MEASUREMENT OF THE MICROWAVE REFLECTION CHARACTERISTICS OF CARBON FIBRE MATERIALS USING A VERY COMPACT CONFIGURATION

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1. Introduction

Lightweight materials such as carbon fibre are of significant interest for the production of reflector surfaces for microwave antennas. In the case of low sidelobe and low cross polar designs it is important to know the reflection properties of the material in some detail and in particular to establish the maximum extent of any cross polar reflections due to the orientation of fibres within the material. Here we shall describe a novel method of making measurements, to establish such effects. The technique requires accurately flat samples of the material to be available.

Figure 1 shows the very compact experimental configuration. The technique has evolved from a system which was originally developed to measure the gain of a reflector antenna(1). The material under test is placed parallel to the antenna aperture plane and in the near field zone of the antenna.

A uniform phase front is incident on the plane sheet of material, and is reflected back via the reflector into the feed. The return loss is then measured at either a spot frequency or swept over a band. Multiple reflections within the antenna feed system will in general occur, so the original gain measurement technique(1) used an averaging of return loss over a small band of frequencies. For comparative measurements at a spot frequency, we must ensure that the distance to the reflecting sheet is constant. Diffraction losses in the measurement are less than 0.02dB for an antenna of diameter 30 cm when the distance to the sample is about 15cm(1), at 3 cm wavelengths.

2. Measurements

The above configuration has been used for comparative measurements on the reflecting properties of the sheet of material under test. The following properties were measured: (i) the reflectivity of the material - by comparison with a metal sheet; (ii) the anisotropy of the reflection coefficient, both in amplitude and phase, by rotating the sample (about the axis of the parabolic reflector).

The accuracy of the measurements is critically dependent on the flatness of the test sample, and the precision of the turntable when rotated. Returns from the turntable (with a metal reflection surface) showed a variation of 0.04dB and 0.4 of phase in the reflected signal when rotated, thus setting limits on the measurement accuracy. The test sheet of material was larger than the reflector (70cm x 90cm compared to 30cm diameter), so it was possible to illuminate different areas of the sample to test flatness.

As well as the very small effects of diffraction mentioned above, a further possible source of error is scattering by the antenna feed and its supports, i.e. blockage. However, the antenna polarization is fixed relative to the blocking structure, so relative variations with sample orientation should be unaffected. This was confirmed by introducing scattering objects into the set-up, and re-measuring.

3. Results

Three separate measurements were made with the sample at different distances from the antenna, comparing the reflectivity of the carbon fibre material with a plane metal sheet, averaged over the band 11.7 to 12.1GHz. The results are shown in Table I. The reflection coefficient of the carbon fibre material is deduced as 0.991, while the variation of results indicates the accuracy of the measurement (0.04dB in return loss).

The variation of the reflection coefficient as a function of sample orientation was measured at spot frequencies in the band 11.7 to 12.1GHz, with plots made against turntable angle. Four different areas of the sample were illuminated for each frequency. Table II shows the phase results and Table III the amplitude results. The average phase variation (max to min) of 1.4 is significant, given the expected accuracy of 0.4 . The amplitude variations (max to min) are small: 0.04dB for the first set of three measurements, 0.08dB for the second set of five, with an expected accuracy of 0.04dB. The interesting point here is that the second set were made two weeks later than the first set - and the anisotropy, although still very small, has increased. This may be due to slight warping of the sample with time, for example by curving slightly in one direction.

4. Conclusions

A very compact measurement technique has been described which can be used for accurate measurements of the microwave reflection characteristics of carbon fibre materials. The measurement accuracy was 0.04dB in amplitude and 0.4 of phase. An accurately flat sheet of the material, 30cm across, is needed. Results for one particular material show a reflection coefficient of 0.99, and an anisotropy of reflection coefficient of 1.4 of phase and 0.08dB in amplitude.

Acknowledgements

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Reference

1. Hoque M., Smith M.S. and Davies D.E.N. "Compact gain measurements on reflector antennas" IEE Proc., 131 part H, pp 371-378 (Dec. 1984).

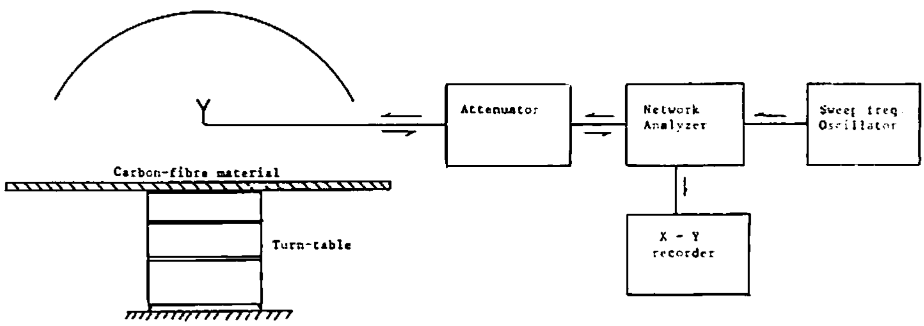

Fig. 1. Experimental set-up to measure the cross-polar response of the carbon-fibre material.

TABLE - I

Measurement number	Distance from the aperture in cm	Average difference of return-loss	Reflection co-efficient	Average
1	11.9	0.044	.995	
2	12.5	0.10	.988	.991
3	12.9	0.08	.990	

TABLE - II

Measurement Number	Frequency in GHz	Phase difference through 0-90° rotation	Average phase difference at each frequency	Overall Average phase difference
1		2°		
2	11.7	1.2°	1.813°	
3		1.862°		
4		2.19°		
5		1.53°		
6	11.8	0.6°	0.783°	
7		0.6°		
8		0.4°		
9		1.66°		
10	11.9	1.59°	1.725°	1.411°
11		1.59°		
12		2.06°		
13		1.33°		
14	12.0	1.3°	1.22°	
15		1.06°		
16		1.2°		
17		1.53°		
18	12.1	1.4°	1.51	
19		1.4°		
20		1.73°		

TABLE III

No of experiment	Frequency in GHz	Variation in dB through the rotation of 90°	Average Variation in dB
1	11.5	.033 dB	
2	11.7	.034 dB	.036 dB
3	12.0	.042 dB	
4	11.7	.08 dB	
5	11.8	.076 dB	.083 dB
6	11.9	.08 dB	
7	12.0	.11 dB	
8	12.1	.07 dB	