PHASE CONTROL OF REFLECTION COEFFICIENTS FOR THE STRIP ARRAY ON A GROUNDED DIELECTRIC SLAB

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1. Introduction

Transversely corrugated surfaces have for many years been used to design hybrid mode horn antennas with symmetrical radiation patterns and low cross polarization[1]. In principle, they act as shorted transmission lines for the longitudinal polarization and transform the short to $Z_l = \infty$ at the aperture of the corrugations for a proper slot depth[2]. Longitudinally corrugated surfaces act like shorted transmission lines for the transverse polarization and the depth of them must be chosen to give $Z_t = \infty$ at the aperture of the corrugations. The surfaces with such characteristics have been defined as artificially soft and hard surfaces for electromagnetic waves[3]. The classical structures to realize artificially soft and hard surfaces are corrugated surfaces and conducting strips on a grounded dielectric slab[4]. The latter one has the merits of easy production and properties control in comparison with corrugated surfaces[5]. In this study, the characteristics and the realization of artificially soft and hard surfaces by conducting strips on a grounded dielectric slab are discussed in terms of reflection coefficients phase[6]. Analytical expressions for the design of artificially soft and hard surfaces are presented. Wide phase controllability suggests us the use of such surfaces as the flat focusing reflectors.

2. Characteristics of Artificially Soft and Hard Surfaces

Artificially soft and hard surfaces have the different reflection characteristics from the ordinary conducting surface. For ordinary conducting surface, the reflection coefficients are minus one and plus one for horizontal and vertical polarization directions, respectively. That is, the reflection coefficient will change according to the polarization direction of the incidence. For artificially soft surface, the reflection coefficients will be always minus one for any direction of polarization. Total electromagnetic fields at the surface are always zero. So this reflection surface is called soft surface. Artificially soft surface is usually made by using transversely corrugated surface or transverse conducting strips on a grounded dielectric slab. This is shown in Fig.1. For artificially hard surface, the reflection coefficients will be always plus one for any direction of polarization. Total electromagnetic fields at the surface will be maximum. This reflection surface is called hard surface. Artificially hard surface is usually made by using longitudinally corrugated surface or longitudinal conducting strips on a grounded dielectric slab. This is shown in Fig.2. Reflection characteristics of artificially soft and hard surfaces are shown in Fig.1 and Fig.2, respectively.

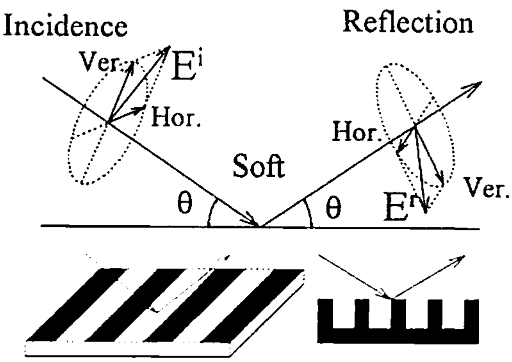

Fig. 1 Reflection Characteristics of Artificially Soft Surface

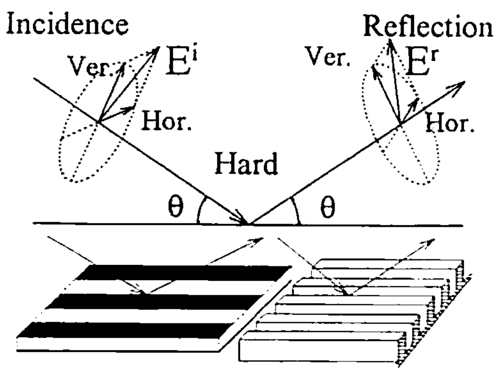

Fig. 2 Reflection Characteristics of Artificially Hard Surface

3. Analytical Expressions of Reflection Coefficients for Conducting Strips on a Grounded Dielectric Slab

The artificially soft and hard surfaces can be made of conducting strips on a grounded dielectric slab by selecting the values of structural parameters properly. The analytical expressions for reflection coefficients of the model in Fig.3 with arbitrary incident angles θ and ϕ were derived in [6]. For transverse (ϕ = 0°) and longitudinal (ϕ = 90°) strips, the expressions can be simplified as follows:

$$B_0 = \frac{a_3 - a_5}{a_5 - a_2} \cdot E_y^i \tag{1}$$

$$D_0 = \left(1 - \frac{2}{b_1}\right) \cdot H_y^i \tag{2}$$

Bo and Do are y components of reflected electric and magnetic fields. E_y^i and H_y^i are corresponded components of incident electric and magnetic fields. Coefficients a_2, a_3, a_5 and b_1 are constants determined by the structural parameters and incident angles θ and ϕ. The expressions for them are shown in reference [6]. If the structural parameters P, L, W, ε_r and incident angles θ and ϕ are given, the reflected fields can be calculated easily and the ideal soft and hard surface conditions can be derived.

