EM Performance Improvement of a Large A-type Sandwich Radome

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Abstract

Large sandwich radomes are widely used for radar antennas because of the desired some characteristics. They are constructed by connecting small panels for the restrictions on manufacture. These connection parts yield undesired scattered waves and generate higher sidelobes. We present a novel method to overcome this problem by optimizing the radome geometric design. The scattering characteristics of radome seams are simplified by using physical optics technique with some corrections. This method achieves the fast computation that is appropriate for iterative optimization. Simulated annealing method is used to obtain the optimized radome geometry that has well-behaved sidelobes. Simulation results are also presented in order to validate our proposed method. It is shown that the desired radiation pattern is obtained.

1. INTRODUCTION

Sandwich radomes are widely used in order to protect antennas from wind and weather in the ourdoor environment. The panels of A-sandwich are composed of rigid skins and a core of low-loss dielectrics. They have high intensity mechanically and also have excellent electrical performance[1]-[3]. Large-sized sandwich radomes are constructed by connecting many small panels because of the restrictions on manufacture. The scattered fields generated from the connection parts cause electrical performance degradation of the enclosed antenna such as higher sidelobes and gain reduction[4][5]. It is more desirable to lessen the kind of panel in order to reduce the number of form blocks. So the same panels are arranged periodically and the interference of scattered waves by radome seams yields higher sidelobes.

We present methods to overcome the above problems. The transmission loss of sandwich panels is adjusted to be sufficiently small. We show that the transmission characteristics are improved for inserting the suitable metal pattern inside the seams. Next we optimize the radome geometric design using simulated annealing method[6]. Only the scattered waves by the seams of radome are considered in the effect of a radome. The scattering characteristics of seams are simplified by using physical optics technique with some corrections. Simulated annealing method realizes optimized radome geometry that has well-behaved sidelobes. Simulation results using a simple radome model are also shown.

2. TRANSMISSION PERFORMANCE IMPROVEMENT OF RADOME SEAMS

A. Transmission Performance of Radome Seams with Conducting Wire

Fig.1 shows the composition of an A-type sandwich radome. The thickness of skins and a core of an A-type sandwich radome is adjusted to achieve high transmittance. However the transmission characteristics of radome seams is not so good. The transmission characteristics are improved for inserting the suitable metal pattern inside the joint part of radome panels[5]. However, there are some ambiguous points in the detailed procedures. We analyze the transmission characteristics of the seams by our own methos.

It is difficult to obtain analytical formula of scattering characteristics because of the complexity consisting of both conductor and dielectric material. We analyze the scattering characteristics of seams by method of memoment based on the volume integral equation[7]. Especially in the moment method based on the volume integral equation, the number of unknowns become very large as the analysis domain becomes large. In the method of moment using a volume integral equation, it is necessary to develop with the current of three directions of the X, Y, and Z-axis and the unknowns increase as an analysis domain becomes large. It becomes difficult to calculate an inverse matrix in real time. In this paper, the algorithm using a conjugate gradient method was adopted for shortening of computation time.

B. Simulation and Measured Results

The effect of a conducting wire inside seams is investegated. The calculation model shown in Fig.2 has an uniform metal wire inserted into the seams. The analytical domain is bounded by the finite dimensions of $7.8\lambda(X)\times 7.8\lambda(Y)$ because of the computation time and memory requirement, and divided by $512(X)\times 512(Y)\times 16(Z)$ cells. The computed and measured scattered field at the $y=0\lambda$ and $z=1\lambda$ when a linearly polarized electromagnetic waves of Y-direction are incident on the seams are shown in Fig.3. Here the amplitude of scattered field is normalized by the intensity of incidence field. The componet of incident field is subtracted from total field in the measurement. The phase distribution has the characteristics of the spherical wave because an transmitting antenna is located in the near-field region. The amplitude and phase of scattered field have big ripples around the seams because of the electrical discontinuity. This influence will degrade the radiation pattern of antenna installed inside the radome.

