Scattering Effect of Seams on Sandwich Radome Performance

by

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Introduction

Large radar antennas are generally covered with radomes to, among other reasons, protect them from any weather condition and enable continuous precision operation. Due to their large size, the radomes are assembled from many panels connected together with seams as shown in Fig.1.

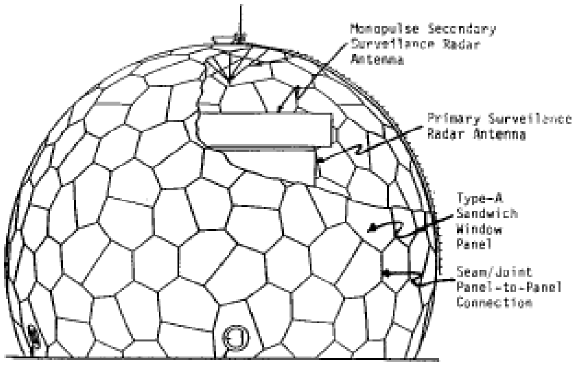


Fig. 1. Sandwich radome geometry.

The frequency bandwidth of the radome, in terms of transmission losses and sidelobe perturbation performance, is determined by the combined effect of the panels and the seams. The panels, usually sandwich A type exhibit a wide frequency bandwidth, which ordinarily does not limit the overall radome performance. The physical dimensions of the seams are determined by the stresses they have to withstand due to all environmental and physical loads including extremely high wind loading. Those seams may degrade the total system performance by introducing high scattering levels and limit the radome’s operational frequency bandwidth. The first analysis of the scattering effect in space frame radomes was conducted by Kay [1].

The reduction of the scattering effect from the seams is discussed in [2], and depends on two factors:

- Minimizing the scattering level from the individual seams.
- Optimizing the radome geometry.

In this paper, the various methods to reduce the scattering effects from the seams in a sandwich radome are described and their influences on the radiation characteristics of an antenna enclosed in the radome are reviewed.

Scattering from an Individual Seam

The scattering from an untuned seam significantly varies with frequency and is related to the polarization current induced in the seam. This effect can be characterized by the induced field ratio (IFR) [3] and the seam scattering pattern. To reduce the scattering effect caused by the seam, tuning techniques such as insertion of conductive strips in the seam are used [4]. The currents induced in the conductive strips tend to offset the polarization current of the seam and consequently reduce the tuned seam IFR. The measured tuned and untuned seam effect on the insertion phase delay (IPD) and the transmission losses (TL) measured on a typical panel for vertical polarization is shown in Fig. 2.

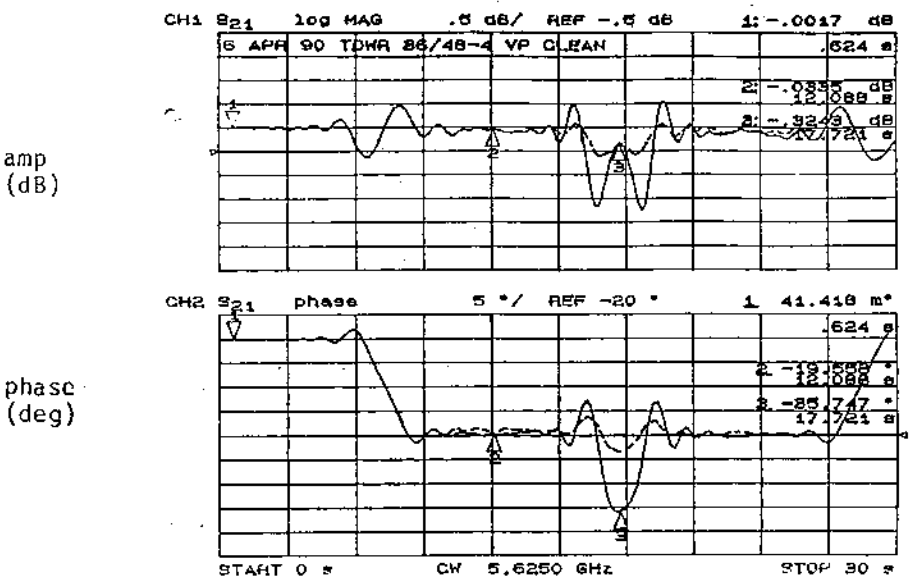


Fig. 2- Measured TL and IPD for tuned (----) and untuned ( ) seam (vertical polarization).

