Proceedings of the Joint Symposium on Antennas & Propagation and Microwave Theory & Techniques, Pretoria, South Africa; 19-21 August 1986, pp. 347-358.

EVALUATION AND MODIFICATION OF THE NIAST MICROWAVE ANECHOIC CHAMBER

D E Baker*

Synopsis

This paper describes the test procedures used and the results obtained during a programme to replace and repair damaged absorber panels in the anechoic chamber. Both the antenna pattern comparison and free-space VSWR methods were used for chamber evaluation with the second method as the main procedure. Results are presented for the reflectivity level in the chamber at 500 MHz (generally the lowest frequency used), 1 GHz and 3 GHz. Measurements before and after the modifications to the chamber show that the performance of the chamber has been improved, particularly at the low-frequency end.

Hierdie referaat beskryf die resultate wat verkry is en die toetsprosedures wat gebruik is om die werkverrigting van die weerkaatsvrye kamer te evalueer nadat beskadigde absorbeerpanele vervang is. Beide die antenne pooldiagram vergelyking en die vrye ruimte SGV metodes is gebruik met die SGV metode as die hoof prosedure. Resultate word gegee vir die weerkaatsvlak by 500 MHz (gewoonlik die laagste frekwensie waarvoor die kamer gebruik word), 1 GHz en 3 GHz. Metings voor en na die modifikasies wys dat die werkverrigting van die kamer verbeter is, veral in die lae frekwensie gebied.

Keywords: Anechoic chamber, reflectivity level, free-space VSWR, chamber evaluation.

---

* National Institute for Aeronautics and Systems Technology, CSIR, P.O. Box 395, Pretoria, 0001.

1 Introduction

The NIAST microwave anechoic chamber was built in 1970 and has since then been a key facility for antenna research in the 0,5 to 18 GHz frequency range. As a general purpose facility it has been used for antenna measurements (mainly patterns and gain) and also for diverse special measurements (radome panels, scattering, system sensitivity, etc.). Over the years absorber panels have been damaged when removing them for special test set-ups. The original absorber panels were unpainted (i.e. the standard black) and they have been exuding a vapour (presumably the binder for the carbon particles in the foam) since their installation with the result that the absorber pyramids have become quite brittle. To extend the life of the absorbers and to improve the lighting within the chamber, the absorbers were removed and sprayed pale blue with a high quality water-based paint.

The primary purpose of the chamber modifications was to extend the useful life of the absorbers by painting the existing absorber blocks and to repair and replace some of the damaged blocks with higher performance absorbers. This paper describes the procedures used and the results obtained before and after the modification programme.

2. Modification Programme

2.1 Existing chamber

Figure 1 shows a plan view of the 3,06 m x 4,18 m x 10,50 m chamber. The main wall behind the test positioner is covered with ECCOSORB HPY-30, the side walls, floor and ceiling are covered with HPY-18 and the rear wall behind the source with HPY-12. Two transmitting positions are normally used, one at 3 m and the other at 7 m range with the option of mounting the source on a trolley to vary the range from 7 m to 3 m. The 3 m position is used primarily for measurements in the 0,5 to 2 GHz region to obtain a more advantageous incidence angle on the side wall absorbers.

2.2 Chamber modifications

As indicated earlier, many absorber pieces had been damaged; these blocks were repaired and replaced. The unpainted blocks were painted with the water-based paint and reinstalled. Apart from the repairs, the major modification was the installation of higher performance absorbers in selected areas. As shown in Figure 2, the HPY-30 blocks on the main wall were replaced by ECCOSORB HPY-40 NRL and some of the HPY-18 absorbers on the side walls, floor and ceiling were replaced by VHP-26 NRL and VHP-18 NRL in the specular reflection regions. In addition, the receive test positioner was moved forward to about 1,7 m from the tips of the HPY-40 absorber blocks. A third source position was established in the rear wall to obtain a 7,6 m transmit range, primarily for scattering measurements where the source and receiver can be colocated in a small equipment room.

3. Evaluation Programme

Two main methods have been proposed for the evaluation of anechoic chambers. These are the free-space VSWR method and the antenna pattern comparison (APC) method[1,2,3]. Because the performance of the absorbers is poorest at their low-frequency limit and because the directivity of typical source antennas at 500 MHz is low (giving poor pattern isolation from the side walls, floor and ceiling) the evaluation programme concentrates on the 0,5 to 1 GHz region with fewer measurements at 3 GHz. An HP 8410B network analyser was used as the test receiver for the measurement programme.

