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SINGLE-LAYER SLOTTED LEAKY WAVEGUIDE ARRAYS FOR APPLICATIONS TO MOBILE SATELLITE COMMUNICATIONS

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1. Introduction

Mobile reception of direct broadcasting from satellite (DBS) has been popular; the number of vehicles with DBS receiving systems is increasing in Japan. Low-profile, mass-produceable, large-beam-tilting and high-efficiency receiving antennas has been desired to this end. We have developed a single-layer slotted leaky waveguide array [1] for a low-profile mobile receiving system of single-polarized DBS in Japan which satisfy all these requirements. This paper summarizes the characteristics of this antenna. Furthermore we extend the concept of the single-layer slotted waveguide array to the reception of dual-polarized DBS in the U.S. The characteristics of the model antenna are also shown.

2. Low-Profile Mobile Receiving System of Single-Polarized DBS

Fig. 1 shows a low-profile mobile DBS receiving system using a single-layer slotted leaky waveguide array. The feed waveguide is placed on the same layer as the radiating waveguides [2][3]. This feed structure is two-dimensional and uniform along the height and is suitable for the mass production by pressing or die-casting. The antenna consists of two pieces and is fabricated easily by placing an etched slotted plate on the groove feed structure. Cross slots are densely arrayed on the broad wall of the radiating waveguides. The leaky wave radiates a circularly polarized beam in a large beam tilting angle of about 50 degrees from the zenith. This is advantageous for mobile DBS reception since the antenna can be installed horizontally on the roof of the vehicles. The total height including a radome is 9 cm and is about half the height of conventional systems using microstrip arrays. The size of the system is 45 cm by 55 cm (about half) and the weight is 8 kg (about one-third) including the control unit. A mechanical system steers the antenna to track a satellite only in the azimuthal plane. Tracking is not necessary in the elevation plane since the beam width of the antenna with short radiating waveguide is broad.

Fig.2 shows the frequency dependence of the gain and the efficiency of a model antenna. The size is 30 cm by 21 cm. The measured peak gain is 26.7 dBi (74 % efficiency) at 11.95 GHz. The gain is more than 26.3 dBi (69 % efficiency) within the DBS band (11.7 GHz - 12.0 GHz) in Japan, where the efficiency is calculated for the aperture projecting in the main beam direction of 51 degrees. The typical measured carrier-to-noise (C/N) ratio is about 12.0 dB at Tokyo in sunny days, which is sufficient for the noiseless reception by a picture tube display. Fig.3 shows the C/N ratio difference between the model antenna with the horizontal installation and a parabolic antenna of 29.5 dBi gain as a reference. In this figure, the radiation pattern of the model antenna in the elevation plane is also shown as a function of the zenith angle of Japanese broadcasting satellite (BS-3) at measuring places. The 1 dB width of the C/N ratio difference is about 7 degrees, which is as wide as the 1 dB beamwdith of the radiation pattern. This confirms the C/N ratio difference mainly comes from the beam-pointing loss of the model antenna without elevation tracking. The horizontal installation enables the noiseless reception over about one-third of the area of Japan

The K- and Ka-band antennas are also fabricated as planar antennas for advanced satellite communication experiments using COMETS satellite which will be launched in 1997. The efficiencies still hold high in the high frequencies due to negligibly small loss of waveguides; 60 % (23.9 dBi gain at 21.0 GHz) for the K-band antenna and 54 % (26.3 dBi gain at 30.8 GHz) for the Ka-band antenna.

3. Two-Beam Slotted Leaky Waveguide Array for Dual-Polarized DBS

A two-beam antenna can be realized by placing two feed waveguides at both ends of the leaky radiating waveguides as shown in Fig.4. These two beams are switched by mechanical azimuthal rotation of 180 degrees. When cross slots are excited by the TE_{10} mode propagating to the $+z$ direction, they radiate the right-hand circular polarization. Due to the leaky wave excitation, the main beam is directed to $+\theta_t$. On the other hand, when cross slots are excited by the mode propagating to the $-z$ direction, the left-hand circular polarization radiates in the $-\theta_t$ direction. Consequently, Ports #1 and #2 correspond the right-hand and the left-hand circular polarizations in the $+\theta_t$ and $-\theta_t$ directions, respectively. For the equal performances between the two polarizations, the antenna structure including the slot arrangement should be symmetrical with respect to the center of the slot array. Fig.5 shows the aperture field distribution which is optimized to maximize the efficiency by using the calculus of variations for an aperture of 230 mm length under this symmetrical condition. The field distribution for uniform slots is added in this figure. The efficiency for the uniform coupling model is 81.45 %, which is almost equal to that of 81.72 % for the optimized coupling model.

A model antenna with the uniform coupling is fabricated. The size is 330 mm by 320 mm. Fig.6 show the radiation patterns in the operations from Ports #1 and #2 in the elevation plane. The radiation patterns are almost the same but the main beams are oriented in the opposite directions. The measured beam tilting angle is 43 degrees, which is shifted from the desired one of 45 degrees. This comes from an error to estimate the phase progress of the cross slots in the waveguides. The axial ratio is about 2.5 dB in the two beams. It will be improved by adjusting the angle of the cross slots. The measured peak gain is about 29.0 dBi both in the two operations and the efficiency is about 65 %.

4. Conclusions

We have developed single-layer slotted leaky waveguide arrays for applications to mobile DBS reception. The array for single-polarized DBS has an efficiency more than 70 % over Japanese DBS band and its horizontal installation enables the noiseless reception by a picture tube display over one-third of the area of Japan. A model of the two-beam antenna for dual polarized DBS in the U.S. has realized the equal performances in the two operations and the peak efficiency of 65 % is obtained.

