A Compact Leaky-Mode Antenna Array

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Introduction

This paper descirbes a novel 21-element, central-series-fed, proximity-coupled, leaky-mode antenna array. Due to the advantages of wide operation bandwidth, frequency scanning, less strangent requirement of tolerance, leaky-mode antennas had been widely developed and operated ay the first higher order mode on microstrip line[1]-[2]. Various methods of exciting the first higher order leaky mode of a microstrip line have been developed. The microstrip leaky-mode antenna showed a narrow radiation beamwidth in H plane, but wide beamwidth in E plane. Therefore a linear antenna array was developed for producing a narrow pencil beam [3]-[4]. Traditional leaky-mode antenna array designs, however, occupied relatively large area and complicated at the feeding structure [5].

The leaky-mode antenna array reported in this paper is designed, keeping the feeding network at the minimal real estate that can be possibly achieved. Simple feeding network, however, can reduce the antenna size, path loss in transmission medium. The novel feeding method is broadband and is suitable for versatile applications for meeting various requirements. The microstrip antenna array presented in this paper is also operated at its first higher order mode. The leaky-mode radiation is achieved by coupling of the feed line and the leaky line with a small gap. Furthermore the antenna array is fed at the central symmetry plane. Therefore the amplitude distribution of the radiation pattern can be made more symmetric with lower side lobe level. The feeding structure provides a simple interface with microwave circuit without any transition. Thus no complicated feeding network and transition circuit are required, rendering compact and efficient integration with circuits such as low noise amplifier and power amplifier.

Antenna Array Design

The leaky-mode antenna array is made on the printed circuit board. The width of the leaky wave microstrip antenna is determined by the frequency band where the space wave leakage occurs. The leaky region of a single leaky line is determined by the normalized phase and attenuation constant of the microstrip line at the first higher order mode, as shown in Fig.1.

Fig. 1 also indicates the possible operating frequency region between 20GHz and 25GHz for the particular EH_1-mode leaky-wave antenna design in view of the dispersion behaviour of the normalized complex propagation constant. The whole antenna is designed and fabricated on a RO4003 substrate of a dielectric constant ε_r =3.55 and the thickness h of 0.508mm. The angle of maximum power radiated can be assessed by the expression

$$\theta_m = \sin^{-1}(\beta/k_0)$$

,where θ_m is the angle of the main beam from the z-axis. The configuration of an n-element, central-series-fed, proximity-coupled, leaky-mode antenna array is shown in Fig.2. The length L of the leaky line is 75mm. Fig. 3 shows the detailed configuration of leaky-wave antenna unit cell fed near the leaky line open end. This feeding method exhibits the broadband characteristic of leaky wave antenna. The feeding line is close the one end of the leaky line. The width of the leaky line is chosen close to one half of the guided wavelength of the feeding line, thus exciting odd-mode leaky wave. In order to have the same excitation of each leaky line, the separation of each leaky line element d, is also choose the one half guiding wavelength. The relative power absorbed (RPA) value, is defined as

$$RPA = 1 - |S_{11}|^2 - |S_{21}|^2$$

When the unit element is well matched, means that $|S_{11}| \cong 0$. The radiation efficiency of the unit cell element antenna can be estimated by the overall PRA. The detailed feeding structure is shown in Fig. 3. The RPA value is greatly dependent on the size of gap. Smaller coupling gap results in the higher RPA value. The coupling gap g is 1mm in this design. The total element number n is chosen as 21 to make the remaining non-radiated power less than 10%. It should be noted that the conductor loss, dielectric loss and any other loss are also included in RPA computation. The whole antenna array size is 158×83mm^2. The feeding structure including input matching network occupies 7% of the total area. The feeding line only occupies less than 3% of the total area.

Measured results

The simulation and measured H-plane patterns are plotted in Fig. 4. The simulation and measured peak gain of the main beam at 24GHz is about 23.6dBi and 21.3dBi, respectively. The H-plane half-power beam width is 16 degree. And the E-plane half-power beam width as shown in Fig. 5. is smaller than 6 degree.