3.1 Choice of evaluation procedure

At the outset of the measurement programme the APC technique was used to evaluate the chamber performance. To ensure that the worst-case reflections are observed with the APC technique the patterns must be taken at spacings of $\lambda/4$ or less[2]. In addition, the longitudinal and transverse displacements of the test positioner must be large enough to ensure that patterns are taken over complete cycles of the interference patterns.

The period of the longitudinal interference pattern P_ℓ is given by

$$P_\ell = \frac{\lambda}{2 \sin^2 \frac{\phi}{2}} \qquad (1)$$

while the period for the transverse pattern P_t is given by

$$P_t = \frac{\lambda}{\sin\phi} \qquad (2)$$

where λ is the wavelength and ϕ is the grazing angle to the specular point[2]. For the configuration shown in Figure 1 with a transmit range of 7,0 m and ϕ = 30,8° we have P_ℓ = 4,2 m and P_t = 1,2 m at 500 MHz. It is clear that P_ℓ = 4,2 m is unrealistically large for evaluating scattering from the specular regions on the side walls of the chamber.

If a volume of 1 m^3 is to be examined, the $\lambda/4$ spacing between patterns requires that a very large number of patterns be taken. It is difficult to obtain the same accuracy with the APC technique as with the VSWR technique and it is best to use a temporary traversing mechanism[4]. A temporary traversing mechanism similar to that in Figure 8.43 of reference 2 was designed, built and installed in the chamber. The test positioner can traverse ±1 m from the centre line of the chamber and its position is fed to the x axis of an x-y plotter.

Because the free-space VSWR technique allows for more rapid detailed evaluation, this technique is used as the main procedure for the chamber with the exception of the main wall. Here a variant of the APC technique can be used because a full cycle of interference from the back wall requires only a $\lambda/2$ longitudinal displacement.

3.2 Measurements before modifications

After some initial APC measurements, VSWR measurement were taken from 0,5 to 1,0 GHz in 100 MHz intervals. Figure 3(a) shows a set of VSWR patterns with the probe horn boresight parallel to the chamber axis for a 7 m transmit range. For the 7 m range with ϕ = 30,8°, the ripple period in Figure 3(a) closely corresponds to that predicted by Equation (2). The gain of the source and probe horns increases from 5,5 dBi at 500 MHz to 9 dBi at 1 GHz. The pattern level a and the reflectivity r can be found from the peak value b and the minimum value c of the ripple[3], thus

$$a = 20 \log \left[\frac{1}{2} \left(10^{b/20} + 10^{c/20}\right)\right] \text{ dB} \qquad (3)$$

and

$$r = 20 \log \left[\frac{1}{2} \left(10^{b/20} - 10^{c/20}\right)\right] \text{ dB} \qquad (4)$$

It is clear from the reflectivity values in Figure 3(a) that there is significant scattering from the specular regions for the 7 m range. The reflectivity is calculated only for transverse displacements between ±0,5 m from the chamber axis.

In order to decrease the angle of incidence θ_i from around 60° to about 45°, the source antenna was moved forward to Tx1 to obtain a transmit range of 3 m. Figure 3(b) shows a set of E-plane scans (i.e. the incident electric field parallel to the plane of scan), there is clearly a significant improvement over Figure 3(a). The peak-to-peak ripple at 500 MHz is about 1,4 dB giving r = -22,6 dB. At the 3 m range the reflectivity at 500 MHz lay in the -20 to -25 dB level.

3.3 Measurements after modifications

After the modifications outlined in Section 2, detailed VSWR measurements were taken at 0,5 and 1,0 GHz for the 3 m transmit range and at 3 GHz for the 6 m transmit range. The probe horn was rotated in 30° steps between each VSWR traverse to evaluate the reflections from various parts of the chamber.

In addition to the absorber modifications, an attempt was made to reduce the E-plane beamwidth of the source antenna. This was achieved by adding 150 mm diameter rolled edges[5] to the aperture of a ridge-loaded horn[6] to reduce the edge diffraction in the E-plane of the horn. The effects of this modification are shown in Table 1. Without the rolled edges there is a significant difference between the power levels at 45° for the E and H planes. With the rolled edges the E and H plane beamwidths are nearly the same to the 45° points.

