A RADIAL LINE SLOT ANTENNA FOR 12GHZ SATELLITE TV RECEPTION

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1 Introduction

Direct broadcast from a satellite (DBS) in 12GHz band has become in commercial use in Japan.[1] Subscriber antennas for receiving DBS should possess high gain characteristics of about 36 to 37 dBi. In addition to conventional reflector antennas, planar antennas using microstrips have also been developed.[2] Unfortunately, for microstrip antennas with large aperture sizes, the conductor loss becomes notable; in designing a subscriber antenna stated before, its actual aperture efficiency is limited to 40%∿50% at most.

This paper presents the design and characteristics of novel planar antennas with circularly polarized pencil beams for 12GHz satellite TV reception.[3] This antenna belongs to a class of slotted waveguide antennas and high efficiency is expected in principle. The aperture efficiency of no less than 70% is theoretically predicted. Experiments were also performed and the efficiency of 57% was realized.

2 Antenna design

2.1 Structure Construction of a radial line slot antenna is presented in Fig.1(a). Three plates equally spaced by d compose a twofold radial line waveguide, the top of which is an aperture with slots. Key features of this antenna consist in its slot arrangement and a twofold radial waveguide. Slots consist of many slot pairs each one of which is a unit radiator of a circularly polarized wave. These slot pairs are arrayed along a design spiral. Though the slot positions to realize a circularly polarized broadside beam are not symmetric, rotational symmetry of the inner field to excite the aperture should not be appreciably disturbed. For the purpose of realizing a stable symmetric inner field, the radial waveguide is folded. A radially inward traveling-wave (TEM) mode, whose symmetry is more stable than that of outward traveling-wave mode, is supported in the upper waveguide and couples to slots. The powerflow in this antenna is pictured in Fig.1(b). There are two more advantages for this structure viewed in terms of aperture efficiency as are explained in 2.2.

In this antenna, the spacings between adjacent slot pairs along the ρ direction S_ρ must be equal to the guide wavelength in the upper waveguide. In order to suppress grating lobes from the array, a slow wave structure in the upper waveguide is necessary.

For the further analyses and experiments, an antenna with diameters of 0.6m are fabricated. The detailed design parameters are listed in Table 1. The antenna has a dielectric sheet (ε_r=2.5) in the bottom of its upper waveguide and λ_g is diminished to 0.82 λ_0. (f_0=12.2GHz)

2.2 Aperture distribution For $d < \lambda g/2$, the only possible symmetrical mode is TEM one. If slots are arrayed over the aperture with equal density, the excitation coefficient of the slot located at ρ is given by $\sqrt{\alpha/\rho}\ \exp(jk\rho+\alpha\rho)$ where α (m^{-1}) is the parameter for the coupling proportionality between the

inner field and the slots.[4] The initial amplitude taper of $\rho^{-0.5}$ is modified by the factor of $e^{\alpha\rho}$ and for some α (>0),the aperture distribution becomes more flat. This is the second reason for the selection of the twofold radial waveguide. In addition, once a almost uniform aperture excitation is realized, the power wasted in the absorber is only ρ_m/ρ_M of the total power. This is the third advantage of this folded structure over the conventional radial waveguide.[5] Aperture distributions for different α are calculated and presented in Fig.2. The distributions for $\alpha=1\sim5$ become rather flat and are favorable in terms of an antenna directive gain.

2.3 **Efficiency** Fig.3 shows the dependence of the aperture efficiency upon the coupling factor α . The efficiency takes its maximum at $\alpha=5$. Decrease of the efficiency for $\alpha<5$ stems from the power loss in the dummy load while that for $\alpha>5$ stems from the nonuniform aperture distribution where the amplitude decreases too rapidly toward its center. For $\alpha=5$, sufficiently high efficiency of more than 70 % is realized in the frequency range of 11.8GHz-12.2GHz. The optimum coupling factor becomes smaller as the diameter increases.

3 EXPERIMENTS

The discussion developed thus far is significant under the condition that the coupling factor α is controlled at our will without disturbing the rotational symmetry of the inner field. These assumptions will be examined experimentally.

3.1 **Coupling factor** Fig.4 shows the frequency characteristics of the coupling factor α estimated from the measured aperture distribution. The value α at 12.2GHz is about 5 and is close to the optimum one.

3.2 **Efficiency and axial ratio** Measured aperture efficiency and axial ratio is presented in Figs.5(a) and (b),respectively. Aperture efficiency of 57% and axial ratio of 1 dB is realized at 12.2GHz. The theoretical ones calculated by making use of α in Fig.4 are presented for comparison. They are showing qualitative agreement. Furthermore, the results for the antenna without absorber are also compared with the theory. The aperture efficiency is a bit lower while the axial ratio increases as are expected theoretically.

