Multiple Beam Antenna Arrays for Indoor Communications

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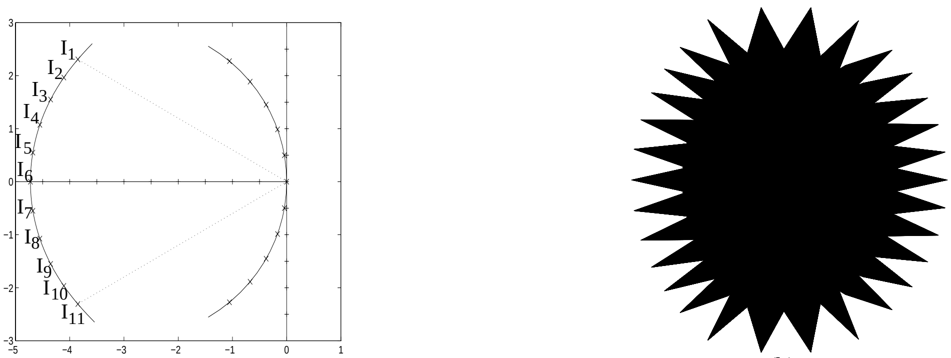
Abstract: A practical design of a compact integrated Rotman lens is presented, which will be used for beamforming of a multiple beam antenna array in millimeter wave band personal communication systems. A novel log-periodic microstrip patch array is designed and tested by series-feeding a linear array of electromagnetically coupled overlaid resonators. Some simulation and experiment results are also presented.

Résumé: Une conception pratique d'une lentille Rotman intégrée est présentée, laquelle sera utilisée pour la formation du faisceau d'une antenne réseau dans la bande millimétrique pour les systèmes de communication personnels. Une nouvelle antenne réseau microruban log-périodique est conçue et testée en utilisant un réseau linéaire de résonateurs superposés couplés électromagnétiquement et alimentés en série. Des résultats de simulation et d'expérimentation sont aussi présentés.

Design of Compact Integrated Rotman Lens

Design of Rotman lens may involve geometry of lens and mutual coupling effects between lens ports. Since the former is important to the realization of an efficient and compact lens, a careful geometrical and electrical constraints design should be accomplished first[1]. Then, adjustments, such as pointing directions of array and beam ports and side wall shape, should be made to reduce mutual coupling effects and multiple reflection inside the lens region by electromagnetic field numerical analyses.

Considering the requirements of multiple beam antennas for indoor communication systems, the following specifications are initially taken into account: frequency range of 27 ~30 GHz, 11 beams covering 120˚ angular sector, around -3 dB adjacent beam crossover levels. From these, 11 array elements with spacing $d = \lambda_{min}/2$ may be inferred to provide a half-power beamwidth of 13˚ to 20˚ depending on the beam scanning angle without appearance of grating lobe, where λ_{min} is the minimum wavelength related to the highest operating frequency. A centre pointing, that is, either array ports or beam ports are assumed to point to the centre of the opposite contour, could create an approximately symmetrical amplitude distributions along the array element aperture. Fig. 1(a) Shows the lens contour designed, and the topography with flared microstrip transitions is given in Fig. 1(b).



(a) (b)

Fig. 1 Rotman lens contour (a) and its topography (b)

For engineering design, a two-dimensional equivalent of the Friis transmission formula is derived to calculate the amplitude distribution of the excitation at the array elements fed by the Rotman lens, and the material losses of both dielectric and copper are also taken into account by adding a term of attenuation factor α_c in the formula.

$$\frac{P_r}{P_t} = \frac{l_A l_B}{\lambda r}\cos^2\theta_A\cos^2\theta_B\left[\frac{\sin(\pi l_A\sin\theta_A/\lambda)}{\pi l_A\sin\theta_A/\lambda}\right]^2\left[\frac{\sin(\pi l_B\sin\theta_B/\lambda)}{\pi l_B\sin\theta_B/\lambda}\right]^2 e^{-2\alpha_c r} \qquad (1)$$

The typical lens gain including the insertion loss of the lens and the half-power beamwidth of each beam (array factor) are given in Table 1.