TABLE 1 : Effect of 150 mm diameter rolled edges on power level at the ±45° points of the source horn pattern.

FREQUENCY (GHz)	CONVENTIONAL HORN		HORN + ROLLED EDGES	
	H-PLANE (dB)	E-PLANE (dB)	H-PLANE (dB)	E-PLANE (dB)
0,5	5,5	1,7	5,8	5,0
0,6	5,0	3,0	5,0	4,5
0,7	6,5	5,0	7,5	7,0
0,8	8,5	5,3	8,5	8,0
0,9	8,5	6,0	10,0	8,5
1,0	9,0	8,5	9,5	11,0
2,0	15,5	8,0	14,0	8,5

Figure 4 shows a set of E and H plane scans at 3 m with the source and probe antenna gains increasing from 8 dBi to 11 dBi from 500 MHz to 1 GHz. There is some ripple on the patterns and the sloping character is caused mainly by the scanning of the source and receive antenna patterns. The scanning is now much more obvious than in Figure 3 because of the reduced beamwidths as shown in Table 1. The dashed curves in Figure 4 result when the pattern scanning is removed by using the nominal patterns of the source and probe antennas.

Figure 5 shows a nominal E-plane pattern at 1 GHz together with a set of VSWR probes with the probe horn scanned to 30°, 60°, 90° and 120°. The inset shows an analysis of the data. Table 2 summarises the results of the chamber evaluations at 0,5; 1,0 and 3 GHz after the modifications to the chamber and the source horn.

TABLE 2 : Summary of reflectivity levels as a function of probe horn scan angle and frequency at 3 m and 6 m ranges (±0,5 m scan off chamber axis).

PROBE SCAN ANGLE DEGREES	0,5 GHz r (dB)*		1,0 GHz r (dB)		3,0 GHz r (dB)	
	Tx - H	Tx - V	Tx - H	Tx - V	Tx - H	Tx - V
-180	30,0	30,3	43,7	41,3	46,0	46,0
-150	34,2	34,2	39,2	39,1	42,3	44,4
-120	36,0	30,6	37,4	41,8	45,3	42,8
-90	30,2	30,4	41,2	43,5	47,5	48,8
-60	29,4	34,5	42,3	44,6	45,8	45,1
-30	31,7	34,6	38,6	44,9	39,9	42,6
0	29,5	32,0	44,8	44,8	41,4	41,8
30	31,1	31,9	38,0	50,2	43,8	40,4
60	28,0	40,8	40,7	40,7	45,4	48,7
90	31,5	35,1	38,7	45,5	51,6	50,6
120	36,2	34,1	38,0	38,1	46,6	46,6
150	36,2	35,7	37,2	39,5	48,5	41,8
180	30,0	30,3	43,7	41,3	48,5	46,0
Source gain (dBi)	8,0		11,0		18,0	
Probe gain (dBi)	8,0		11,0		14,3	
Range (m)	3		3		6	

Tx - H = source polarisation horizontal.

Tx - V = source polarisation vertical.

* negative signs omitted.

4. Conclusions

The measurements before and after chamber modifications show that the performance of the chamber has been improved in the 0,5 to 1 GHz region by a combination of using higher performance absorbers in the specular regions and increasing source horn gain. At 500 MHz, the reflectivity is generally better than -30 dB and at 1 GHz better than -38 dB for the 3 m range while at 3 GHz the level is better than -40 dB for the 6 m range. From 2 GHz up, the full length of the chamber can be used for pattern measurements. The paint used on the old HPY absorbers has stabilised them and given them added strength without degrading their performance.

5. Acknowledgements

The author is indebted to the CSIR for permission to publish this work and thanks Messrs D.C. Geldenhuys and J.A. Meyer who designed and built the temporary traversing mechanism and Mr Geldenhuys for his assistance with the measurements.

6. References

1. IEEE Standard Test Procedures for Antennas, Std. 149-1979, IEEE, New York, 1979, pp. 54-56.

2. Rudge, A.W. et al (Eds.) : The Handbook of Antenna Design, Vol. 1, Peter Peregrinus Ltd., London, 1982, pp. 673-694.

3. Appel-Hansen, J. : Reflectivity level of radio anechoic chambers", IEEE Trans. Antennas Propagat., Vol. AP-21, July 1973, pp. 490-498.

