LOW-PROFILE LEAKY-WAVE SLOTTED WAVEGUIDE ARRAY ANTENNA FOR MOBILE DBS RECEPTION

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1. Introduction

Direct broadcasting from satellite (DBS) has become popular in Japan. Subscriber antennas for use on the roof of cars and trains are now being intensively developed [1]-[3]. They should be thin and have the large beam tilting angle of about 45 degrees, in order to minimize the height of the fairing. A leaky-wave slotted waveguide array [4] is attractive for this use [2][3]. It has negligibly small transmission loss and is advantageous in terms of efficiency as well. However the serious difficulty of this candidate is its high manufacturing cost. A simple structure is highly desired for cost reduction. To this end, the authors had proposed a basic concept of a single-layer slotted waveguide array [5]. The feed waveguide is placed on the same layer as radiating waveguides to minimize the antenna height and to reduce the components. This paper presents the design and predicts the characteristics of this antenna system.

2. Relation between the Aspect Ratio and the Beamwidth

Fig. 1 shows a low-profile leaky-wave antenna for mobile DBS reception which consists of a few sub arrays of single-layer slotted waveguide array. This paper adopts a simple tracking system where the antenna is mechanically steered only along the azimuthal direction. Electrically steering in the elevation plane is realized by adjusting the relative phase between two sub arrays without mechanical steering. It is implicitly assumed that the total gain of the antenna in the specified direction is about twice as high as that of one sub array. The sub arrays are expected to have elliptical beams with broad 3 dB beamwidth of about 10 degrees in the elevation plane shown in Fig. 1(a) to adapt widely to the road gradient within about 5 degrees. It is very important to choose proper aspect ratio of a sub array which determines the beamwidth in the elevation plane and the gain at the beam edge.

Directivity is calculated for various aspect ratios of a sub array with the specified antenna gain of 31 dB in the main-beam direction in this paper. About 500 crossed slots with perfectly right-hand circular polarization are two-dimensionally arrayed with equal spacing over the area of about 1200 cm^2. It is assumed that all slots are ideally excited and the element pattern is that of a short current filament. The parameters are listed in Table 1.

Fig. 2 shows array patterns for various aspect ratios. The numbers of radiating waveguides are indicated in stead of the aspect ratio; the length of radiating waveguides is almost in inverse proportion to their number. In case of 24 radiating waveguides, gain reduction of about 3 dB is observed at the off-beam angle of 5 degrees. In this case, the length of the radiating waveguide is about 23 cm which includes the broad-wall width of the feed waveguide while the length of the feed waveguide is about 52 cm. The aspect ratio (= radiating waveguide width / feed waveguide width) is about 0.440. Fig. 3 shows gain reduction as a function of the aspect ratio for specified off-beam angle in the elevation plane. It is noticed that rather short radiating waveguides must be used to enhance the gain at the large steering angle of more than 5 degrees along the elevation direction.

3. Design of the Cross Slot Array

The couplings of cross slots must get stronger on shorter radiating waveguides. Then the wavelength reduction accompanied by the slot coupling in the radiating waveguide can not be neglected for the design of the array. The wavelength reduction brings about the shift of the main-beam direction. Therefore the broad-wall width of radiating waveguides is determined including this effect [6].

4. Design of the Feed Waveguide

Fig. 4(a) shows the inner structure of the feed waveguide. Some waveguide π-junctions with an inductive post are cascaded [7]. Two adjacent radiating waveguides can be fed in phase through one window when the wavelength in the feed waveguide is set to be twice as long as the broad-wall width of the radiating waveguide. An inductive post is attached in front of the window to suppress reflection [8]. Furthermore it also brings effect on suppressing wavelength reduction due to the coupling in the feed waveguide [9]. The effect has an advantage in exciting equally spaced radiating waveguides.

