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HOLLOW DIELECTRIC BEAMGUIDE AS A FACILITY FOR MODELING OF RADAR POLARIZATION SCATTERING CHARACTERISTICS IN THE SUBMILLIMETER WAVE BAND

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Abstract

New scope for a hollow dielectric beamguide (HDB) such as a facility for scale modeling of polarization scattering characteristics of radar objects in submillimeter wave band is presented. Radar cross sections of real targets at various polarizations is analyzed by scale modeling using measuring installation developed on the base of a circular HDB.

1. Introduction

Hollow dielectric beamguide (HDB) was initially proposed as a transmission line for optics [1]. Subsequently, the HDB was modified [2]-[3] and used by us as a base quasi-optical transmission line for the development of the complete set of short-millimeter and submillimeter wave circuit elements (Fig.1). The set gives a possibility to develop measuring devices and systems for radar, communications, radiometry, and so on. An example of such application is the multi-channel interferometers-polarimeters for the *Tokamak* controlled nuclear fusion machines [4].

HDB is a hollow waveguide channel in a "boundless" dielectric (usually having circular or square cross-section) whose cross-section characteristic size, D, is large compared with the wavelength, λ, ($D/\lambda \geq 10$) and the dielectric constant of the medium filling this waveguide channel is smaller than that of the outer medium. In reality, a dielectric tube plays the role of such a “boundless” dielectric. The tube is made of a dielectric material having a relatively large loss tangent and sufficiently large thickness, so that the wave, which passes through the HDB inner channel boundary, reaches the second (outer) boundary of the dielectric tube with a significant attenuation. To increase the mode filtering, the inner surface of HDB channel is contoured as for example in the ribbed form [2].

We proposed the quasi-optical waveguide modeling (QWM) method for study of scattering characteristics of physical objects [5]-[6]. This method was realized with the aid of a micro-compact range (MCR) [7]. In the method, a test object (or scale model) is placed into the HDB, and waveguide parameters of the fundamental mode HE_{11} (S-parameters) determining the scattering by the object are measured. These parameters definite in a quite manner the scattering characteristics of the same object, as for instance radar cross section (RCS), illuminated by a uniform plane wave in free-space. The comparison of experimental RCS patterns for standard objects, such as a sphere, cylinder, rectangular plate, with corresponding theoretical data confirmed a possibility to use the proposed method as alternative to expansive and complicated compact ranges which are usually applied to study the reflectivity of a real target by scale modeling.

Here electromagnetic parameters of the HDB that are necessary to design the MCR for scale modeling of polarization scattering characteristics of radar objects in submillimeter wave band are given. In addition, data measured from a scale model of the real target are presented.

2. Micro-Compact Range

Using both mode and ray representations of electromagnetic field in the HDB [8] we theoretically determined an area of the cylindrical shape inside the guiding channel where electromagnetic field can be characterized by a linearly polarized plane wave. Under certain conditions this area can be used as a quiet zone for polarization measurements in the MCR. If the HE_{11} mode is excited in the HDB, there are maximum sizes of this zone. We obtained simplified expressions connecting geometric sizes of a quiet zone with geometric, mode, and electrical characteristics of the circular HDB. In particular, the diameter d and length l of the quiet zone can be evaluated by the following formulas:

$$d \approx 0.28 \cdot D\sqrt{\Delta A_r}\ , \tag{1}$$

$$l \approx 0.1 \cdot D(D/\lambda)^2 \Delta A_R \,\mathbf{Re}\left(\frac{2\sqrt{\varepsilon - 1}}{\varepsilon + 1}\right) \tag{2}$$

where ΔA_r stands for the maximum acceptable value of the radial error in the field amplitude of HE_{11} mode at the edge of the quiet zone (in dB); ΔA_R is the maximum acceptable value of the amplitude variation in the axial direction within the quiet zone ; ε is the effective permittivity of the inner boundary for the guiding channel of the HDB. In practice, $\Delta A_r = \Delta A_R = \Delta A$ and ε is between limits 1.1 and 2.3. Fig.2 demonstrates the measurement cell of a MCR implementing the QWM method. The MCR was developed on the base of the circular ribbed HDB with $D = 40mm$ and $\varepsilon = 1.15$.

3. Measurement Data

Using the MCR we obtained experimental patterns of monostatic RCS for a number of standard objets at the horizontal (HH) polarization and the vertical (VV) polarization. These results are in a good agreement with corresponding theoretical data (calculated by the method of Physical Theory of Diffraction developed by P.Y.Ufimtsev [9]) for scattering of the uniform plane wave by the same objects in free space. As an illustration, Fig.3 demonstrates theoretical and measured monostatic RCS for the circular metal cylinder.

As an example of a complicated target, we studied polarization characteristics of the model of the aircraft like SR71. This model was fabricated of metal coated by a plastic layer with the fuselage length of 28mm (7λ), span wing of 16mm (4λ), and two vertical stabilizers of 4mm (λ). The calibration procedure was performed by the metal sphere with diameter 11mm. Fig.4 presents experimental patterns of monostatic RCS for the aircraft model at HH and VV polarizations. Level in 0dB for both cases corresponds 1cm^2 of RCS.

