APERTURE DIAMETER DEPENDENCE OF RADIAL LINE SLOT ANTENNAS

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1.INTRODUCTION

High gain planar antennas are attractive in various subscriber radio systems, such as DBS or satellite communication. Microstrip antennas are popular, but conducting losses degrade the efficiency especially for high gain antenna. A Radial Line Slot Antenna (RLSA) is a kind of slotted waveguide antenna and the better performance is expected for larger antennas[1]. The gain of 36.3dBi and the aperture efficiency of 75%, which is twice as high as that of a microstrip antenna[2], have been realized for the antenna with diameter 600mm. It is important to select the most suitable type of the antenna for required gain, since the performance of antenna depends on its aperture diameter. This paper overlooks the gain, efficiency and band-width of RLSA as function of the aperture diameter.

2.APERTURE DISTRIBUTION AND EFFICIENCY

Figure 1 shows the RLSA and its power-flow. RLSA consists of twofold radial waveguide. Power is fed from the co-axial cable connected at the center of lower guide and rotationally-symmetrical outward traveling wave propagates in the lower guide. At the 180°E-bend, it is transferred into inward traveling wave in the upper guide. A part of power is coupled to slots and the required polarization is radiated. The power unradiated is absorbed by the matched load at the center of guide. To suppress the grating lobes, a slow wave structure is set in the upper guide.

Let us assume the weak slot-coupling and the rotational symmetry; the aperture field of RLSA is approximated by (1).

$$f(\rho)=\frac{\exp(\alpha\rho)}{\sqrt{\rho}}\cdot\exp\{j2\pi(\frac{1}{\lambda_g}-\frac{1}{S_\rho})\} \tag{1}$$

where α is the coupling factor which indicates the attenuation of inward traveling wave. S_ρ is the spacing between adjacent slot pairs in ρ direction. When the space density of slots is constant, α is also constant all over the aperture. λ_g is the guide wavelength and the slow wave factor ζ is defined as the reduction ratio of the wavelength as;

$$\lambda_g=\zeta\cdot\lambda_0 \tag{2}$$

where λ_0 is the free space wavelength.

To increase the antenna gain, the coupling factor should be chosen properly so that the aperture field distribution given by (1) may be close to uniform. On the other hand, to reduce the loss power at the matched load, the coupling should be strong to some extent. Taking all these into account, we calculate the gain of RLSA as function of coupling factor α and antenna diameter d as in Fig. 2. Figure 3 shows the optimum aperture efficiency η and coupling factor α as function of antenna diameter. The optimum value of α decreases as d increases. When d is small, the efficiency is low because the uniformity of aperture distribution is not good for any α and the termination loss is large. Moreover, when α is too large, the rotational symmetry of the traveling wave is excessively perturbed, which can not be evaluated quantitatively in these figures. Those results give the lower limitation for antenna diameter of RLSA.

3. FREQUENCY CHARACTERISTICS

Figure 4(a) shows the frequency characteristics of coupling factor α, slow wave factor ζ and corresponding antenna gain for usual RLSA in 12GHz band. Dashed and dotted line indicate the optimum value of α and ζ in terms of efficiency. Resonant characteristics of slots result in the two peaks of gain at different frequencies. At each peak, 3dB band-width is about 450MHz. If those peaks approach each other into a single peak, wide band-width can be realized. The suppression of coupling is one solution for this problem.

Figure 4(b) shows the frequency characteristics of the fictitious model. The α takes its optimum value around the resonance while ζ is constant, since the inner wave is almost unperturbed. The peak of gain becomes single and the band-width is about 700MHz.

Figure 5 shows the diameter dependence of the band-width. As RLSA is a traveling-wave antenna, the essential limitation of band-width is in inverse proportion to aperture diameter, which is indicated by the dashed line. It is obtained by assuming the uniform amplitude distribution and constant slow wave factor. The band-width of actual RLSA is limited by the resonant characteristics of slots Fig. 4(a), as is shown by solid line. It is almost independent of antenna diameter. Dotted line indicates the band-width for the suppressed coupling model Fig. 4(b), which is almost 1.6 times as wide as that of usual RLSA. For antennas of larger diameter, it is as wide as the theoretical limit. In this point of view, suppression of coupling is a key technology for wider band-width.

4. CONCLUSION

This paper presented the aperture diameter dependence of RLSA fundamental characteristics. The optimum coupling factor α is given as function of the diameter for the use of practical design. The maximum gain of RLSA shows that the larger diameter is advantageous in terms of efficiency. The band-width of RLSA is evaluated and it is pointed out that slot coupling control is the key technique for wider band-width.