4. Appel-Hansen, J. : Private Communication, 27 Nov. 1985.

5. Baker, D.E. and van der Neut, C.A. : A compact, aperture-matched, balanced transmission line antenna, Trans. SAIEE, Vol. 76, No. 2, June 1985, pp. 62-66.

6. Van der Neut, C.A. : Beamwidth control in pyramidal horns, Proc. SAIEE Symposium on AP, 16-18 May 1983, Pretoria, pp. Y-1 to Y-8.

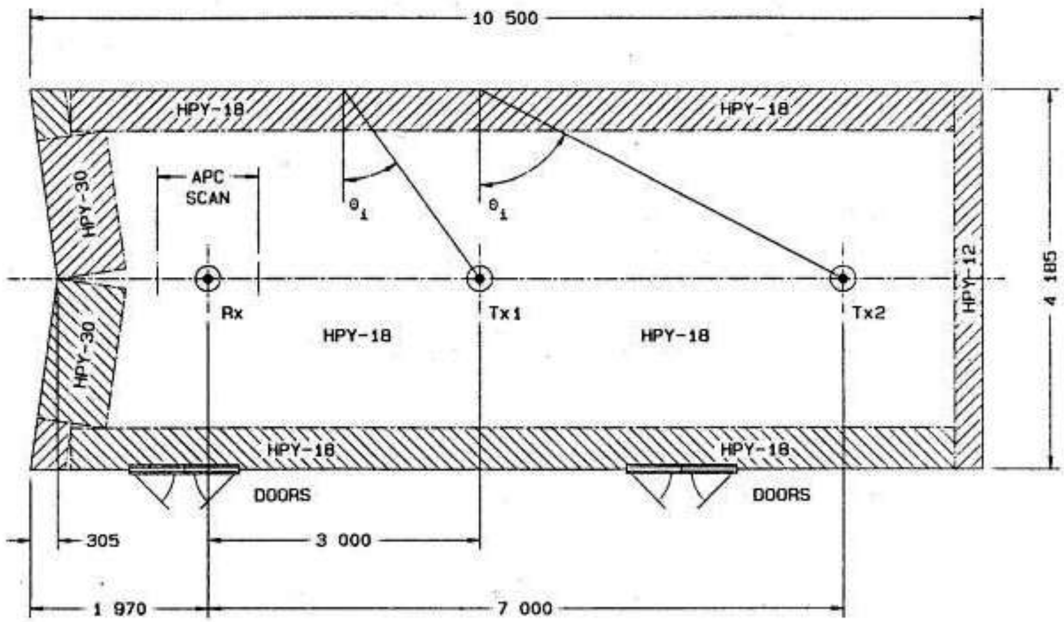


FIGURE 1 : Plan view of anechoic chamber before modifications.

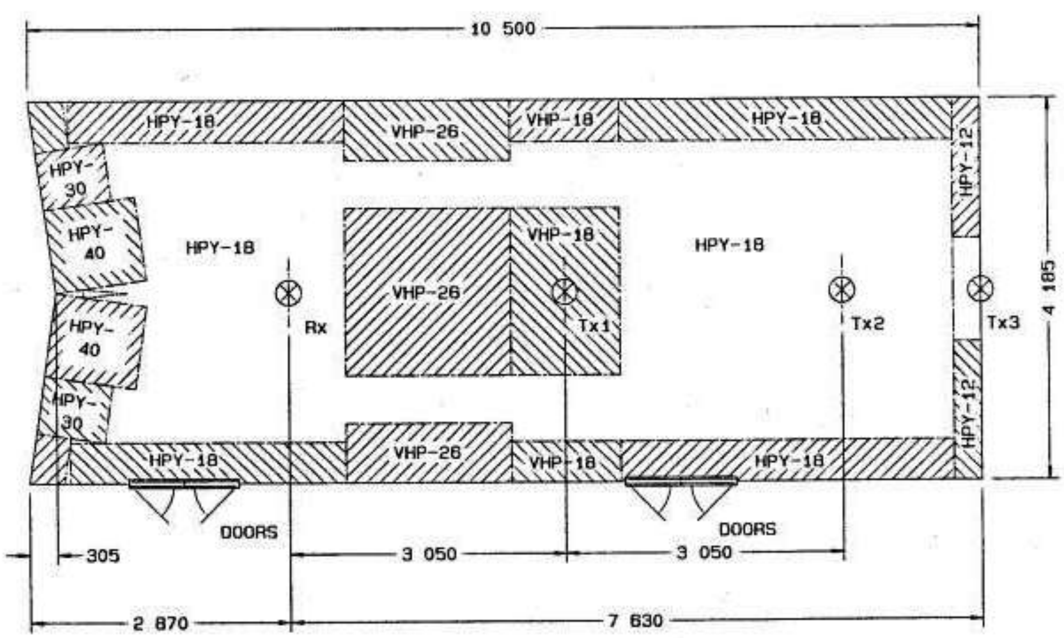


FIGURE 2 : Plan view of anechoic chamber after modifications.