One can observe the significant reduction in the IPD caused by the seam using tuning techniques like insertion of conductive strips in the seam. Fig. 3 shows the improvement in the scattering pattern in a tuned compared to untuned seam, especially in the forward direction.

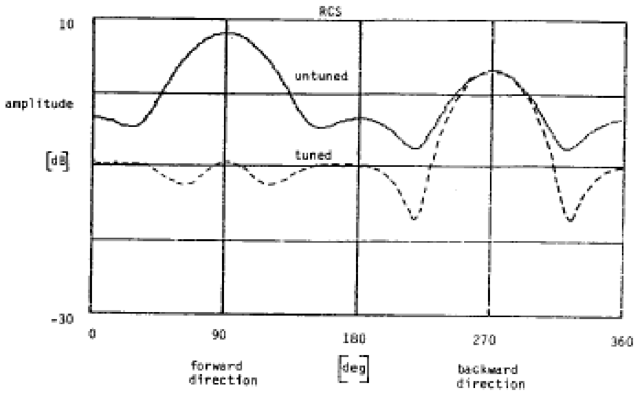


Fig.3- Scattering pattern for tuned and untuned seam.

Optimization of the Radome’s Seam Geometry

The total scattering effect from all the seams in front of the antenna’s aperture is computed by super-position of all scattering effects from the individual seams. Optimization of the radome geometry taking in consideration factors like minimization of the total seam length, increase in panel dimensions, minimization of the total number of parallel seams and uniform seam density throughout the antenna/radome scan angles are considered in all designs by ESSCO. Fig.4 shows the difference in the seams scattering level and distribution for a radome geometry projected on a circular antenna aperture in case of a parallel (bad) geometry compared to a quasi random (good) geometry.

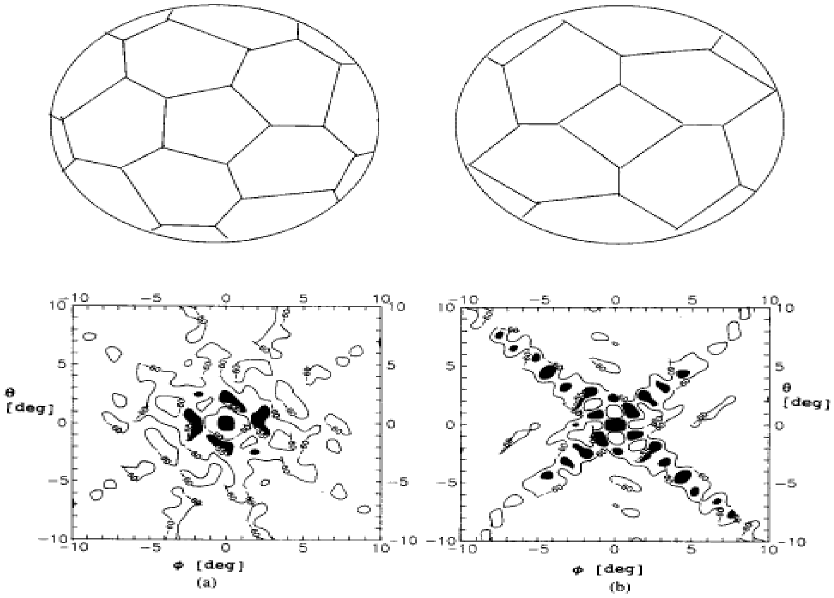
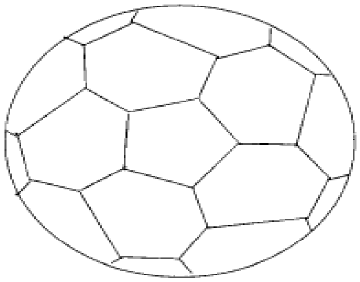


Fig. 4- Comparison in the radome scattering patterns between a quasi-random (a) and parallel (b) geometries.

One can observe that the scattering level in the case of the quasi-random geometry is uniformly distributed and at a lower level. Accordingly, the effect on the radiation characteristics of the enclosed antenna in the radome is lower. Fig.5 shows the difference in the seams scattering level and distribution for a quasi-random radome geometry with tuned and untuned seams.