Study of scale models monostatic RCS of real objects measured at various polarizations gives a possibility to detect characteristic properties of these objects which can be used as necessary information for classification and recognition of radar targets. For instance, in Fig.4b we can see the sharp burst of RCS at angles $\theta \approx 0^\circ$ that is caused, obviously, by a resonance of the vertically polarized wave scattered by the stabilizers when the aircraft is illuminated from the tail.

4. Conclusion

Thus our investigations have confirmed the possibility to use a HDB for modeling of polarization scattering characteristics for radar targets by QWM in submillimeter and short-millimeter wave bands.

References

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Fig.1. Set of quasi-optical elements on the base of the circular HDB for the short-millimeter and submillimeter wave bands.

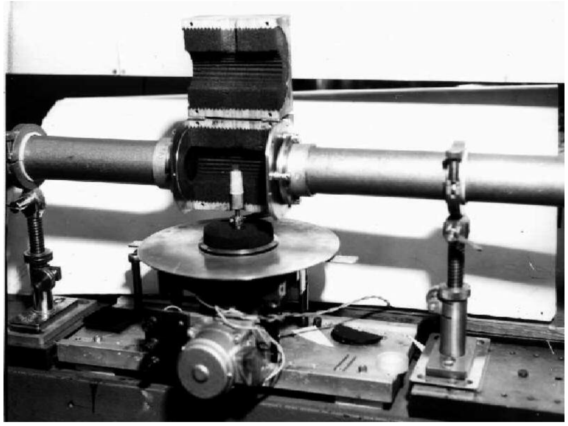
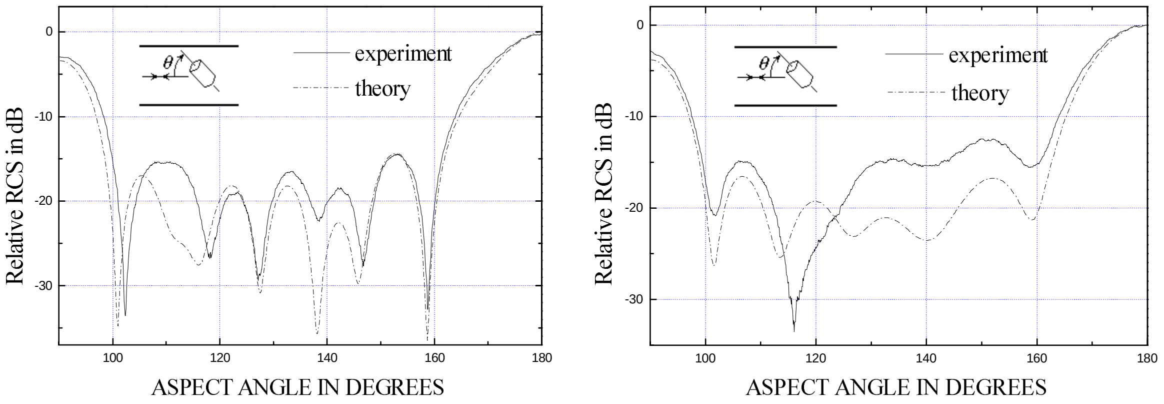
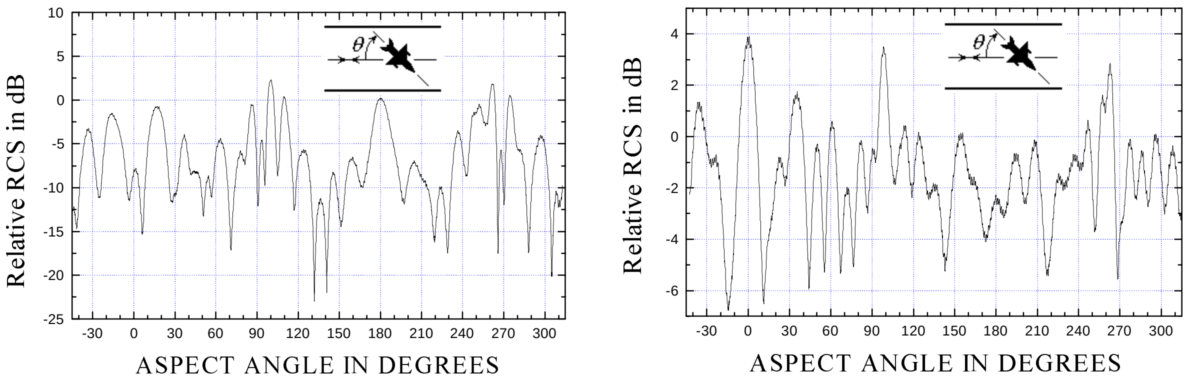


Fig.2. Measurement cell in the MCR made on the base of the circular ribbed HDB with $D = 40mm$.



(a) (b)

Fig.3. Normalized RCS patterns of the metal circular cylinder with 7mm diameter and 10mm length measured in the HDB of D=40mm at F=75GHz for HH-polarization (a) and VV-polarization (b).



(a) (b)

Fig.4. Normalized RCS patterns of the aircraft scale model measured in the HDB of D=40mm at F=75GHz for HH-polarization (a) and VV-polarization (b).