TABLE 6. The beamwidth of lens-fed array factor and lens gain at frequency of 30 GHz

Beam port	I_1 (50° beam)	I_2 (40° beam)	I_3 (30° beam)	I_4 (20° beam)	I_5 (10° beam)	I_6 (0° beam)
Beamwidth	20.9°	17.3°	15.3°	14.1°	13.5°	13.2°
Lens gain	4.91 dB	5.85 dB	6.67 dB	7.30 dB	7.69 dB	7.82 dB

Design of Wide Band Antenna Array

The novel log-periodic microstrip patch array is designed by series-feeding a linear array of electromagnetically coupled overlaid resonators[2]. The patch resonators located on the upper substrate are spaced by half a wavelength in the feed line and laterally displaced in alternate directions from the feed line in order to produce radiation in phase from adjacent patches, as shown in Fig. 2. The length L, width W and spacing S are constrained by

$$\tau = \frac{L_{n+1}}{L_n} = \frac{W_{n+1}}{W_n} = \frac{S_{n+1}}{S_n} \qquad (2)$$

where τ is a design constant. To produce a truly log-periodic array the substrate height should be similarly scaled, producing a tapered configuration. In the array described here, a flat substrate is used for fabricating simplicity, and this results in some deviation from log-periodic performance.

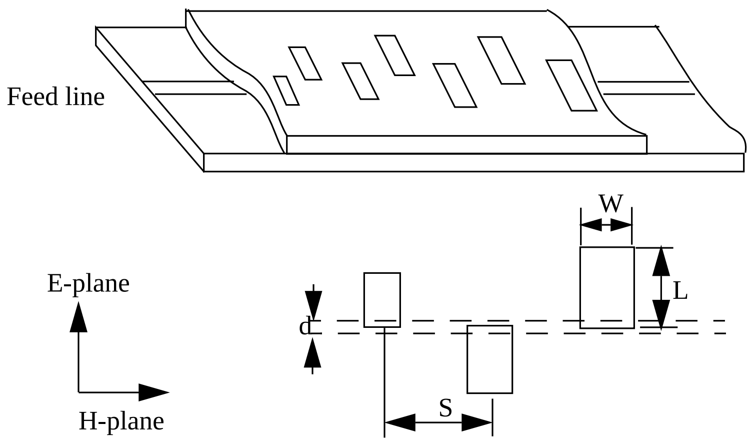


Fig. 2 New wide band log-periodic microstrip patch array

An array having 9 patches is designed and tested for the frequency range around 30 GHz. L, W and S are calculated using eqn. 2 for $\tau = 1.05$. The lateral displacement d was empirically optimized to the best VSWR over the frequency band. Fig. 3 shows the radiation patterns in the H-plane at 31, 32, 33 and 34 GHz. The VSWR performance will be measured soon.

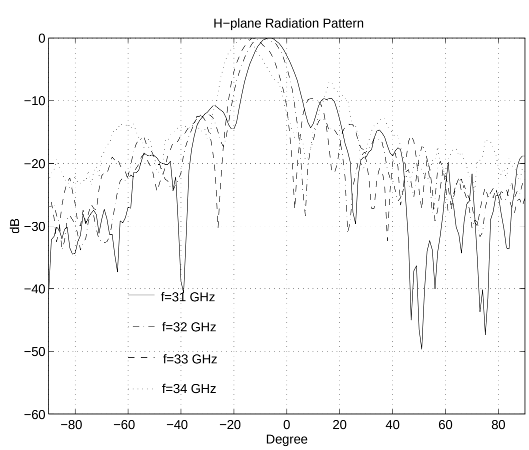


Fig. 3 H-plane radiation patterns at 31, 32, 33 and 34 GHz

References

[1] Y. M. Tao and G. Y. Delisle, “Multiple Beam Antenna Arrays for Indoor Communications”, Digest of ANTEM’96, Montreal, August 1996

[2] P. S. Hall, “New Wide band Microstrip Antenna Array Using Log-Periodic Techniques”, Electron. Lett., Vol. 16, Feb., 1980, PP. 127-128