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A Low-Cost Beam-Steering Antenna Using a Moveable Dielectric Slab Inside a Leaky Waveguide

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Abstract

A low-cost beam-steering antenna using a leaky waveguide is studied. By moving the dielectric slab inside the waveguide, the field distribution and its propagation constant are varied accordingly. This results in steering of antenna main beam. The phase and attenuation constant are calculated by the transverse resonance equation and then the radiation far field pattern is determined. Excellent agreement of the radiation pattern between the measured and theoretical data demonstrates the validity of this beam-steering technology. The low-cost, robust and reliable characteristics of such antenna give a prospective future in commercial or military applications.

Introduction

Ever since the invention of the first directional antenna, many methods have been developed to steer the antenna main beam. Gimbaled type antenna system was developed fist [1]. This type of antenna system prevails for a long time since WWII until the invention of electronic beam-steering systems. However, it is expensive to implement and inherently slow in dynamic response. Therefore, other researchers proposed various novel beam-steering techniques [2-4]. This paper proposes a novel design of the low-cost beam-steering antenna based on the characteristics of leaky waves. The leaky-wave antenna is made up of a rectangular waveguide cut with slot in the center of the side wall, which is first proposed by Hansen [5]. A mechanical set-up is made to insert a dielectric slab longitudinally into the waveguide, and makes it moveable inside the waveguide such that the electromagnetic fields is perturbed accordingly. The transverse resonance equation is employed to calculate the dispersion relation of the non-homogeneous waveguide. And the propagation constant including the phase and attenuation constants is found. So, the proposed beam steering technique is thus accomplished due to changing in the phase constant.

Experimental and Theoretical Results

To demonstrate the beam-steering capability of the proposed leaky wave antenna, a dielectric slabs is used to prove the validity of this technique. Figure 1 (a) and (b) give the structural descriptions of the antenna. Figure 2 shows the variation of phase constant versus shift distance for different cases. The variation of the normalized attenuation constant ($\sim^{a}$) versus the shift distance for the three cases is depicted in figure 3. Figure 4 shows the distribution of power leakage versus antenna length, which is normalized to free-space wavelength, is studied for several slot widths, *1.0 mm*, *1.5 mm* and *2.0 mm*, respectively. To investigate the radiation pattern of the antenna at different shift distances, typical result is shown in figure 5. The measured data shown in the above figure agrees fairly well with the theoretical results

Conclusion

We have validated the characteristics of beam steering by means of theoretical and experimental studies in this paper. Examples with certain dielectric constant and thickness of substrate are employed to examine the performance of this antenna. As a rule of thumb, the larger the factor ($\pounds_s t$), the stronger deviation of the propagation constant is. This means that the antenna will experience a large beam-steering angle in a small shift distance. Consequently, it is required to control the shift distance precisely. The characteristics of low-cost, robustness and reliability of this antenna show the promising applications such as point-to-point wireless communication and car collision avoidance radar systems. In addition, since the mechanism is frequency independent, it can be applied in any frequency band without any difficulty. The excellent agreement of the radiation pattern between the measured and numerical calculation also confirm the validity of design concept and theoretical analysis.

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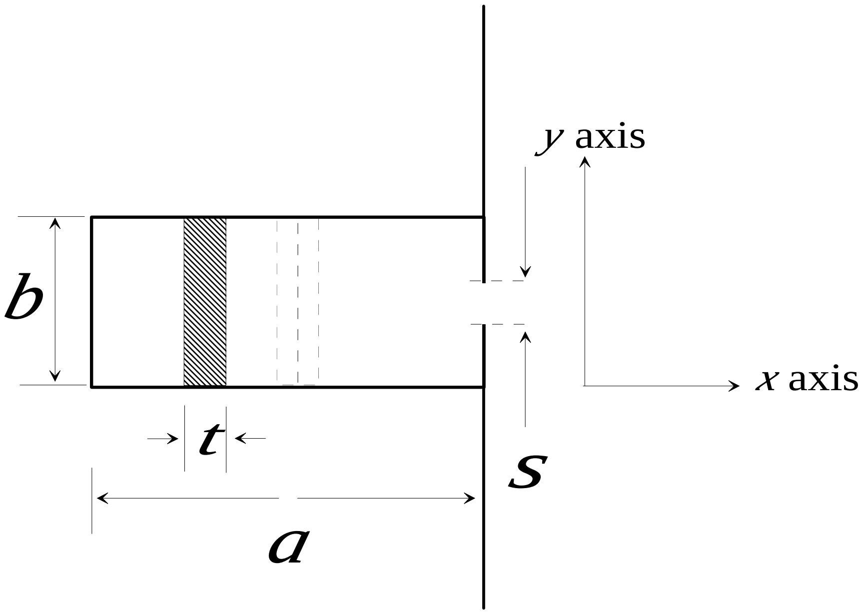