Conclusions

The paper presents a compact central-series-fed, proximity coupling, leaky-mode antenna array. The leaky-mode antenna array is demonstrated. The antenna array is synthesized by printed microstrip line employing the first higher order mode. The simulation and measured results are matched quite well. The proposed antenna array is fairly compact. And radiation area occupies more than 90% area is size efficient.

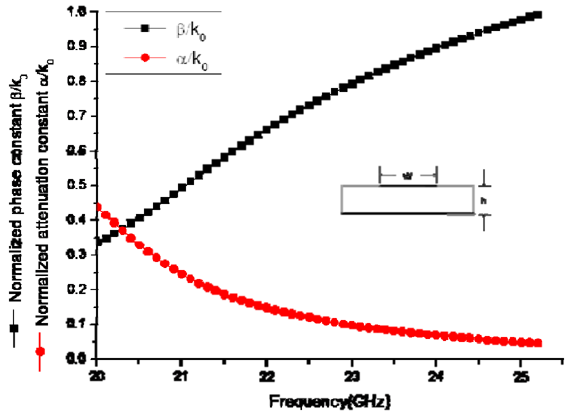

Fig. 1. The normalized complex propagation constant.

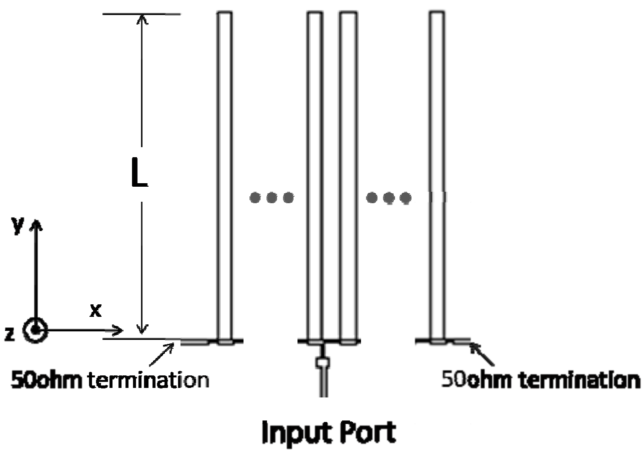

Fig. 2. Proposed n-element antenna array.

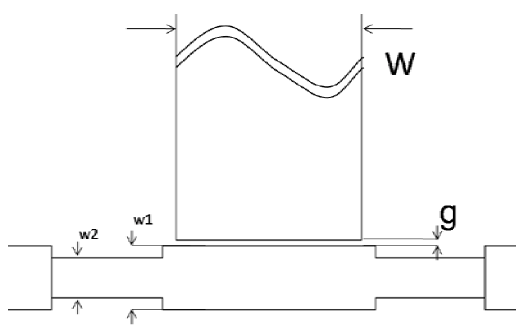

Fig. 3. The detailed configuration of leaky-mode antenna unit cell.

(w1 = 1.2mm, w2 = 0.7 mm. W = 3mm.)

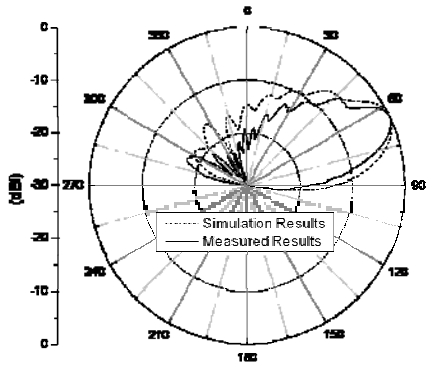

Fig. 4. Simulation and measured radiation pattern in the H-plane(y-z plane).

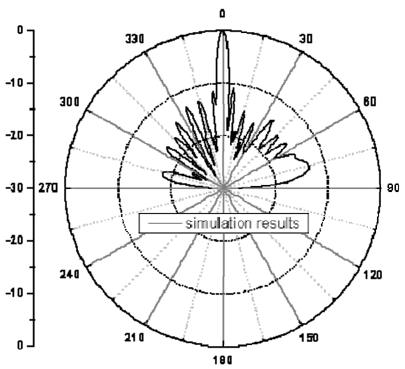

Fig. 5. Simulation radiation pattern in the E-plane(x-z plane).

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