Wideband trapezoidal strip grating for elimination of specular reflection

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A trapezoidal strip grating surface that eliminates specular reflections almost over the entire X-band frequency range for TM polarisation is reported. This new grating structure overcomes the bandwidth limitation of conventional rectangular strip grating surfaces.

Introduction: Blazed reflection gratings, capable of scattering plane electromagnetic waves to first order diffracted waves have been studied extensively [1, 2]. The most common blazed grating consists of rectangular corrugations on a conducting surface. Reflector backed rectangular strip gratings have been reported that can be used to simulate the effects of corrugated surfaces [3]. They have the advantages of ease of fabrication and light weight. However, these surfaces could eliminate specular reflections only over a narrow frequency range.

Recently, attempts have been made to exploit the blazing effects of these surfaces for the reduction of radar cross-section (RCS) and for the design of frequency scannable reflectors [4, 5]. An enhancement of bandwidth for the elimination of specular reflection is needed for the efficient operation of the grating for RCS reduction and frequency scanning applications. In a recent communication [6], the authors reported a novel grating structure for the elimination of specular reflections over a wide frequency band (1.5GHz) for TM polarisation. In this Letter, a technique for further enhancement in bandwidth using a trapezoidal strip grating surface is presented. The elimination of specular reflection almost over the entire X-band frequency range is achieved for TM polarisation.

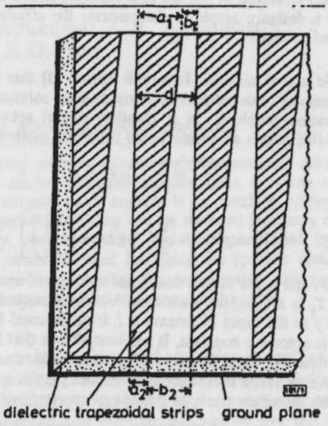

Fig. 1 *Schematic diagram of trapezoidal strip grating*

Experimental results: The strip grating surface is fabricated by etching thin metallic strips of trapezoidal shape on a reflector backed dielectric substrate (ε_r = 2.56) of size 30 × 30cm². The schematic diagram of the trapezoidal strip grating surface is shown in Fig. 1. The diffraction measurements are made with the usual arrangements in X-band for TM polarisation [6]. The reflected power from the strip grating surface is measured for different angles of incidence and is compared with that from a plane metallic surface of the same dimensions. A magic-tee analogue cancellation method is used for the measurement of backscattered power.

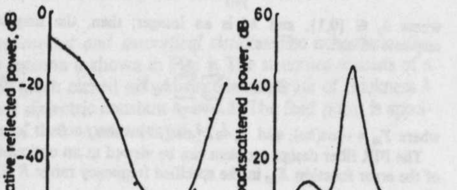

Fig. 2 *Variation of relative reflected power and backscattered power with angle of incidence for trapezoidal strip grating*

$d = 0.833\lambda$, $a_1/\lambda = 0.666$, $a_2/\lambda = 0.166$, $h/\lambda = 0.123$

The typical variations of relative reflected power and backscattered power with angle of incidence for EM waves of frequency 10GHz are presented in Fig. 2. The specular reflection is completely eliminated for an angle of incidence θ_i = 50°.

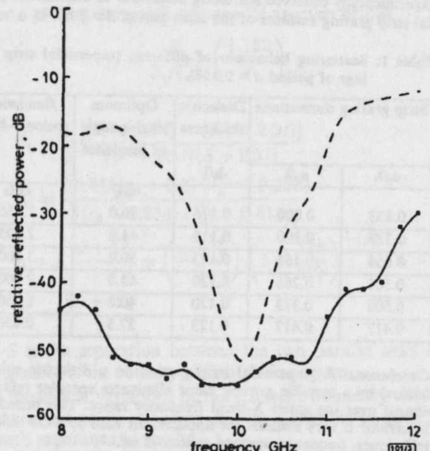

Fig. 3 *Variation of relative reflected power with frequency*

—— trapezoidal strip grating: $d = 0.833\lambda$, $a_1/\lambda = 0.666$, $a_2/\lambda = 0.166$, $h/\lambda = 0.123$, $\theta_i = 37.5°$
----- Rectangular strip grating: $d = 0.833\lambda$, $a\lambda = 0.417$, $h/\lambda = 0.123$, $\theta_i = 37.5°$

Fig. 3 shows the variations of relative reflected power with frequency of the incident EM waves. The solid line shows the variation for trapezoidal strip grating surface and the dotted line for the conventional rectangular strip grating. The specular reflection below −40dB is achieved over a wide frequency range (3.6GHz) for the trapezoidal strip grating surface. It may be noted that for the conventional rectangular strip grating surface, this frequency range is very narrow (0.65GHz).