Figure 1: (a) Front view of the leaky wave antenna
(b) Equivalent transmission line network of the leaky wave antenna

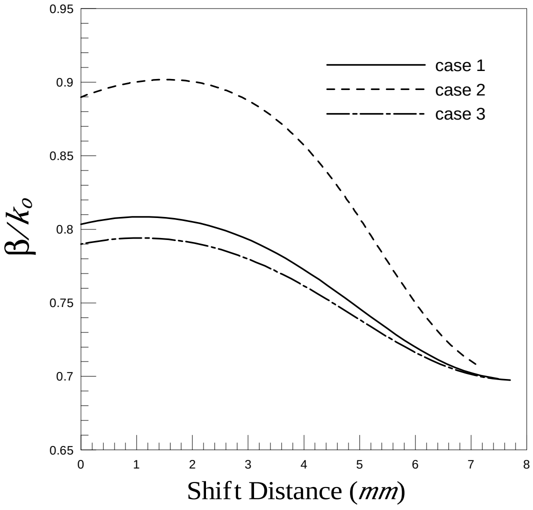

Fig. 2. Normalized phase constants as a function of shift distance for case1, case2, and case3.

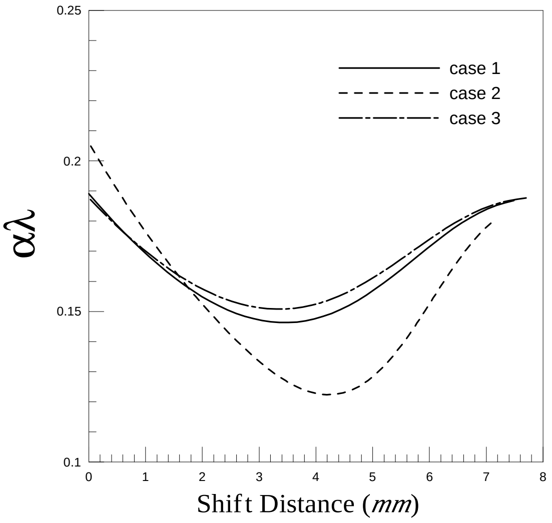

Fig. 3. Normalized leakage constants as a function of shift distance for case1, case2, and case3.

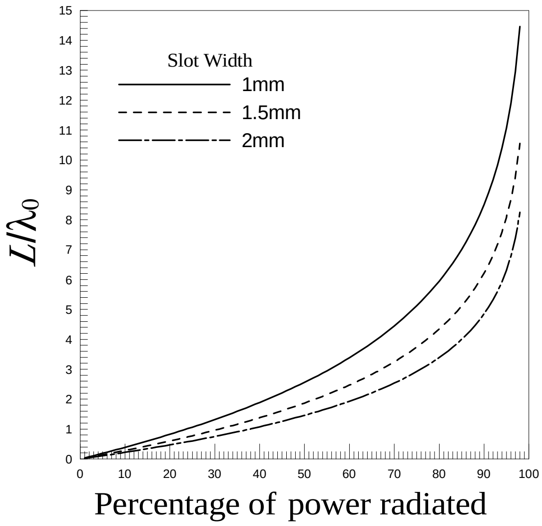

Fig. 4. Relationships of normalized slot lengths as a function of percentage of radiation power, when slot widths are *1*, *1.5*, and *2mm.*

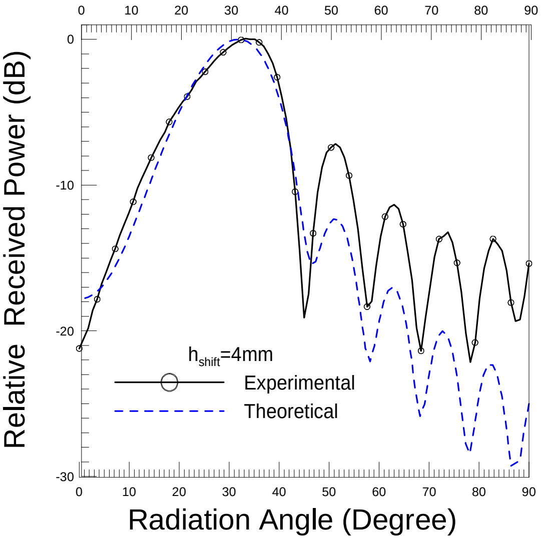

Fig. 5. Theoretical and experimental radiation patterns of case 2, the relative dielectric constant and thickness (mm) of the dielectric slab are 2.55 and 1.62 respectively, when h_{shift}=*4mm.*