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Development of a new reflecting surface for electromagnetic waves

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Abstract: *A new reflecting surface capable of simulating identical reflecting properties of a metallic plate with rectangular corrugations is reported. The new surface which is fabricated with a low loss dielectric plate of uniform thickness .One surface of the plate is periodically loaded with a grill structure of conducting wires and the other surface is completely metalized with copper. Depending on the grating parameters and the thickness of the dielectric plate, on reflection it is capable of rotating the plane of polarization or producing circular polarization of the incident electromagnetic wave. Compared to existing metallic corrugated surfaces, it is light in weight, less expensive, and mass production of large surfaces is possible by photolithographic method.*

Keywords: *Electromagnetic waves, Microwaves, Polarisers, Corrugation Simulated, Reflectors*

I. Introduction.

Metallic surfaces with rectangular corrugations are capable of rotating the plane of polarization of an incident linearly polarized electromagnetic wave or producing a circularly polarized wave [1, 2]. However, fabrication of such extensive surfaces with the required precision is very tedious and time consuming. Moreover a large amount of material is also wasted. In this paper, an alternative surface which exhibits identical results is presented. The newly developed surface is easy to fabricate, less expensive and light in weight. As this surface simulates all the identical properties of a corrugated metallic reflecting surface, it is termed as "**S**imulated **C**orrugate **R**eflecting **S**urface" (SCRS).

I.I Design Details of SCRS

The schematic representation of a SCRS is given in fig.1. One surface of a low loss dielectric plate of uniform thickness "h" is loaded with thin conducting wires or strips at a period "d" and gap "g". The parameter " d " is such that $d < \lambda/2$ so that higher order modes are not propagated. λ is the free space wavelength of the incident e.m wave. The other surface of the dielectric plate is completely metalized. Depending on the grating parameters "g", "d "and the thickness "h", the SCRS is found to be capable of tilting the plane of polarization of the incident wave or producing circular polarization. The phenomenon of rotation of plane of polarization or the production of circular polarization of the incident wave can be qualitatively explained as follows. If the electric field of the linearly polarized wave is incident at an angle of $\Phi = 45^{\circ}$ to the length of the strips, it can be resolved in to two components namely TE (component parallel to the length of the strip) and TM (component perpendicular to the length of the strip). During reflection, the TE component is totally reflected from the top of the conducting strips, while TM component penetrates in to the dielectric plate and gets reflected from the conducting ground plane. Hence the reflected TM component lags the corresponding TE component by a phase of $4\pi h/\lambda_d$, where λ_d is the wavelength inside the dielectric medium. By adjusting the thickness "h " of the dielectric plate, any desired polarization can be achieved at a particular frequency.

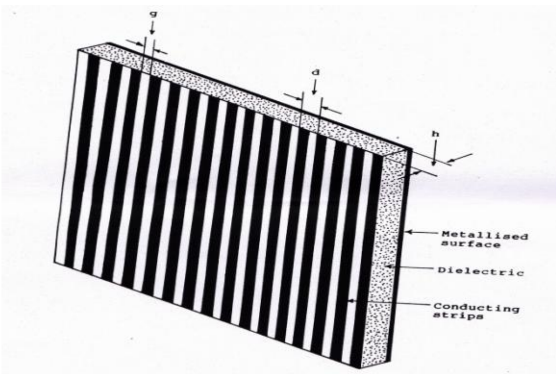

Fig.1. Schematic representation of a simulated corrugated reflecting surface

II. Experimental Arrangement

A small X-band pyramidal horn antenna of high polarization discrimination of −30 dB is used as the transmitter antenna of e.m waves. Another similar antenna which is mounted on a polarization positioner with automatic rotation facility about its axis is used as the receiver antenna.

In order to avoid direct coupling between the transmitting and the receiving antennas, they are placed in such a way that the angle of incidence is 9° as suggested by Jull [1] for metallic corrugated plate. For total elimination of coupling, microwave absorbers are interposed between them. It has been established that, for angles of incidence less than 10 °, the differential change in phase shift between the TE and TM components is less than 1 °. Hence the present experimental setup satisfies the condition of normal incidence. The entire experiment is conducted in a microwave anechoic chamber.