The feed waveguide consists of some π-junctions cascaded in a transmission line of dominant TE_{10} mode shown in Fig. 4(b). The matching unit terminated by a short circuit is used. The incident power is divided to N π-junctions cascaded on one side in equal amplitude and phase [10]. Fig. 5 shows the frequency characteristics of the reflection at the feed point for various numbers of π-junction. It is assumed that no reflection comes back from radiating waveguides. The reflection at the feed point is suppressed below -30 dB over DBS band in Japan (11.7 GHz to 12.0 GHz). Fig. 6 shows the frequency characteristics of the gain reduction due to the deviation among the divided power of radiating waveguides. The gain is calculated by the factors of one dimensional array. The total length of the feed waveguide is 7.2 (cm) times as long as the number of π-junction N. The total number of junctions 2N fed by one feed point is determined in terms of the gain at the edge of the DBS band.

5. Conclusions

This paper presents the theoretical design of a single-layer slotted waveguide array antenna for mobile DBS reception. This antenna has so large beam-tilting angle due to leaky-wave excitation that it can be applicable for a low-profile one attached on the roofs of vehicles. The relation between the aspect ratio of the antenna and the beamwidth in the plane containing radiating waveguides is made clear. The broad beam in the elevation plane is better in terms of a simple tracking system where the antenna is mechanically moved only along the azimuthal direction. For an example, 31dB antenna with the aspect ratio of 0.440 has 3 dB gain reduction at the off-beam angle of 5 degrees in the elevation plane.

Acknowledgement

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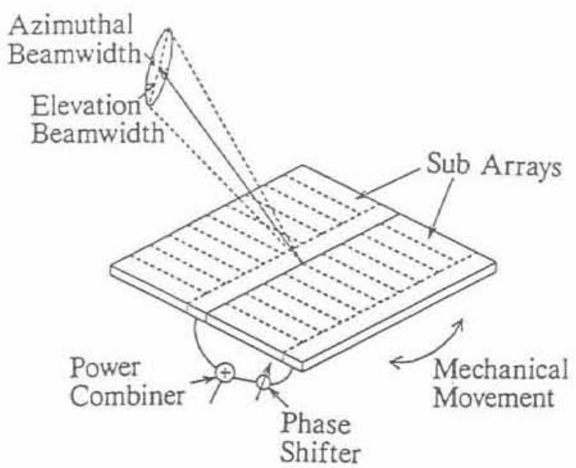
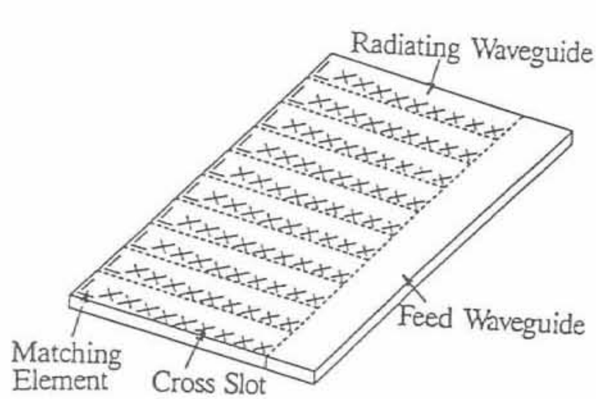


