A REFLECTION CANCELING SLOT SET USING PARALLEL SLOT PAIRS FOR LINEARLY-POLARIZED RADIAL LINE SLOT ANTENNAS

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1. Introduction

A radial line slot antenna (RLSA) is a high gain and high efficiency planar antenna for DBS reception [1]. The unique difficulty of linearly-polarized RLSA (LP-RLSA, Fig. 1) is return loss degradation peculiar to the annular slot arrangement [2]. The authors proposed to add slots specially designed for canceling reflection from original ones [3]. Reasonable improvements in antenna efficiency were reported.

This paper presents an alternative and more general slot design for reflection cancelation in LP-RLSA using parallel slot pairs [4]. A parallel slot pair consists of two parallel slots and radiates power without causing reflection in the waveguide. By using one or two of these pairs, a slot set with small reflection is designed for desired polarization. A model antenna is fabricated and the experiments confirm the design.

2. Parallel Slot Pair

Figure 2 shows the configuration of a parallel slot pair. Two slots are parallel and spacing $d = 1/4\lambda_g$ along the current flow. The reflected waves from these slots cancel each other in the guide. Though the main radiation of a pair is not broadside but rather the endfire direction, the antenna pattern does not reflect this element pattern when a large number of the elements are arrayed.

To cancel the reflection from a pair, the length L_1 and L_2 together with the spacing d should be numerically optimized taking account of the mutual coupling [5].

3. Configuration of a Slot Set for LP-RLSA using Parallel Slot Pairs

To suppress the reflection from a slot set (a unit radiator of desired polarization), every slot in a slot pair for original LP-RLSA (LP pair) [2] should be replaced by parallel slot pair. One slot set consists of 4 slots. In order to array many sets densely, some slots in a set may be omitted. Then three types of the slot sets are considered as shown in Fig. 3. In the 4-slot configuration (b), both slots in an LP pair are replaced by parallel slot pairs. In the 3-slot configuration (c), only the strongly-coupled slot is replaced. In the 2-slot configuration (d), the weakly-coupled slot in an LP pair is removed and only one parallel pair radiates the desired polarization. To radiate the X-polarized wave, θ_I , θ_2 and θ_3 are defined as [2]

 $\theta_I = -\phi/2$, $\theta_2 = (\pi - \phi)/2$, $\theta_3 = \pi/2 - \phi$

In the practical design, the parameters for each parallel pair are optimized in the manner discussed in Sec. 2. The other independent parameters, e.g. L_1 , L_3 and d_2 in 4-slot configuration, are selected so as to suppress the cross polarization.

Since the configuration of a slot set for LP-RLSA varies with the current flow direction ϕ in the aperture, these three configurations are used complementarily to cover the whole aperture as are shown in Fig. 4. The boundary angles ϕ_1 and ϕ_2 (0°< ϕ_1 < ϕ_2 <90°) are

determined as follows: ϕ_1 is determined by the maximum coupling strength of 2-slot configuration, which decreases with the increase of ϕ . On the other hand, ϕ_2 is mainly determined from the reflection characteristics.

4. Numerical Results

Figure 5 shows the reflection coefficient of a slot set as a function of coupling factor [1]. Since the cross polarization suppression is forced upon in the design, the reflection is a little bit large especially for $\phi \approx 90^{\circ}$. Anyway, the reflection is suppressed to $-10 \sim -30 \, dB$.

5. Experiments

Using the numerical results, a model antenna is fabricated. The design parameters are listed in Table 1. Figure 6 shows the slot arrangement. In this model, only 2-slot and 3-slot configurations are used.

The return loss, shown in Fig. 7, is suppressed to less than -13dB. The aperture field distribution is given in Fig. 8. The uniformity of amplitude is observed in ρ direction. However, the amplitude pattern around Y-axis is a bit asymmetrical, which may be due to the discontinuity of the configuration of slot sets at $\phi=\pm90^\circ$. The cross polarization components are very small. The gain and the efficiency of the antenna are shown in Fig. 9. Though the peak frequency is shifted from the designed one, the maximum gain of 34.4dBi and the efficiency of 52% are measured at 11.6GHz.

6. Conclusion

This paper presents the reflection canceling slot sets for LP-RLSA using parallel slot pairs. Three types of slot sets using parallel slot pairs are proposed. They are numerically optimized to reduce the cross polarization with small reflection. The gain of 34.4dBi and the efficiency of 52% are measured at 11.6GHz with 60cm diameter model antenna.

The improvement of the uniformity of the aperture illumination is left for future study. The final criterion of the efficiency for commercial use is more than 80%.