Fig.4 shows the scattered filed of seams with a conducting wire. The ripples around the seams become to be small by inserting a conducting wire. The scattered field pattern is approaching the transmission characteristic of the flat panel itself. It is shown that the transmission performance is improved. Moreover, the computed results by the method of moment based on a volume integral equation agree well with the measured ones. The validity of the analysis method is demonstrated.

3. ANALYSIS OF UNDESIRABLE SCATTERED FIELD FROM THE RADOME SEAMS

A. Simplified Model of Scattering Patterin by Radome Seams

The connecting parts of sandwich radome panel yield undesirable scattered field because of the discontinuity. The effect of scattered filed from these seams must be considered in order to evaluate the degradation of antenna performance such as the gain and sidelobe level. Fig.1 shows the composition of sandwich radome panels. The undesirable scattered waves would be produced by the seam of radome panels which has different dielectric constant and thickness from another parts. In order to analyze these effect accurately, numerical analysis such as FDTD or Moment Method will be applied. However such methods require huge computation time to obtain the scattering characteristics for the every incident angles. When optimizing the geometric design of radome seams, the scattering characteristics of seams must be evaluated many times. So they are inadequate for the optimization. For the purpose of fast computation, the seam is simplified by a conducting strip of W[mm] in width and we calculate the effect of scattered field by using physical optics method Fig.5 shows a model of seam. Scattered field $\mathbf{E}^{PO}$ of the strip model are obtained by physical optics

$$\begin{aligned} \mathbf{E}^{PO} &= \frac{j\exp(-jkR)}{\lambda R}\{\hat{\mathbf{z}}\times(\hat{\mathbf{s}}\times\mathbf{E}_0)\}\times\hat{\mathbf{o}}\times\hat{\mathbf{o}} \\ &\cdot\ LW\mathrm{sinc}\left\{\frac{k(o_x-s_x)L}{2}\right\}\mathrm{sinc}\left\{\frac{k(o_y-s_y)W}{2}\right\}. \quad (1) \end{aligned}$$

where $\mathbf{E}_0$ is the incident field strength at origin. This equation is insufficient to predict scattering characteristics of seams which are made of a dielectric. We will revise this equation in order to coincide representative scattering pattern in case of vertical incidence (-Z direction) with more accurate data obtained from numerical analysis or measurement. Constant:A which determines the strength of scattering level is introduced in the above equation

The undetermined constants A and W will be determined by the shape and absolute value of forward scattering pattern.

The scattering characteristics of seams depend on the polarization. The incident field is decomposed into parallel and perpendicular polarization to seams by using Ludwig's third definition[8]. The effect of polarization is considered by determining the constants A and W in both polarizations.The above method can predict the scattering characteristics in a short time. The scattering characteristics in case of almost vertical incidence will be obtained accurately.

B. *Geometric Design Optimization of Seams*

The radiation pattern including scattering effect of seams can be calculated by the proposed method described in the preceding section. Here we will explain a method for the suppression of sidelobe degradation by optimizing the geometric design of Seams. Fig.6 shows a radome model which is composed of some panels on a sphere. This model is constructed by arranging a composition unit periodically in order to reduce the total number of panel kind. The whole shape of a radome is determined by a configuration unit. So we will optimize the coordinates of each node only for a configuration unit. The objective function:E which reduces sidelobe level can be determined

$$\begin{aligned} E &= \frac{1}{N}\sum_{n=1}^{N} G(S_n) && (2) \\ G(S) &= B + S_0 - S(S > S_0) && (3) \\ &= B(S \leq S_0) \end{aligned}$$

where N is the number of sampling points in order to evaluate sidelobe level and S_n is the sidelobe level at each sampling points. $G(S)$ is an objective function for sidelobe level and it is determined by target perfomance:S_0 and an appropriate constant B. This objective function has a maximum when the target antenna pattern is obtained. The maximum of this objective function will be obtained by optimizing the displacement of polar coordinates θ and ϕ in terms of each node. The permissible angle of displacement is restricted in optimization. We will optimize the above objective function by using simulated annealing method[6] which is a kind of nonlinear optimization technique.