(a) Concept of the Tracking System



(b) Configuration of the Sub Array

Fig.1 Low-Profile Leaky-Wave Antenna for Mobile DBS Reception

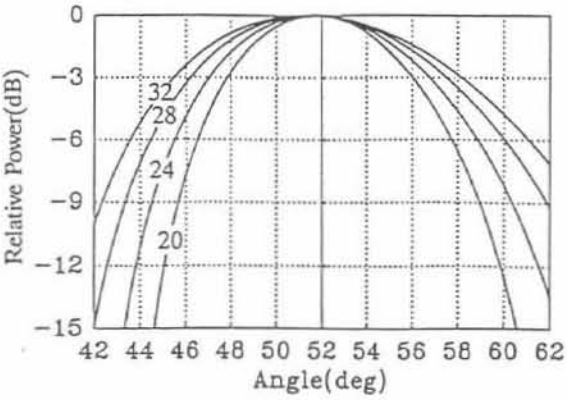


Fig.2 Array Patterns in the Plane Containing Radiating Waveguides

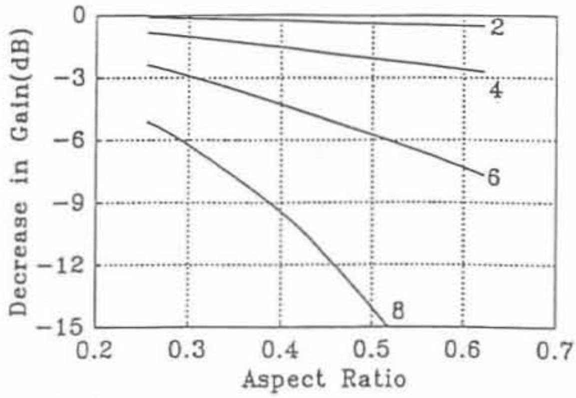
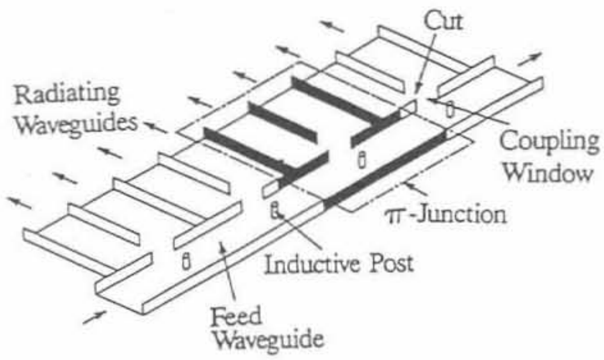


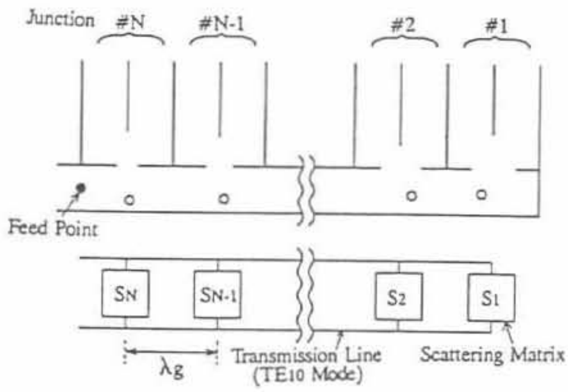
Fig.3 Gain Reduction as a Function of the Aspect Ratio

Beam-Tilting Angle	52.0 deg
Design Frequency	11.85 GHz
Crossing Angle between Two Slots	63.2 deg
Pair Spacing along Radiating Waveguide	10.1 mm
Pair Spacing along Feed Waveguide	21.55 mm

Table 1 Parameters of the Two-Dimensional Crossed Slot Array



(a) Inner Structure



(b) Cascade of the π-Junctions

Fig.4 Configuration of the Feed Waveguide

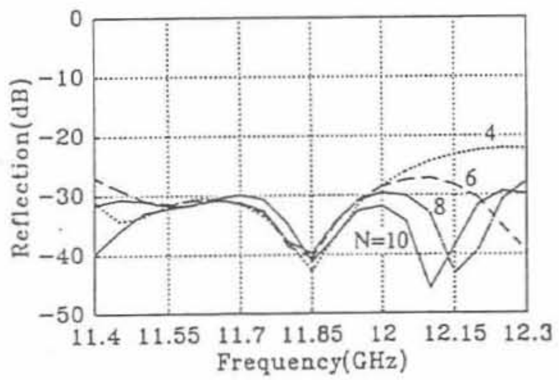


Fig.5 Reflection at the Feed Point

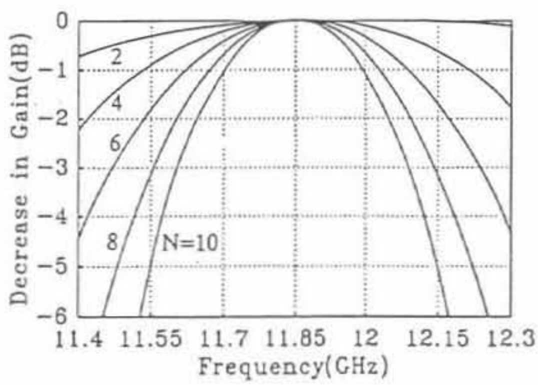


Fig.6 Decrease of the Gain by the Feed Waveguide