REFERENCES

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[2] Moriyama, Takada, Ando and Goto:"A radial line slot antenna with a expanded polyethylene slow wave structure", Trans. of IEICE, vol.E71, No.10, pp.961-971, 1988

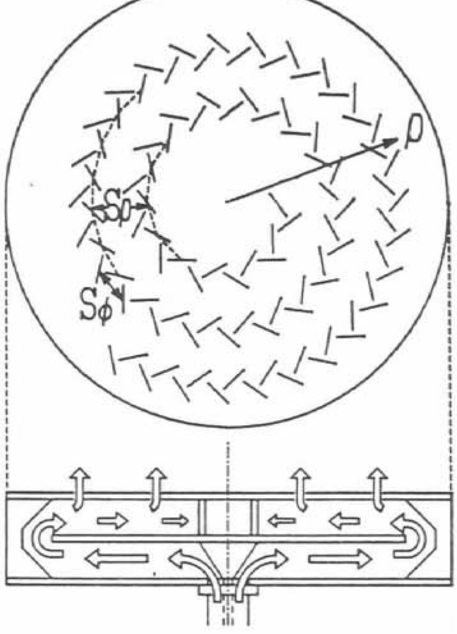


Fig.1 Radial line slot antenna (RLSA).

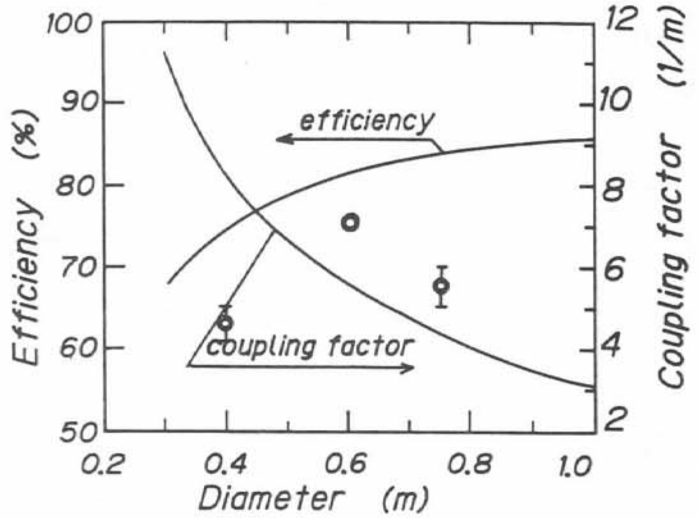


Fig.3 Optimum coupling factor and efficiency.

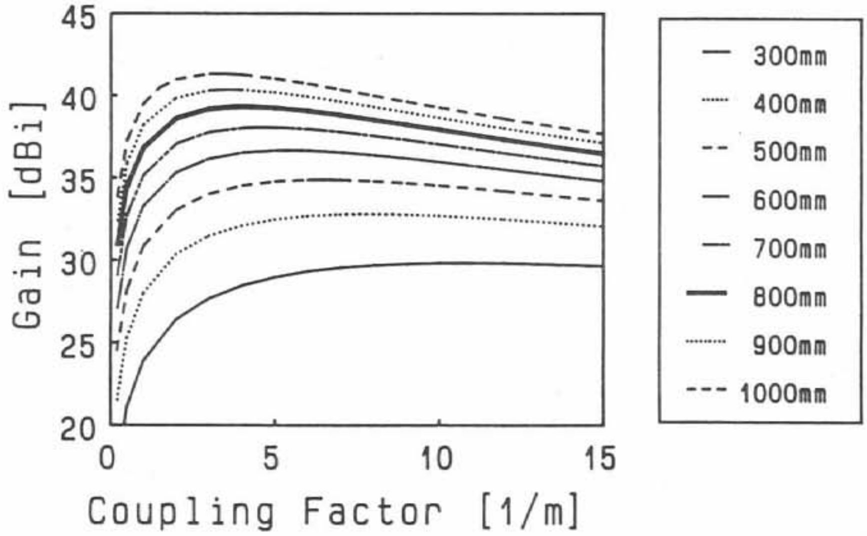
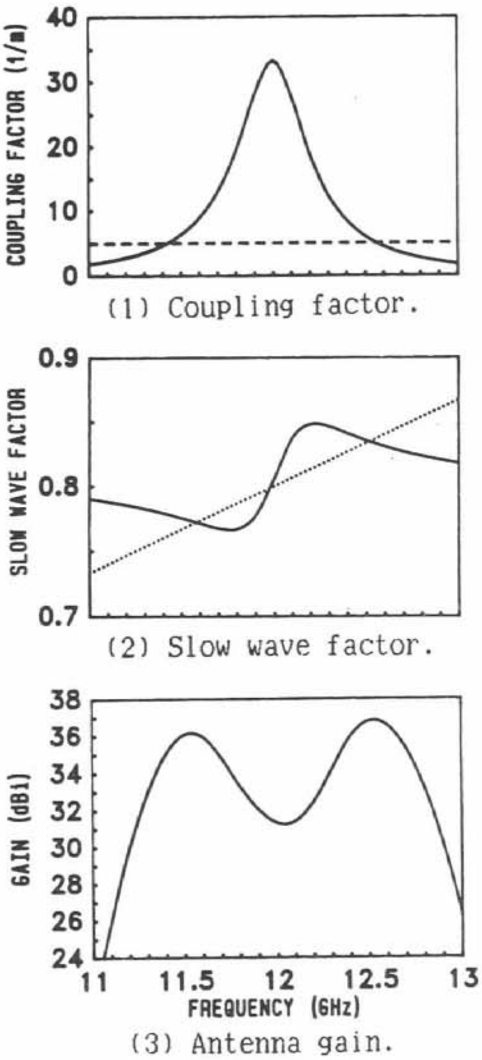