The signal received by the receiver antenna mounted on the polarization positioner is plotted using an X-Y plotter.

III. Experimental Results

The experimental results are presented in two parts. In the first part, the experimental results of SCR surfaces which are capable of converting a linearly polarized incident e.m wave in to a circularly polarized wave are presented. In the second part, experimental results of a SCRS which tilts the plane of polarization of an incident e.m wave are discussed.

III.1 Production of Circularly Polarised Waves

The design parameters of different SCR surfaces used for the experimental investigation are given in the table. The typical variation of axial ratio with frequency of the reflected wave from different SCR surfaces investigated are presented in figures 2, 3, and 4.

Table showing the design details of the SCR surfaces investigated

SCR surface	d/λ	h/λ	g/λ	Frequency (GHz)
1.a	0.093	0.1085	0.96	9.3
1.b	0.165	0.1155	0.96	9.9
2.a	0.1092	0.1092	0.96	10.92
2.b	0.1958	0.1175	0.96	11.75
3.a	0.1373	0.103	0.892	10.3
3.b	0.1587	0.0992	0.892	11.9

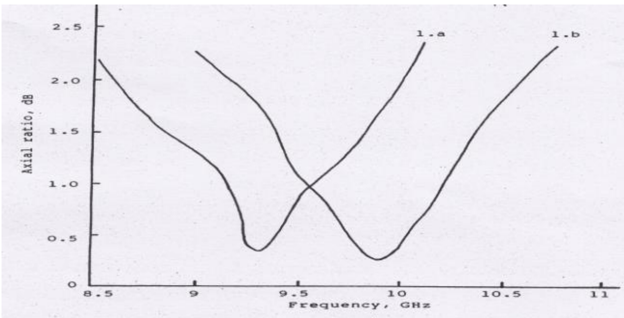

Fig.2. Variation of axial ratio with frequency of SCR surfaces 1.a and 1.b.

From the figures it is evident that the newly developed SCR surfaces areproducing circularly polarized wave by reflection. When h = d = 0.1092λ, and g/d=0.96, the minimum axial ratio obtained is 0.145 dB at 10.92 GHz. For analyzing the sense of circular polarization of the reflected wave, left and right handed circularly polarized helical antennas were used as the receivers. The observations have showed that when the conducting wires or strips of the grill structure on the SCRS is at an angle of 135° with respect to the H- vector in the clockwise direction, a left handed circular polarization is obtained. On the other hand, when this angle is 45°, a right handed circular polarization is resulted.

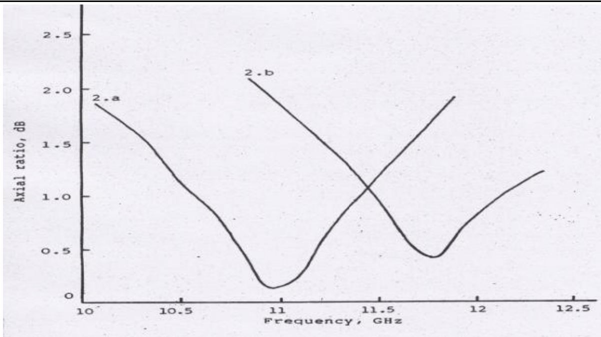

Fig.3. Variation of axial ratio with frequency of SCR surfaces 2.a, and 2.b.

III.2 Rotation of Plane of Polarization by SCRS Technique

It has been observed that, for an optimum dielectric substrate thickness, the SCR surfaces are producing circularly polarized waves for g / d ≈ 1. However, when the value of g / d is decreased, the SCR surface is found to be exhibiting the property of tilting the polarization of the linearly polarized incident wave. SCRS with different grating parameters and dielectric substrate thickness were fabricated and tested. A SCRS with g / λ = 0.1433, h / λ =0.1082, and g / d = 0.5, at an angle of incidence of 20 ⁰ exhibited a polarization tilt of 90 ⁰ for 48 ⁰ orientation of the incident electric field with the length of the strip. When the incident electric field is parallel or perpendicular to the length of the strip, the reflected wave is found to be plane polarised in the same plane as the incident wave and the surface behaves just like a conducting surface. The results are shown in fig. 5.

