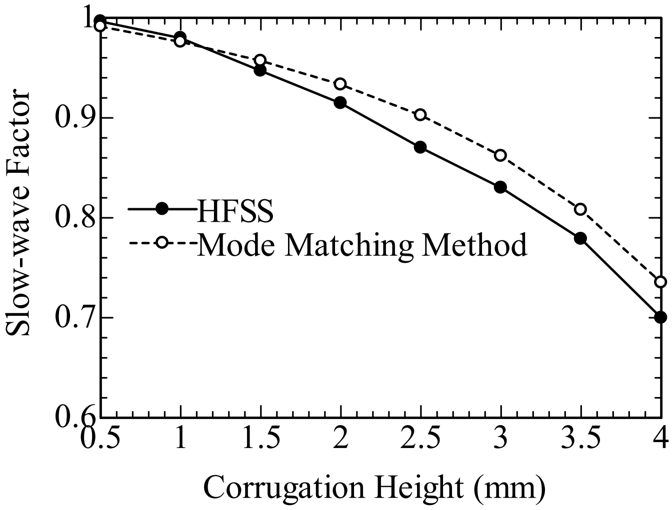



Figure 4: Calculated result of slow-wave factor (*b*=7mm, *d*=5mm, *s*=2.5mm, *c* is variable at 12GHz)

## 3. Method of Moments for slot coupling in a corrugated waveguide

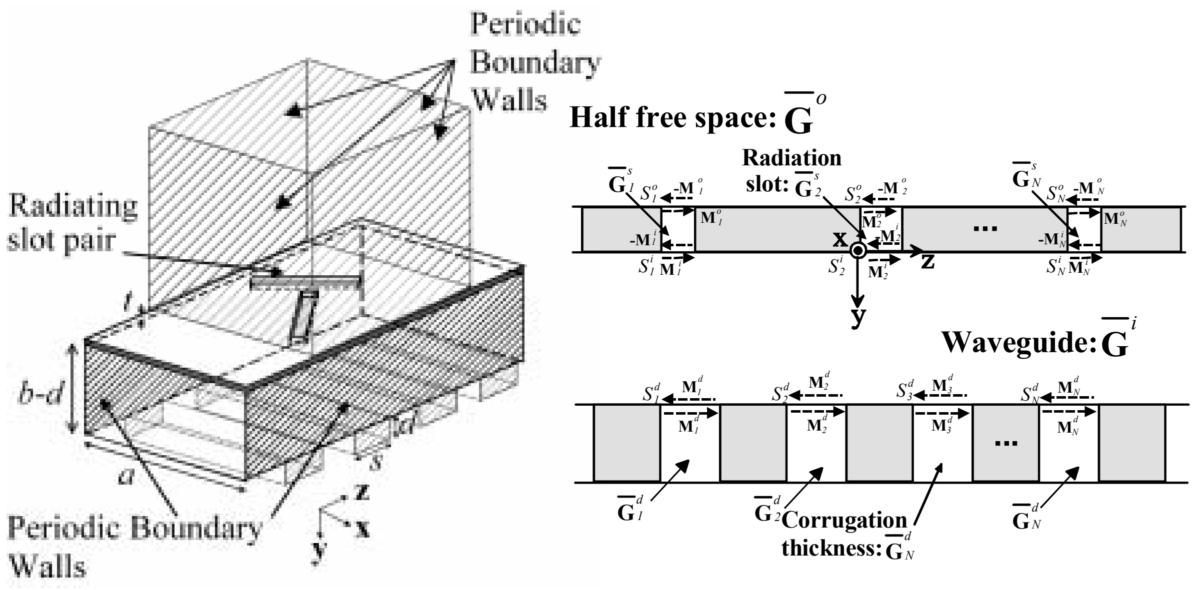
Figure 5 shows an analysis model of the corrugated waveguide by MoM. The internal region of the parallel plates is replaced with a rectangular waveguide with the periodic boundaries in the narrow walls because of the periodicity of field in the transverse direction. A slot pair radiating a circularly polarized wave and several corrugations per guided wavelength are included in the model. The external region is replaced with another rectangular waveguide with two sets of periodic boundary walls.

By using the field equivalence theorem, slot and corrugation apertures are covered by perfect electric conductors (PECs) with unknown equivalent magnetic current. The analysis model is divided into four types of regions; a half free space, slot regions, a waveguide and corrugation regions. In this analysis, the waveguide is infinitely long. Integral equations are derived from the continuity condition of the tangential component of magnetic field on all the apertures. Each unknown magnetic current is expressed as a sum of basis functions with unknown coefficients. By applying the MoM, we can derive a set of linear equations for the unknown expansion coefficients. We can find the magnetic currents by solving this set of linear equations. The reflection, transmission and radiation coefficients are calculated by the magnetic currents.

The magnetic currents on the corrugation apertures should be expanded by the eigenmode functions of a waveguide with the cross section of the apertures. Due to the orthogonality of the eigenmode functions, the self reactions of the magnetic currents in the corrugation regions can be simply expressed without take a mode summation. Even though the number of the corrugations increases, the computational effort does not increase very much because of this simplification. Since the corrugations are cut along the whole broad wall of the rectangular waveguide in the $x$-direction, the self and mutual reactions of the magnetic currents on the corrugation apertures in the waveguide region can also be simply calculated without taking a mode summation in terms of the $x$-ditrection due to the orthogonality of eigenmode functions as well.

## 4. Conclusion

In this paper, a corrugated waveguide with no radiating slots has been analyzed by the mode matching method. A slow-wave factor for the corrugated waveguide is variable by changing the period, width and height of the corrugations as well as the waveguide height. As a result of the calculation, the proper factor of 0.8 to 0.9 is realized for around $s/d$=1.2. Next, we have proposed an analysis method for the structure including radiating slots by using the MoM. By using eigenmode functions of waveguides with cross section of the corrugation aperture as the basic function of the magnetic currents there, we have presented the calculations of the reactions can be simplified due to the orthogonality of the eigenmode functions. In my presentation, I will show the calculated results.




(a) Air view (b) Cross section

Figure 5: Analysis model for method of moments

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