3.3 **Radiation pattern** The far field radiation patterns at 12.2GHz are presented in Fig.6, together with the theoretical ones. The agreement of the experiments with the theory verifies the design and analysis of the radial line slot antenna.

4 Conclusion

A planar type slotted waveguide antenna is proposed. A radially inward traveling mode is adopted in order to increase the aperture efficiency. Antenna characteristics are analyzed and the promising performances are pointed out. Experimental results are also presented to indicate the validity of the design and the analysis of this antenna. Optimization of the slot arrangements is open for further investigation.

Acknowledgement

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References

[1] Y.Ueda,K.Ishibashi and Y.Ichikawa,"Operational Broadcasting Satellite Program in Japan," IAF,Rome Italy,1981

[2] E.Rammos,"New Wideband High-Gain Stripline Planar Array for 12 GHz Satellite TV," Electronics Letters, vol.18, No.6, March 1982

[3] N.Goto and M.Yamamoto,"Circularly Polarized Radial-Line Slot Antennas," Tech. Rep. IECE Japan, AP80-57, Aug. 1980

[4] M.Ando etc.," Radiation Patterns of a Radial Line Slot Antenna," Tech. Rep. IECE Japan, AP84-31, June 1984

[5] F.J.Goebels and K.C.Kelly,"Arbitrary Polarization from Annular Slot Planar Antennas," IRE Trans. Antennas Propagat., vol. AP-9, No.4, July 1961

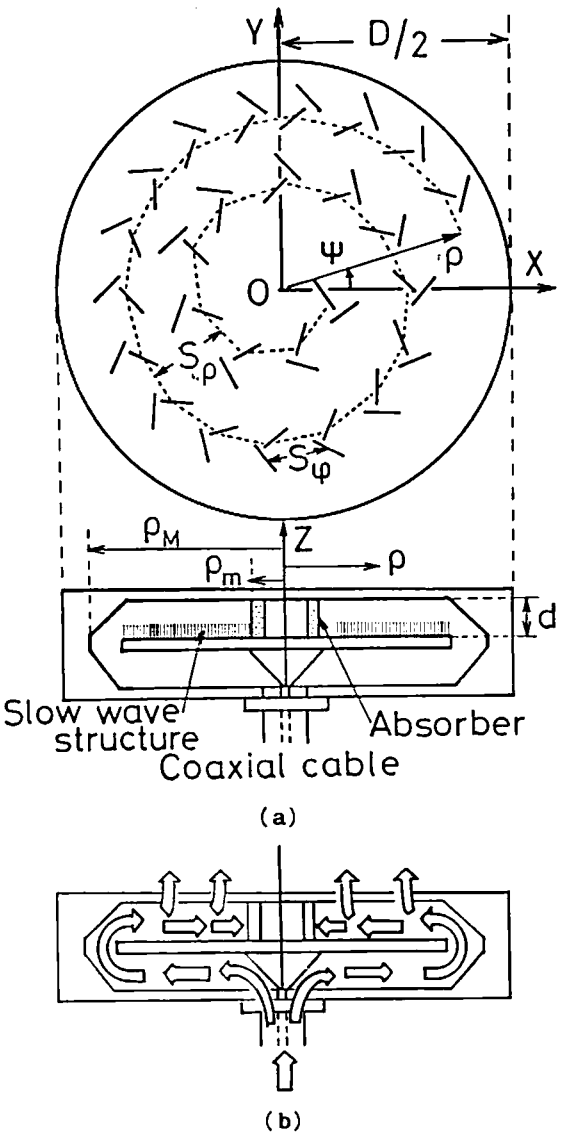


Fig.1 Radial line slot antenna.
(a) Structure (b) Powerflow

Table.1 Antenna design parameters

D (m)	0.625
ρ_M (m)	0.3
ρ_m (m)	0.06
d (m)	0.0075
S_ϕ (m)	0.0125
S_ρ (m)	0.02
N *	2038

* Number of slots

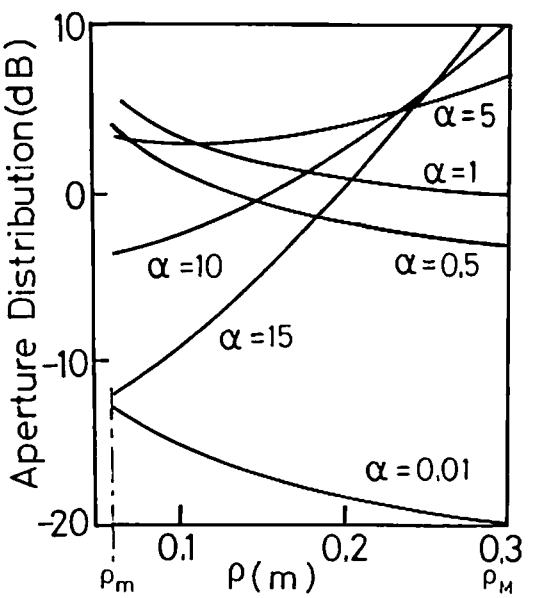


Fig.2 Aperture distribution for various coupling factor. (ampl.)