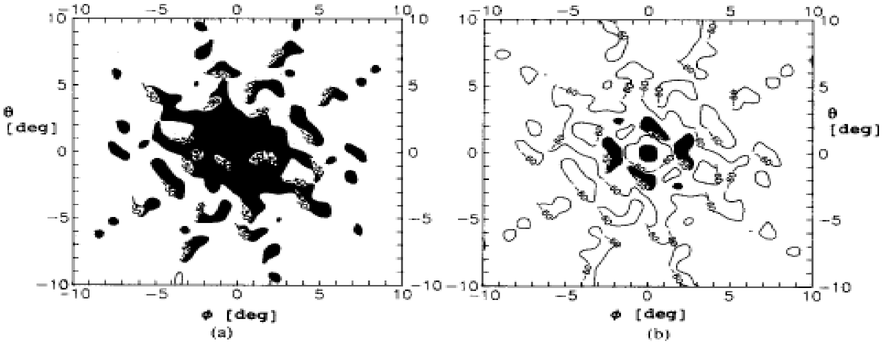


Fig.5- Comparison between the scattering patterns from a randomized geometry with (a) untuned and (b) tuned seams.

The results in Fig.5 demonstrate the significance of tuning the seams in a sandwich radome. Another important factor in the radiation characteristics of an enclosed antenna in a sandwich radome is the variability of the seams blockage with the antenna aspect angle through the radome. In a “good” designed radome the blockage to the antenna is almost independent on the aspect angle of the antenna relative to the radome, while in a “bad” designed radome a large variability may be encountered. Fig.6 shows the variability of the seams blockage in a “good” and a “bad” sandwich radome design.

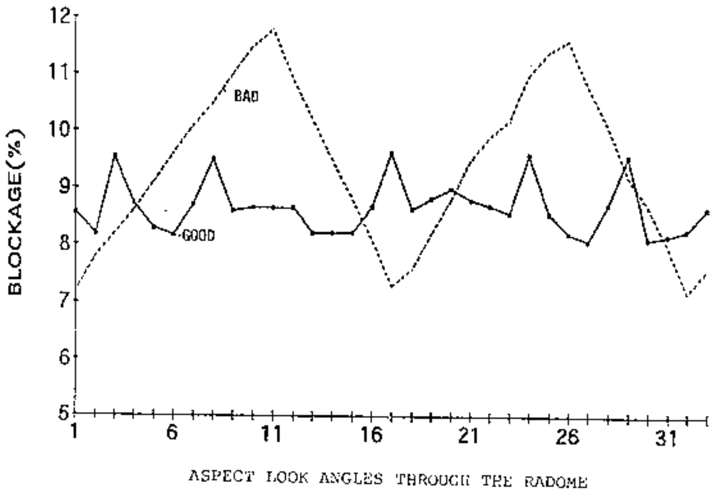


Fig.6- Seams blockage dependence on aspect angle for a “bad” and a “good” (uniform density) radome geometry.

Radiation Parameters Affected by the Scattered Energy from the Seams

The scattered energy by the seams affects a number of radiation parameters [5]:

- Transmission loss.
- Sidelobe level increment of the enclosed antenna
- Null depth in a difference pattern
- Beamwidth change
- Boresight error
- Boresight error slope
- Cross-polarization ratio
- Antenna noise temperature

Transmission loss

The transmissivity through the radome depends not only upon the construction of the radome wall, but also upon the antenna look angle, the field distribution over the antenna aperture, the location of the antenna inside the radome and radome/antenna size ratio. Using ray tracing methods [1], [2], the transmissivity of the radome can be determined by summing the losses from all rays, which have different weight functions and look angles. The total loss through the radome, L_t is equal to

$$L_t=L_w+L_j \quad ,$$

where

L_w- transmission loss due to the sandwich wall in *dB*

L_j- transmission loss due to the seams scattering in *dB*

$$L_j = 10 \cdot \log \left| 1 + \rho_s \cdot \mathrm{Re}\{IFR\} \right|^2 \qquad (1)$$

ρ_s- physical blockage of seams on antenna aperture

<u>Sidelobe level increment</u>

At each angle the energy scattered by the radome and computed by the model presented in [1], interferes with the radiated energy according to the amplitude and phase relations between these two contributions. A sidelobe level, *SL(dB)* below the peak of the sum pattern is affected by the scattered energy, *SE(dB)* relative to the peak resulting in sidelobe perturbation, *ΔSL(dB)* computed by

$$\Delta SL = 20 \log\left(1 + 10^{(SE-SL)/20}\right) \qquad (2)$$

ESSCO developed computer programs which generates topographical maps of scattered energy as displayed in Fig.'s 4-5.