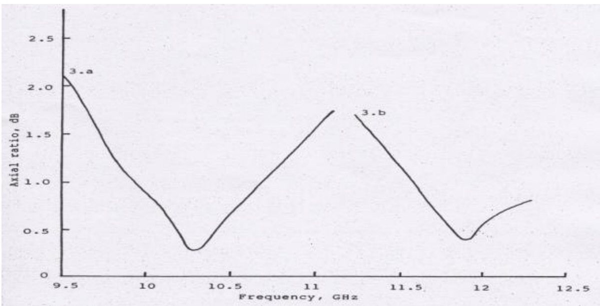

Fig.4. Variation of axial ratio with frequency of SCR surfaces 3.a and 3.b.

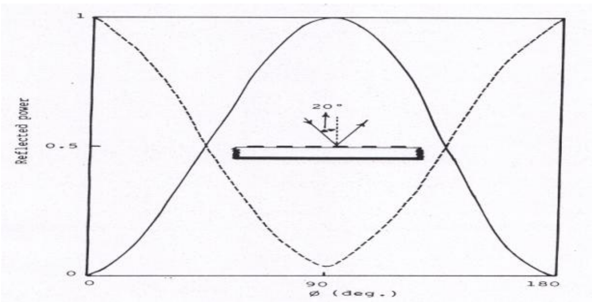

Fig.5. Reflected power from a SCRS (g/λ=0.1433, h/λ=0.1082 and g/d=0.5) at an angle of incidence of 20⁰.

——— Incident electric field parallel to the length of the strip.

——— Incident electric field at 48⁰ to the length of the strip.

The experiment is repeated for different angles of incidence. It is observed that, as the angle of incidence is increased, the angle of orientation (φ) of the incident electric field with the length of the strip, required for a 90 ⁰ tilt of plane of polarization is also increased. As in the case of metallic corrugated surface [1], here also, for small angles of incidence (< 10 ⁰), the angle of orientation of the incident electric field required for the 90 ⁰ tilt of plane of polarization of the reflected wave is found to be nearly 45 ⁰ and beyond that it increases. The variation of the required angle of orientation φ of the incident electric field with the angle of incidence is given in fig .6.

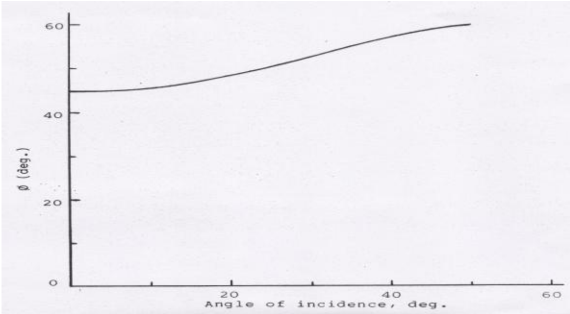

Fig.6. Variation of optimum angle (φ) with angle of incidence.

IV. Conclusions

The experimental investigation on the reflection characteristics of SCRS has showed that the newly developed SCRS simulates the identical reflection characteristics of a metallic surface with rectangular corrugations. However, SCRS are much light, less expensive and easy to fabricate. This type of surface can be easily fabricated with photolithographic technique with high precision. These SCRS may find application in cassegrain antenna design, in the reduction of radar cross-section of targets, and in reduction of permanent echoes from buildings at airports provided with instrument landing systems.

References

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[2] P.O Paul and K.G Nair, "Rotation of plane of polarization of a beam of microwaves by corrugate reflectorsurfaces",ibid,Vol.18,No.8,pp.338-339,April,1998