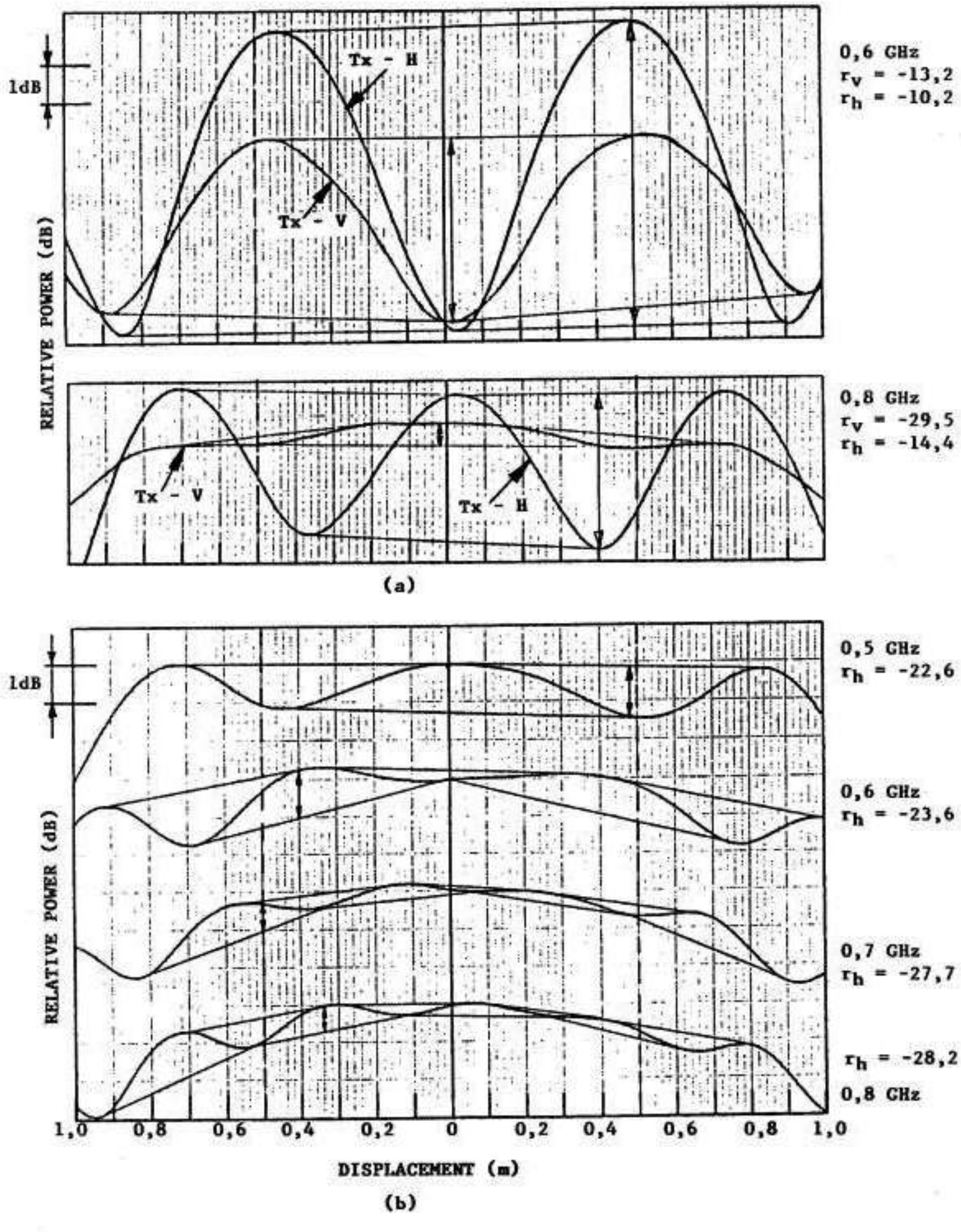


FIGURE 3 : Free-space VSWR traverses at peak of probe horn pattern before chamber modifications (a) R = 7 m, Tx vertical and horizontal and (b) R = 3 m, Tx horizontal.

