FULL SCALE SEGMENTED RADOME PERFORMANCE
EVALUATION USING A SSR ANTENNA

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ABSTRACT

The paper contains the results obtained during the evaluation of the performance of a 6.7m segmented radome. The tests have been carried out at a calibrated outdoor ground reflection range. The analysis of the results has focused on the SLL perturbation of the antenna pattern, the beamwidth, the loss in gain, and the maximum boresight error (BSE). These measurements concentrate on the antenna pattern characteristics and not on the system performance in its totality. Very satisfactory results have been obtained with respect to a pre-determined specification for an acceptable pattern degradation.

INTRODUCTION

In this paper the combined effort of two companies, ADC and Raytheon Systems LTD, will be demonstrated. The former provided the radome, which is an A-sandwich, spherical radome 6.7m in diameter. The latter provided one of their standard Secondary Surveillance Radars (SSR), namely the Flat Plate Antenna (FPA) as well as the facilities to perform the measurements.

So far Raytheon and other companies producing radar systems, have been using geodesic quasi-random type radomes to cover their Large Vertical Aperture (LVA) or other SSRs. The driving force of the experiments was to investigate the suitability of the segmented type radomes for SSR antennas. Since the IFR approach, [1]-[3] is not suitable for this type of radome it was considered necessary to manufacture a full size radome and to test its performance. Since it was not feasible to build a 9.5m radome and erect it on the control towers of Raytheon using the LVA, we proceeded with a smaller radome and a smaller similar type antenna. The aim of the research was to establish the radome performance of a full size segmented radome, using a proven operational radar antenna, in a properly calibrated antenna range.

EXPERIMENTAL SET UP AND RELATED HARDWARE

Antenna Under Test

The FPA is a patch array, with dimensions 4.3m x 0.5m x 0.345m. It is shown in Fig. 1. This radar antenna is used for ground, ground mobile and shipborne SSR applications. Normally the FPA does not require a radome but the size restrictions rendered it necessary to use this unit instead of the larger LVA. However, the radiation characteristics are very similar with the only exception of the elevation pattern, which is a fan beam in the FPA case whereas in the LVA case it is a shaped modified cosecant squared pattern. Also the azimuth beamwidth of the FPA is slightly larger than that of the LVA since it is electrically smaller in the horizontal dimension. Nominally the FPA has a gain of 19.5dBi. The azimuthal Half Power BeamWidth (HPBW) is 5° and the first SLL is about –24dB. The antenna is vertically polarized and its modes of operation include sum (Σ), difference (Δ) and control (C) channels/patterns.

Antenna Range Specification

The FPA is fixed on an azimuth, elevation, azimuth pozitioner located near the edge of the building in order to avoid intercepting any edge diffracted waves. The antenna range is an outdoor ground reflection L-band range. The power from the transmitting antenna is of the order of few mWatts, the distance between transmitting antenna and Antenna Under Test (AUT) is approximately 670m and the height of both antennas from the ground is about 6m. The control tower is shown in Fig. 2. The quiet zone is over 9m, with an amplitude taper of less than 0.15dB and a peak-to-peak ripple of about 0.5dB.

Fig. 1. The FPA antenna on its positioner inside the radome.

Fig. 2. The Raytheon control tower with the radome on the roof.

MEASUREMENTS

All patterns were taken at the two SSR frequencies of 1030MHz and 1090MHz. Almost all information were extracted by comparing the measured pattern with the radome on, and the measured pattern without the radome. To verify repeatability, the antenna pattens were also measured after the dismantling of the radome.

The four main points of focus were the gain variation, the SLL variation, the HPBW of the azimuth and elevation beams and the maximum BSE. Comparing the pattern with and without the radome, we were able to estimate with sufficient accuracy the scattered field pattern in the azimuth plane. The gain was extracted using the Substitution method.

The acquired antenna patterns included elevation patterns as well as azimuth patterns for various elevation positions. All patterns were acquired with the radar receiving the transmitted signal. Hence for the 1030MHz frequency band the Reciprocity principle is used.

RESULTS

Gain

The variation in gain is summarized in table 1. It becomes evident that the loss in gain is of the order of 0.1dB. To appreciate the effect of this gain loss, the following equation is quoted. The signal-to-noise ratio (SNR) is inversely proportional to the distance R between SSR and transponding aircraft and the various system losses L. These system losses are related to the range R via (1),

$$SNR = \frac{P_T G_{SSR} G_{TP} \lambda^2}{(4\pi)^2 N R^2 L} = \frac{const}{R^2 L} \tag{1}$$

where P_T is the transmitted power, G_{SSR} is the gain of the SSR antenna, G_{TP} is the gain of the transponding antenna, λ is the wavelength and N is the noise level. According to (1) for a loss of L=0.1dB, to produce the same SNR, a target at 100nmi has to come closer by 1.15nmi.

Table 1. Gain readings at the two SSR bands at various stages of the measurements.

	1030MHZ	1090MHZ
Before	20dBi	19.9dBi
During	19.9dBi	19.8dBi
After	20dBi	19.7dBi

HPBW in Azimuth and Elevation

The variation of the HPBW in both planes and for the Σ channel is recorded in table 2.

Table 2. HPBW variations with and without the radome.

	WITHOUT RADOME	WITH RADOME	
1030 MHz	4.98°	5°	Azimuth
1090 MHz	40.33°	39.54°	Elevation

It is seen that the broadening of the beam is of the order of 0.1° or less. The experimental error of the system in measuring angular intervals is ±0.01°.