Fig.2 Antenna gain as function of coupling factor.

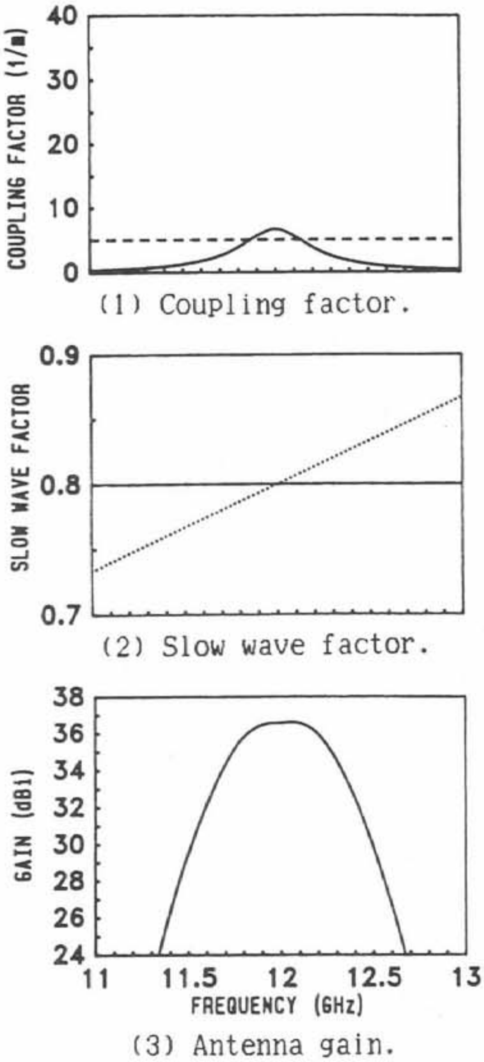


(1) Coupling factor.

(2) Slow wave factor.

(3) Antenna gain.

Fig.4(a) Frequency characteristics of usual RLSA.



(1) Coupling factor.

(2) Slow wave factor.

(3) Antenna gain.

Fig.4(b) Frequency characteristics of coupling suppressed model RLSA.

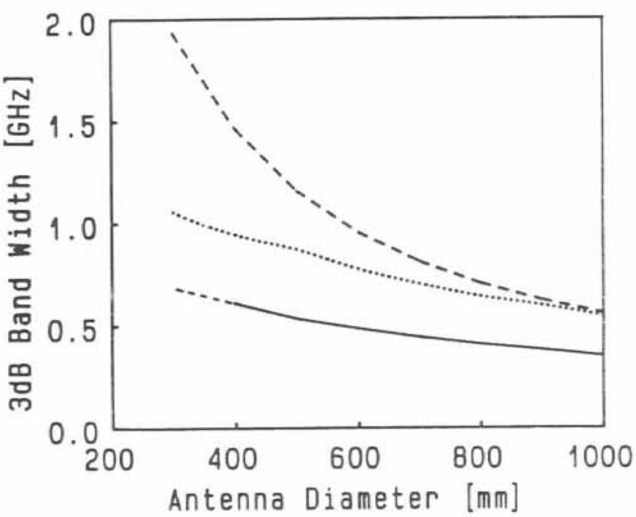


Fig.5 -3dB band-width of RLSA.

———— :Usual RLSA.

·········· :Coupling suppressed model RLSA.

------ :Limitation of traveling wave antenna.