References

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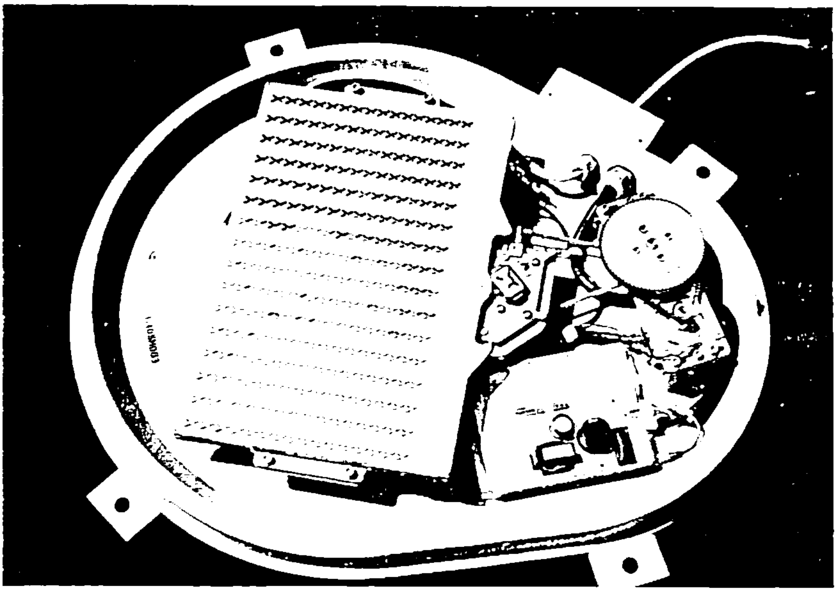


Fig.1 Low-Profile Mobile DBS Receiving System
using a Single-Layer Slotted Leaky Waveguide Array

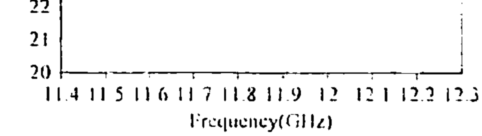


Fig.2 Antenna Gain and Efficiency of
the Single-Polarized DBS Antenna

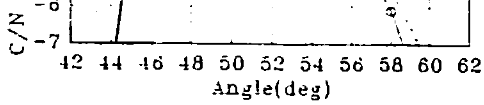


Fig.3 C/N Ratio Difference between
the Model Antenna with the Horizontal
Installation and a Reference Antenna
(Solid Line: C/N Ratio Difference,
Dotted Line: Radiation Pattern)

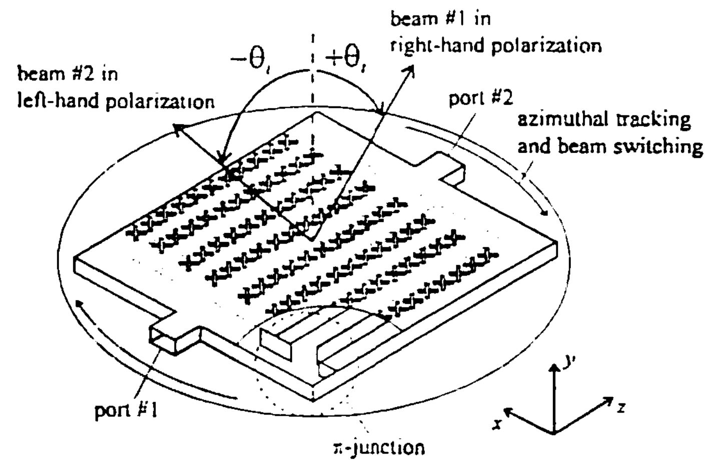


Fig.4 Two-Beam Slotted Leaky Waveguide Array for Dual-Polarized DBS

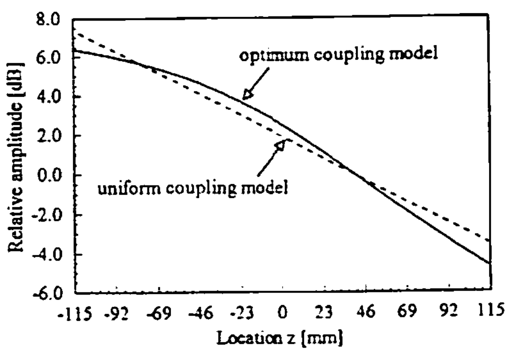
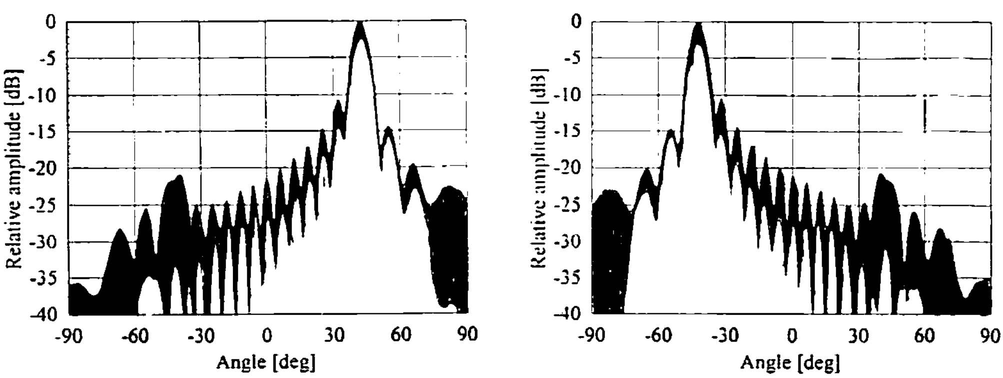


Fig.5 Aperture Field Distributions



(a) Operation from Port #1

(b) Operation from Port #2

Fig.6 Radiation Patterns in the Elevation Plane