C. *Simulation Results*

We will investigate the validation of the proposed method by using a radome model(Diameter:2.5m) shown in Fig.6. The assumed antenna installed inside this radome is a circular aperture in the XY-plane which has the circular Taylor distribution(SL:-30dB,$\bar{n} = 5$). The scattering characteristics of W=30mm and A=-6dB at 5GHz are used for both polarizations. Fig.7 shows a radiation pattern for the initial radome seams. The radiation pattern is periodical because of the periodicity of the composition unit. The interference of scattered field by some seams give rise to high sidelobes of -25.8dB.

Next the coordinates of nodes will be optimized under the condition that the permissible angle of displacement from the initial state is 5 degree. The simulated annealing method is used to achieve the target sidelobe performance of $S_0 = -29dB$. Fig.8 shows the geometry of seams before and after the optimization. The optimized radiation pattern obtained in this optimization is shown in Fig.9. The interference waves by seams are scattered in the whole region and the high sidelobes at the particular directions are cancelled. The proposed method has realized the desired radiation pattern.

4. CONCLUSIONS

We proposed the analysis method to predict radiation pattern including the scattering effect from radome seams. The revised physical optics method achieves the fast computation which is appropriate for iterative optimization. The suppression method of sidelobe degradation by optimizing the geometry of seams is also presented. The proposed method is applied for simple periodical radome model and the desired radiation pattern is obtained. The validation of our proposed method is demonstrated.

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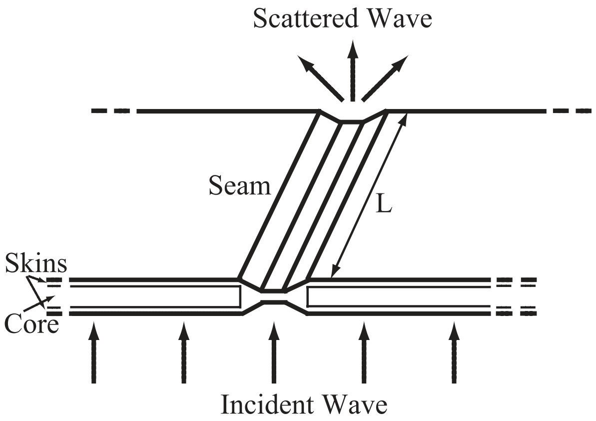