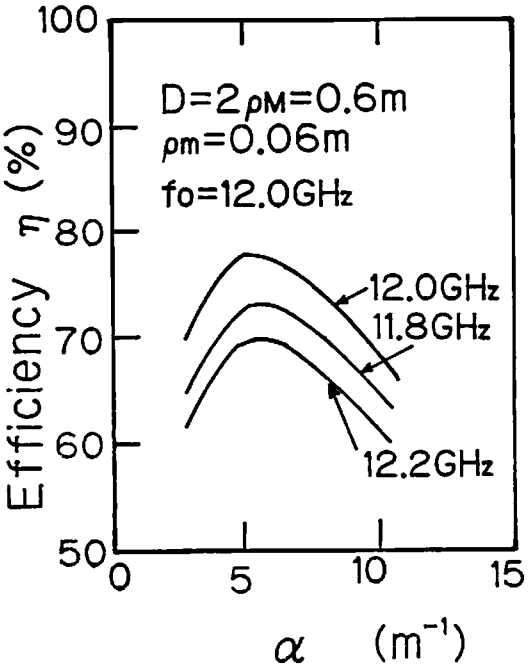


Fig.3 Aperture efficiency vs. coupling factor α.

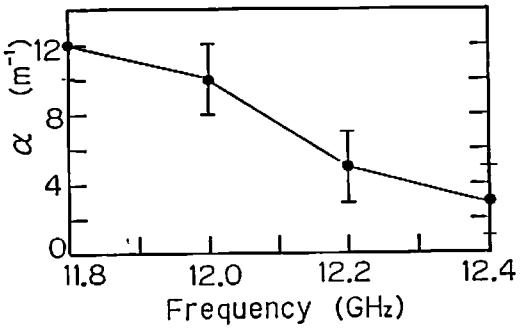
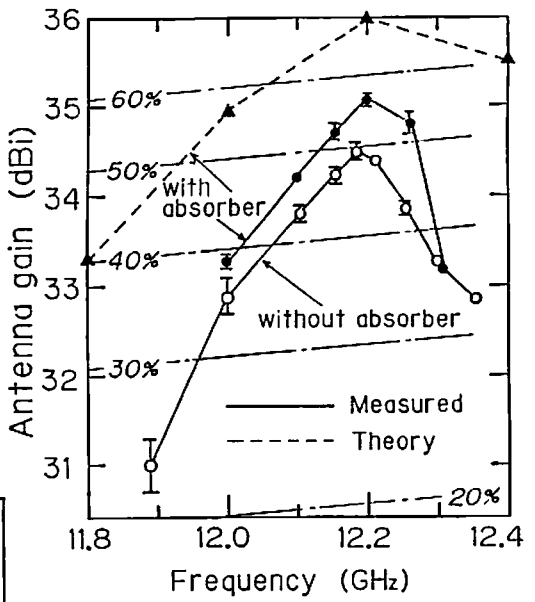
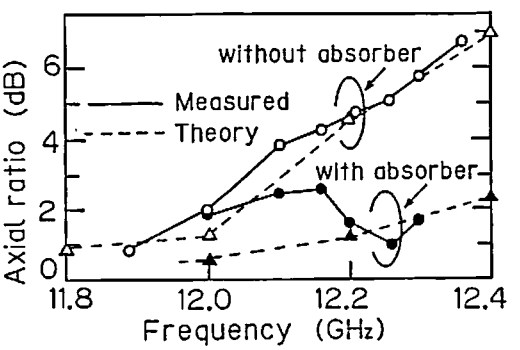


Fig.4 Measured coupling factor.



(a)



(b)

Fig.5 Measured antenna performances. (a) Antenna gain (b) Axial ratio

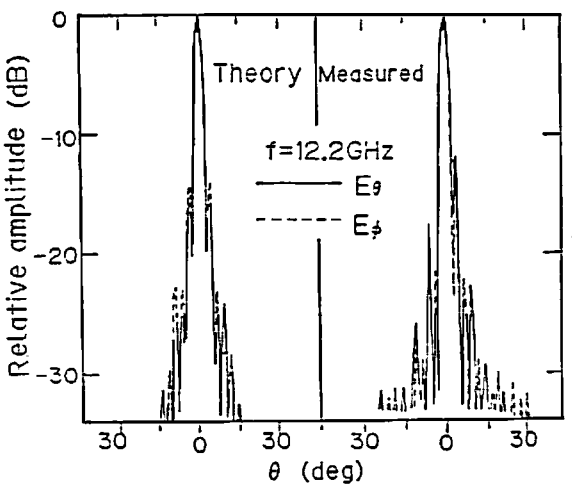


Fig.6 Radiation pattern.