Acknowledgement

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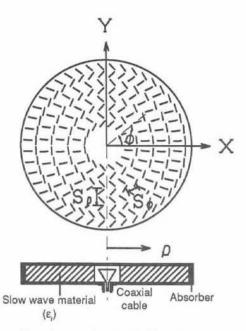


Fig.1. A linearly-polarized radial line slot antenna (LP-RLSA).

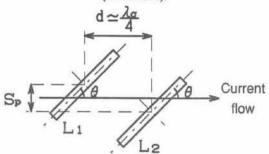


Fig. 2. Parallel slot pair.

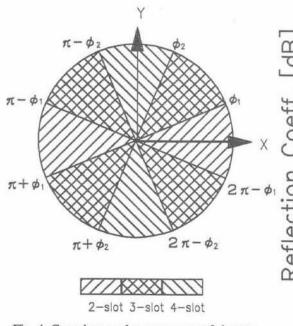
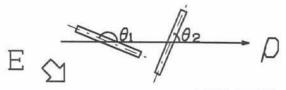
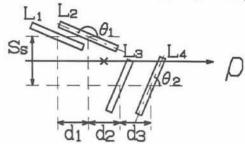


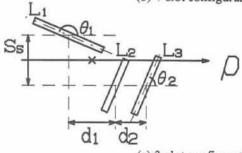
Fig. 4. Complemental arrangement of slot set over the aperture.



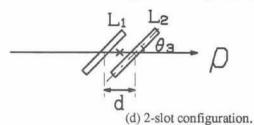
(a) Original LP-pair.



(b) 4-slot configuration.



(c) 3-slot configuration.



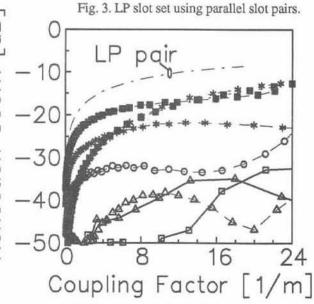


Fig. 5. Reflection coefficient of a slot set.

□:\$\phi=0°\$, \$\triangle:\$\phi=22.5°\$, \$\cdot\$:\$\phi=45°\$, *:\$\phi=67.5°\$, \$\boldsymbol{\omega}\$:\$\phi=90°\$ -: 2-slot, - - - - : 3-slot, · · · · · : 4-slot.

Frequency f [GHz]	12.0
Antenna diameter 2pmax [mm]	600
Blocking diameter 2pmin [mm]	60
Waveguide height du [mm]	7.5
Relative permittivity &	1.48
Slot set angular spacing S _♥ [mm]	16.25
2-slot and 3-slot boundary ϕ_1 [deg]	22.5
3-slot and 4-slot boundary \$\phi_2\$ [deg]	90.0
Maximum coupling factor α _{max} [1/m]	20.0
Slot length at φ=0° Lo [mm]	7.8~10.7
Slot length at φ=90° L ₉₀ [mm]	8.6~10.8
Number of slot N	2236
Theoretical termination loss T	15 %
Theoretical antenna efficiency η	57 %

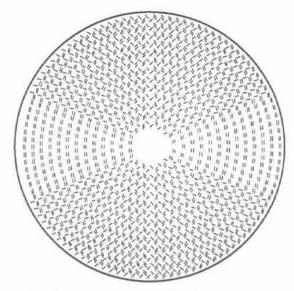


Fig. 6. Slot arrangement of model antenna.

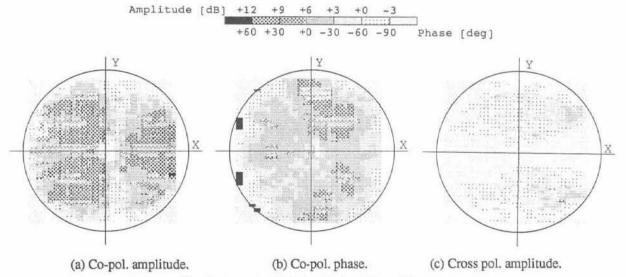


Fig. 8. Aperture field distribution of model antenna.

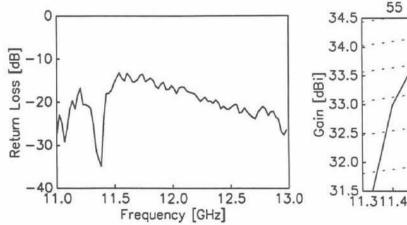


Fig. 7. Return loss characteristics of model antenna.

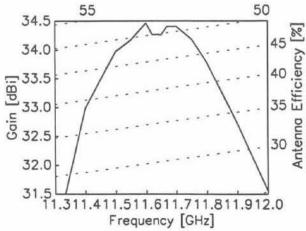


Fig. 9. Gain and efficiency of model antenna.