According to Kalhor [7], specular reflection from a strip grating is highly influenced by the strip width '*a*' for a constant period '*d*'. For a trapezoidal grating, the period '*d*' is constant, but the strip width '*a*' changes gradually. This gradual change in strip width results in a large number of elementary gratings of various '*a*' and '*b*' values which will resonate for different frequencies. This explains the increase in bandwidth.

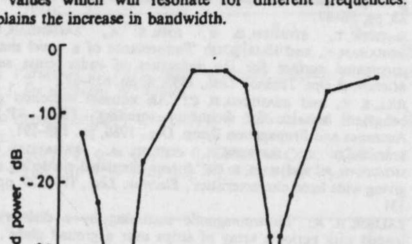

Fig. 4 *Variation of relative reflected power with dielectric thickness for trapezoidal strip grating* $\theta_i = 50°$

The effect of variation of dielectric thickness (h) of the trapezoidal strip grating surface is presented in Fig. 4. Table 1 shows the experimentally observed scattering behaviour of different trapezoidal strip grating surfaces of the same period $d = 0.833\lambda$.

Table 1: Scattering behaviour of different trapezoidal strip gratings of period $d = 0.833\lambda$

Strip grating dimensions		Dielectric thickness	Optimum blazing angle of incidence	Bandwidth (below −40dB)
a_1/λ	a_2/λ	h/λ		
			deg	GHz
0.833	0.000	0.116	36.0	1.455
0.733	0.100	0.116	44.0	2.305
0.666	0.166	0.123	50.0	3.600
0.566	0.266	0.120	45.0	2.800
0.500	0.333	0.120	40.0	0.950
0.417	0.417	0.123	37.5	0.650

Conclusions: A trapezoidal strip grating on a dielectric substrate backed by a metallic ground plane eliminates specular reflections almost over the entire X-band frequency range. This broad-band behaviour is very suitable for applications such as RCS reduction techniques, frequency scanned reflectors etc.

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References

1 JULL, E. V., HEATH, J. W., and EBBESON, G. R.: 'Gratings that diffract all incident energy', *J. Opt. Soc. Am.*, 1977, **67**, pp. 557–560
2 HEATH, J. W., and JULL, E. V.: 'Perfectly blazed reflection gratings with rectangular grooves', *J. Opt. Soc. Am.*, 1978, **68**, pp. 1211–1217
3 JOSE, K. A., and NAIR, K. G.: 'Reflector backed perfectly blazed strip gratings simulate corrugated reflector effects', *Electron. Lett.*, 1987, **23**, pp. 86–87
4 MATHEW, T., STEPHEN, D. S., JOSE, K. A., AANANDAN, C. K., MOHANAN, P., and NAIR, K. G.: 'Performance of a novel simulated corrugated surface for the reduction of radar cross section', *Microw. & Opt. Technol. Lett.*, 1993, **6**, pp. 615–617
5 JULL, E. V., and BEAULIEU, N. C.: 'An unusual reflection grating behaviour suitable for frequency scanning'. IEEE AP-S Int. Antennas and Propagation Symp. Dig., 1980, pp. 189–191
6 STEPHEN, D. S., MATHEW, T., JOSE, K. A., AANANDAN, C. K., MOHANAN, P., and NAIR, K. G.: 'A new simulated scattering surface giving wide band characteristics', *Electron. Lett.*, 1993, **29**, pp. 329–331
7 KALHOR, H. A.: 'Electromagnetic scattering by a dielectric slab loaded with periodic array of strips over a ground plane', *IEEE Trans.*, 1988, AP-36, pp. 147–151