4. Reflection Phase Control for the Surface of Conducting Strips on a Grounded Dielectric Slab

From equations (1) and (2), we can see that the absolute values of Bo/E^i_y and Do/H^i_y remain unity, because of the conservation of energy on the no loss structure. Only the phases of them are changeable according to the changes of structural parameters and incident angles θ and φ. If the phases of Bo/E^i_y and Do/H^i_y are 180°, the total fields of Ey and Hy at the aperture are zero. Then, the ideal soft or hard surface condition is realized for φ = 0° or 90° respectively. The phases of Bo and Do depend on the geometrical parameters P, L, W, and θ, εr, as well as the wavelength λ. In general cases, the phase of Bo/E^i_y = 180° is usually satisfied in a wide range of parameters and frequency change, while the phase of Do/H^i_y can be controlled easily from 0 to 360° by adjusting the structural parameters of P, L, W and εr for given incident angles θ and φ[6]. The phase of Do/H^i_y is expressed as:

$$\frac{D_0}{H^i_y} = e^{-j2\arctan(I_\#)+j\pi} \qquad (3)$$

where: $I_\# = P/\lambda \cdot Y_2 \cdot \cos\theta \cdot (1+\tau) - \cot(\alpha_0 W/\lambda)\cdot \tau \cdot \cos\theta / Q$

$$Y_2 = -2\ln(\sin\frac{\pi L}{2P}),\ \tau = 1 + (1-\varepsilon_r)/(\sin^2\theta \sin^2\phi - 1),\ Q = \sqrt{\varepsilon_r - \sin^2\theta},\ \alpha_0 = 2\pi Q$$

If the incident electric field is perpendicular to the conducting strips, the reflective phase can be controlled in wide range. Figure 4 shows the phase distribution of Do/H^i_y, where the parameters are a: L = 0.02λ, W = 0.01λ, εr = 1.48; b: L = 0.01λ, W = 0.01λ, εr = 5.0; c: L = 0.04λ, W = 0.08λ, εr = 1.48 and d: L = 0.04λ, W = 0.2λ, εr = 1.48. The incident angles are θ = 10° and φ = 0°. The solid lines show the calculated results by equation (3). In graph a, b and c, the thickness W is small and the period P does not satisfy the assumptions of P << λ and exp(4πW/P) >> 1. In those cases, the accurate results should be calculated by Point Matching Method (PMM). The calculated results by PMM are shown in dotted lines. From Fig.4, we can see that the reflective phases can be fully controlled in a large range using low value of thickness W, provided the period P is accurately designed. It is attractive that the flat reflector can be realized by controlling only the period P with a constant value of dielectric slab thickness W.

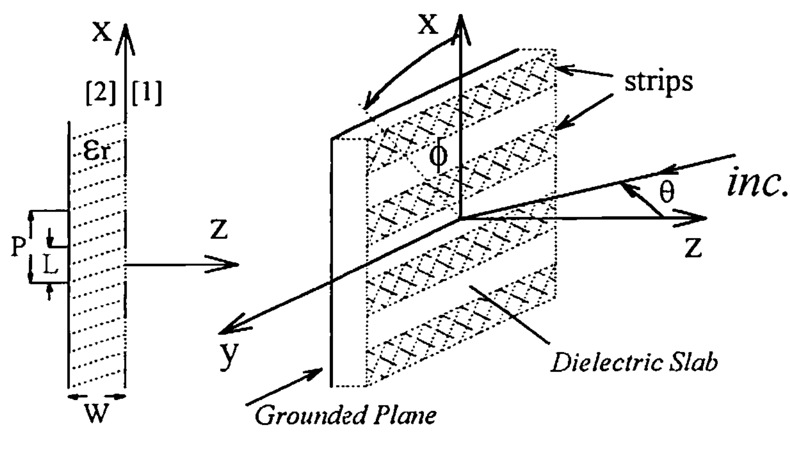

Fig. 3 Conducting strips on a grounded dielectric slab

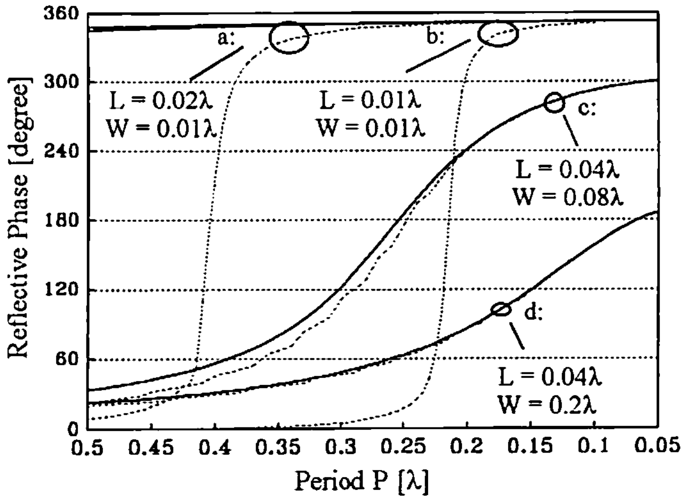

Fig. 4 Reflective phase of different thickness L and W

5. Conclusion

We have studied longitudinal and transverse surfaces of conducting strips on a grounded dielectric slab and have found that under certain conditions they have the characteristics of artificially soft and hard surfaces in electromagnetics. A common characteristic of both soft and hard surfaces is that they do not create cross polarization by geometrical optics reflection. The reason for this property of the artificially soft and hard surfaces is that the GO reflection coefficient is equal to minus one for the soft surface and plus one for hard surface irrespective of polarization.

References

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