Fig. 1: Composition of Sandwich Radome Seam

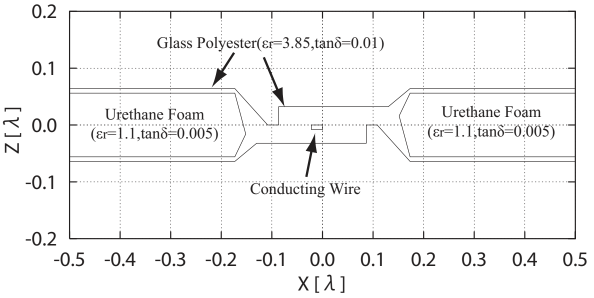


Fig. 2: Calculation Model

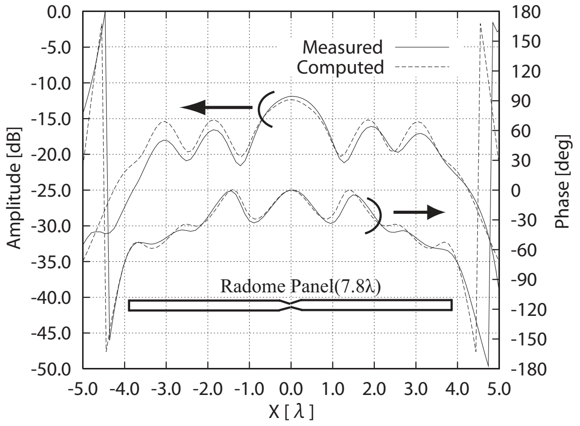


Fig. 3: Scattered Field without Conducting Wire

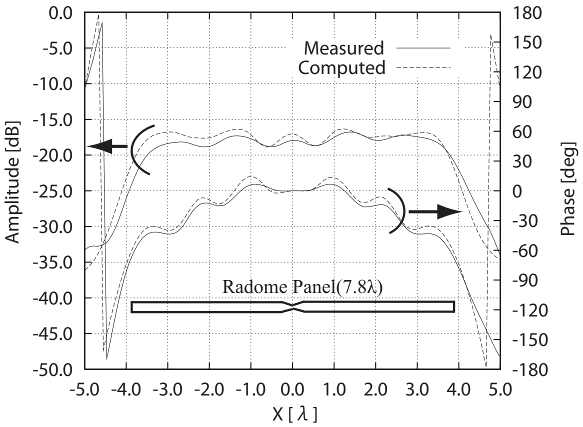


Fig. 4: Scattered Field with Conducting Wire

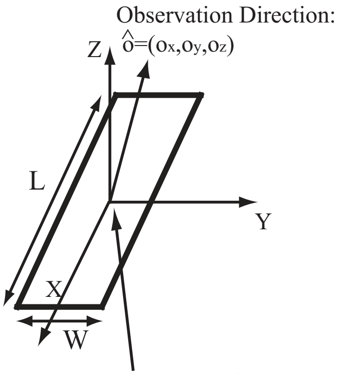


Fig. 5: Conducting Strip Model

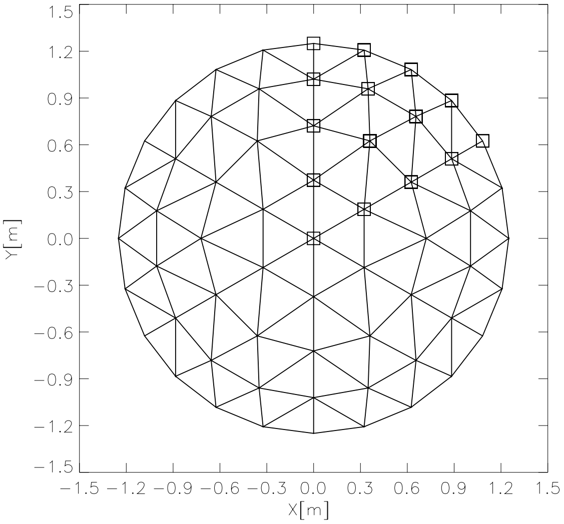
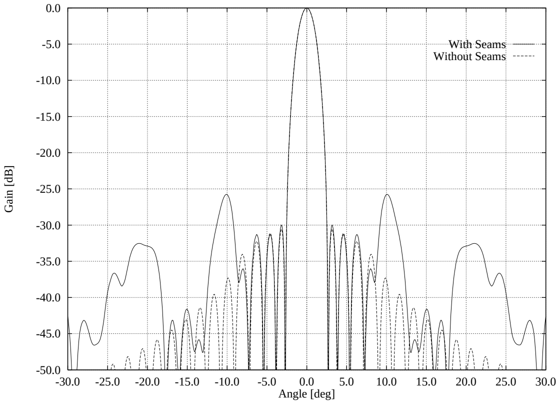
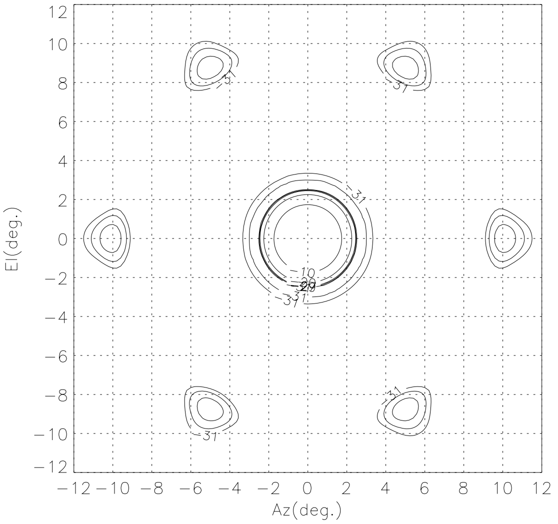