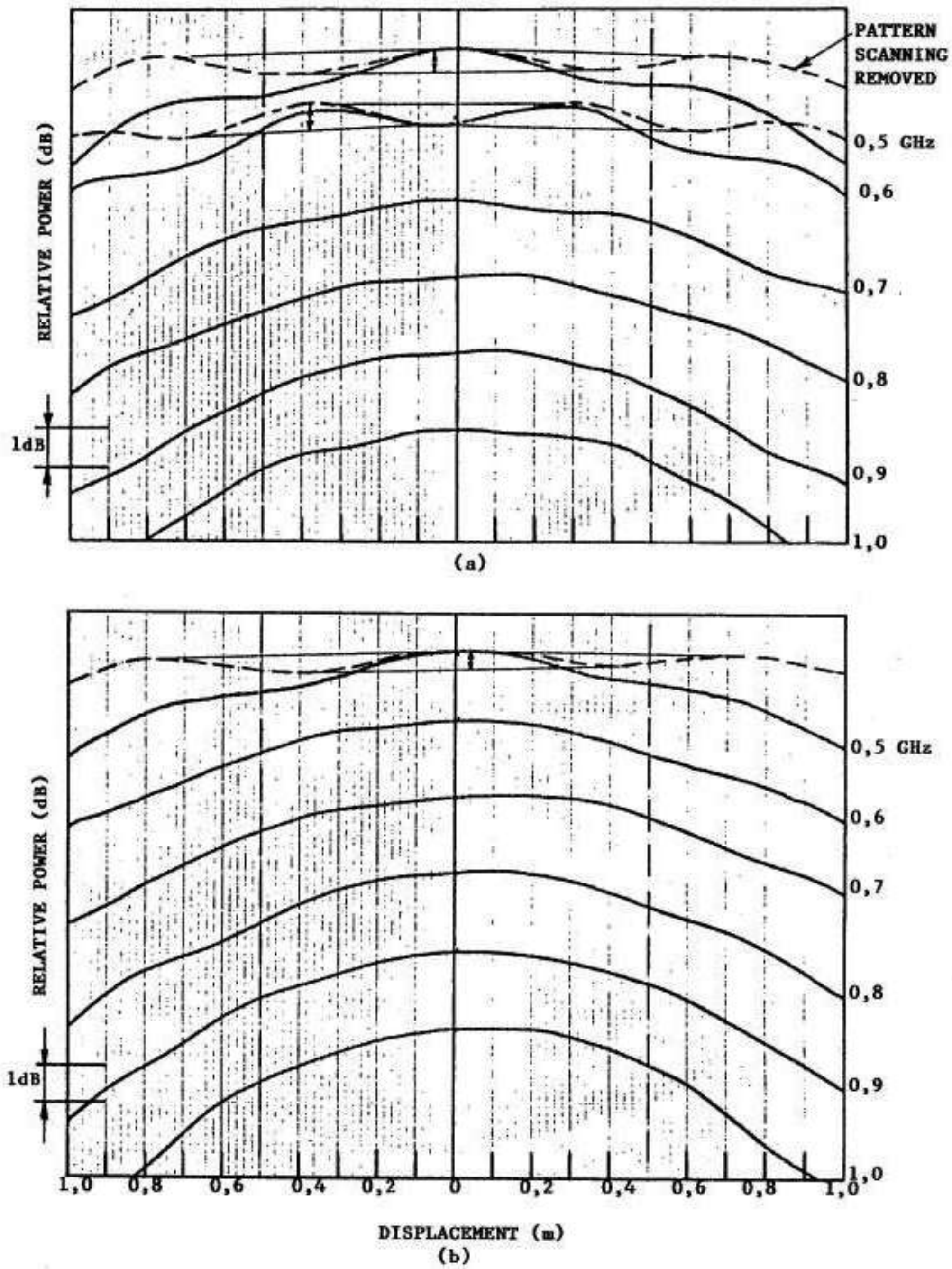
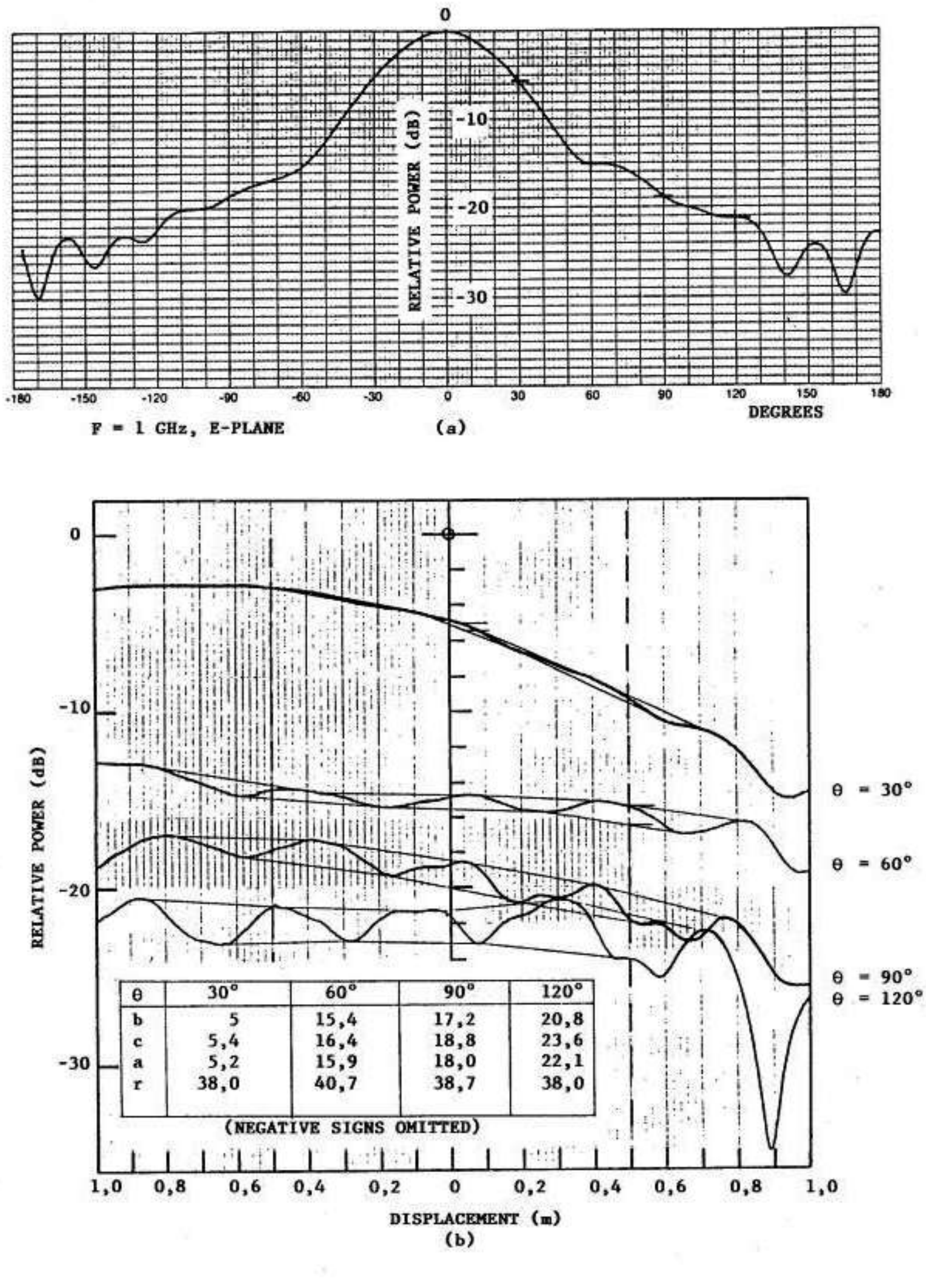


FIGURE 4 : Free-space VSWR traverses at peak of probe horn pattern after chamber modifications at R = 3 m (a) source horn polarisation horizontal and (b) vertical.



θ	30°	60°	90°	120°
b	5	15,4	17,2	20,8
c	5,4	16,4	18,8	23,6
a	5,2	15,9	18,0	22,1
r	38,0	40,7	38,7	38,0

FIGURE 5 : (a) E-plane pattern of probe horn at 1 GHz and (b) free-space VSWR traverses for the probe horn rotated off the chamber axis (transmit range = 3 m).