SLL and Overall Pattern Comparisons

In the next four figures, Fig. 3-6, the elevation patterns and the azimuth patterns for the Σ, Δ and C channels are shown.

Scattered Field

The scattered field was calculated by subtracting the complex field without the radome from the complex field with the radome. Two features are worth discussing. Of these, the main beam lobe represents the fact that the radome joints tend to scatter constructively i.e. in-phase in the boresight direction, and the second is the periodicity of the location of the other lobes which corresponds to the angle between the joints on the radome. The latter effect is more prominent on the left side of the graph in Fig. 7.

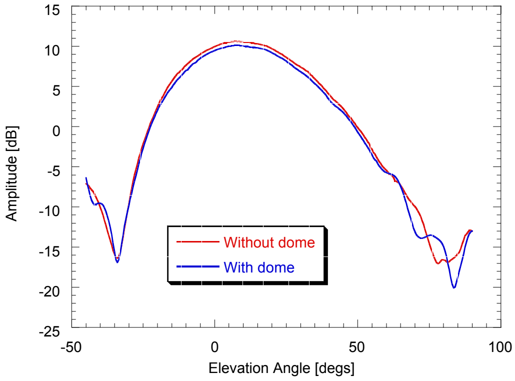

Fig. 3. Elevation pattern, Σ channel, 1030 MHz.

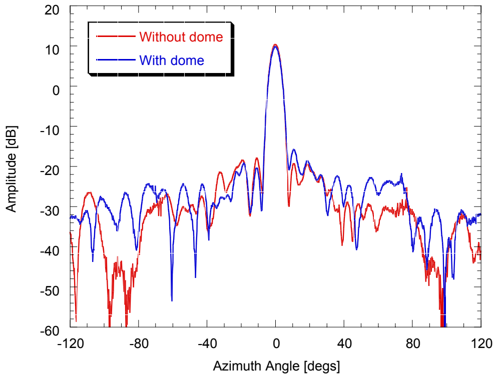

Fig. 4. Azimuth pattern, Σ channel, 1030 MHz.

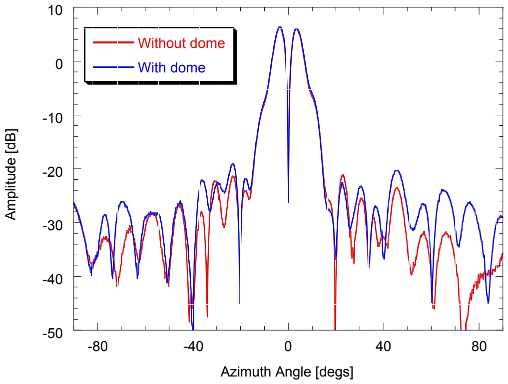

Fig. 5. Azimuth pattern, Δ channel, 1090 MHz.

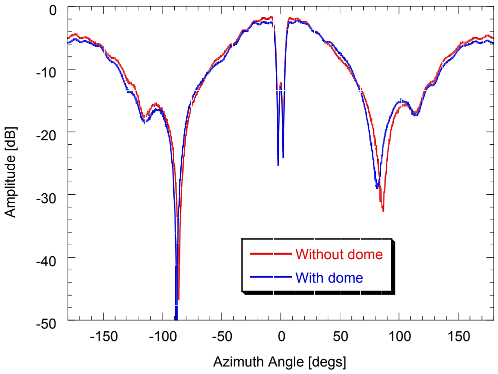

Fig. 6. Azimuth pattern, C channel, 1030 MHz.

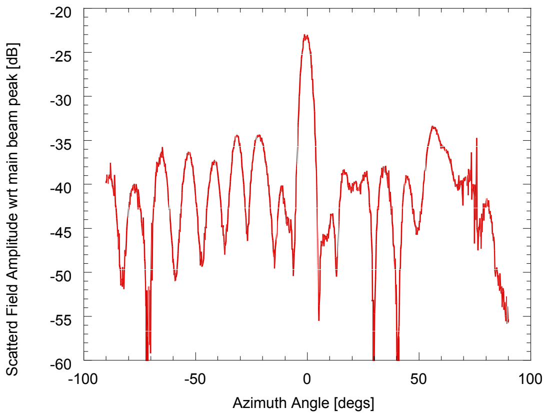

Fig. 7. Scattered field pattern at 1030 MHz for the Σ channel.

Maximum BSE

This quantity was calculated in two ways since the accuracy of the tests was of the same order of magnitude as the required specification. Sufficient resolution e.g. ±0.001° could not be achieved in order to definitively estimate a beam squint of the order of 0.01°. As a first approach we interpolated through the measured data and compared numerically the location of the peak of the patterns. That gave a worse case BSE of 0.05°. In the second case, we calculated the separation between the midpoints of the corresponding half power (HP) points for each pattern according to,

$$BSE = \left| \frac{HP_{right}^{without} + HP_{left}^{without}}{2} - \frac{HP_{right}^{with} + HP_{left}^{with}}{2} \right| \tag{2}$$

This approach gave a maximum BSE of 0.034°.

CONCLUSIONS

The present paper contains material that is seldom found in the literature and especially in the public domain one. Accurate antenna pattern tests have been performed proving the suitability of the segmented type radomes for use by SSR antennas.

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