Fig. 6: Shape of Periodical Radome Seams (□:Composition Unit)



(a) Radiation Pattern (XZ-Plane)



(b) Two Dimesional Radiation Pattern (indicates -31,-29,-27,-20,-10dB lines)

Fig. 7: Radiation Pattern Before Optimization

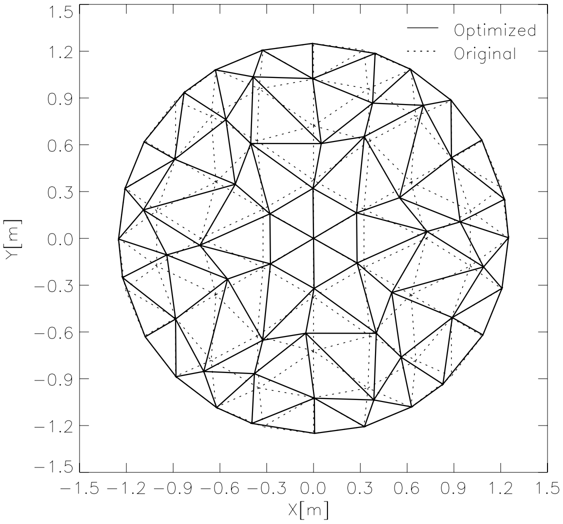
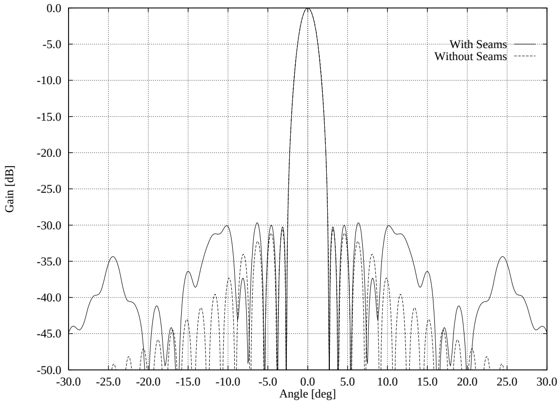
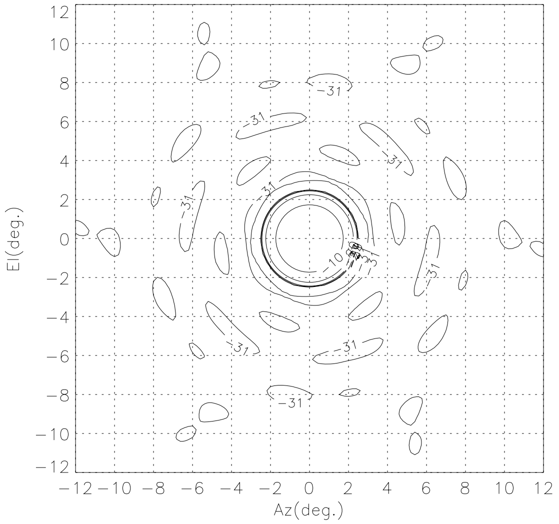


Fig. 8: Shape of Periodical Radome Seams After Optimization



(a) Radiation Pattern (XZ-Plane)



(b) Two Dimesional Radiation Pattern (indicates -31,-29,-27,-20,-10dB lines)

Fig. 9: Radiation Pattern after Optimization