<u>Null depth increment</u>

Scattered energy, whether it is co-polarized or cross-polarized, fills in the null of a monopulse system. The on-axis contribution of the scattered energy interacts with the weak energy radiated in this direction in the null pattern and affects the pattern according to the amplitude and phase relations between the two sources. The null depth increment can be computed in the worst case by eq. (2) in which *SL(dB)*can be replaced by the null depth.

<u>Beamwidth change</u>

The interference of the scattered energy, *SE(dB)* with the main beam energy causes a change, *Δθ* of the antenna beamwidth, *BW*. Maximum effect occurs when both sides of the beam are affected the same way, with either in-phase or out-of-phase combination. The antenna beamwidth variation at the *3dB* points is described in [5],

$$\Delta\theta = \frac{2 \cdot BW \cdot 20 \log\left(1 + 10^{\frac{SE+3}{20}}\right)}{12} \qquad (3)$$

This formula assumes addition in phase the antenna and the radome contributions at the -3dB points.

<u>Boresight error</u>

Boresight error is the result of some imbalance between the two halves of the antenna. The source of the asymmetry may be a difference in panel construction or the presence of more seams in front of one side of the antenna. The tight controls of ESSCO on the process and materials used in panel construction virtually eliminate the first contribution. The contribution of the seams is a function of their distribution in front of the antenna. An approximate formula [5], which estimates the seam induced boresight error is:

$$BSE(rad) = \frac{0.27 \cdot \lambda \cdot L \cdot W \cdot \left|\mathrm{Im}\left(IFR\right)\right|}{R^3} \qquad (4)$$

where

W-the width of the seam

L- the average length of the seams

R- the radius of the antenna

λ- the wavelength

This formula assumes that there is a whole seam on one side of the aperture, uncompensated by the presence of another seam on the opposite half. The actual imbalance is smaller in the large antenna case.

Boresight error slope

The rate of change of the boresight error is dependent on the change in the amount of dielectric seams in front of the antenna and it can be evaluated by [5],

$$Slope = BSE / \theta_r \qquad (5)$$

where

BSE- boresight error

θ_r- subtended angle of the radome seam (typically 9°)

Cross-polarization ratio

The way in which the radome affects cross-polarization is also the same as the way it affects a sidelobe; that is, the scattered energy adds vectorially with the antenna radiation pattern without the radome. The principal difference here is that the energy scattered into the cross polarization must be less than half of that scattered energy into the main polarization; thus the scattered-energy level used for the effect on cross-polarization energy is 3 dB below the assumed for the sidelobe-level-change calculation.

Antenna noise temperature

The noise temperature contribution due to the radome includes three factors:

- Noise temperature contribution, NT_1 due to absorption in the radome wall

- Noise temperature contribution, NT_2 due to reflection in the radome wall
- Noise temperature contribution, NT_3 due to scattering from the seams

The noise contribution due to absorption in the radome wall can be approximated by, $NT_1=300*P_a$, in which P_a is the amount of energy absorbed in the radome walls. In the case of the reflection contribution, it is assumed that half of this energy is reflected to the cold sky and half to the warm earth (300°K), therefore $NT_2=150*P_r$, in which P_r is the amount of energy reflected by the radome walls. In case of the scattering the noise temperature contribution is dependent on the antenna elevation angle. Thus, for a typical 10° elevation angle and making the assumption that half of the scattered energy goes forward to the cold sky and half backward of which half is reflected by the antenna reflector back to the cold sky we obtain, $NT_3=75*P_s$, in which P_s is the amount of energy scattered by the radome seams.

Summary

In the design of sandwich radomes, scattering effects from the seams play an important role. To obtain a high performance radome, one should consider both reducing the scattering from the individual seams and optimizing the seam geometry.

The scattering from the seams affect many radiation characteristics of the antenna and not just the transmission loss as many companies would like you to believe. ESSCO developed throughout the years the analytical tools and the computer programs to analyze these effects.

References

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