Leaky Wave Antenna with Non-Radiative Dielectric Superstrate

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***Abstract*— In this paper, a leaky wave antenna (LWA) with non-radiative dielectric superstrate (NRDS) is proposed. The proposed antenna is having a dielectric superstrate and an asymmetric, half-filled dielectric spacers forming a quasi-cutoff region in the unfilled region. A high gain, unidirectional tilted beam with wide-angle characteristics is demonstrated using numerical simulations.**

***Keywords*— Leaky wave antenna, Tilted beam, Quasi-cutoff**

I. Introduction

Next mobile communications are expected to use high-frequency bands such as millimeter wave and terahertz bands. These high-frequency bands have high straightness and high propagation loss, which limit the coverage area of a single base station. Therefore, a dense arrangement of base stations and multi-beam switching antennas with multiple antennas having different beam directions with low loss and flexible installation are expected as base station antennas in urban areas for next-generation mobile communications [1].

A leaky wave antenna with dielectric superstrate (LWADS) has been studied as a method to obtain a high gain pencil beam [2]-[6]. LWADS has the advantage of simple construction, low profile, and high gain with only a single feed. LWADS can also produce conical beams by changing the height and thickness of the dielectric superstrate. If this conical beam can be converted into a tilted beam with a single radiation direction, it is effective as a multi antennas with different beam direction as expected [7]-[9].

In this paper, a LWADS with an asymmetric structure on a dielectric spacer is proposed [10]. Effect of the quasi-cutoff region in which no leaky wave modes is demonstrated by simple simulation models.

II. ANTENNA DESIGN

Consider a LWA with a dielectric superstrate (h_2, ε_{r2}) on a dielectric spacer (h_1, ε_{r1}). The optimum thickness of each layer to obtain maximum gain toward the desired beam direction θ_p is generally provided as

$$h_1 = \frac{m\lambda_0}{2}\frac{1}{\sqrt{\varepsilon_{r1} - \sin^2\theta_p}} \quad (1)$$

$$h_2 = \frac{(2n-1)\lambda_0}{4}\frac{1}{\sqrt{\varepsilon_{r2} - \sin^2\theta_p}}, \quad (2)$$

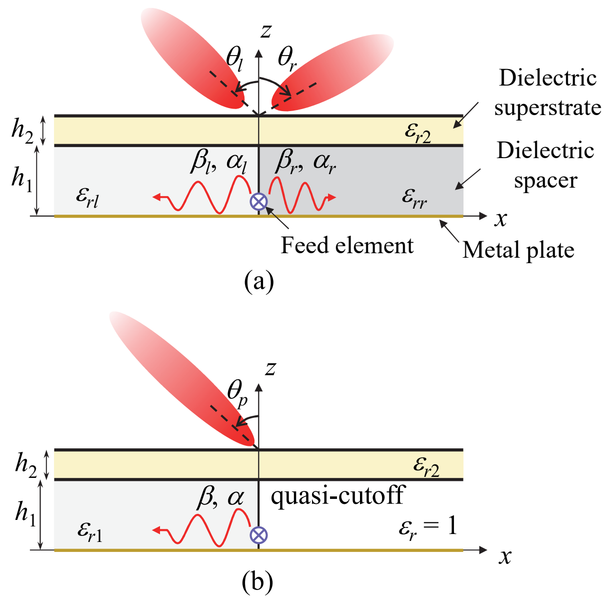

Fig. 1. Geometry of the LWADS with dielectric superstrate on asymmetric dielectric spacer. (a) Two different dielectric spacers with different permittivity ($\varepsilon_{rr} > \varepsilon_{rl}$). (b) Dielectric spacer with truncated right half region.

where λ_0 is the wavelength in free space, and m and n are positive integers. In the case when $\theta_p = 0°$, a pencil beam toward the broadside will be radiated.

In general, a conical beam with tilt angle of θ_p can be obtained by changing the height of the dielectric spacer, which makes the configuration of a multibeam antenna system with different height antennas. This problem can be solved by sandwiching dielectrics with different relative permittivity, as shown in Fig. 1(a).

To obtain a single tilted beam as shown in Fig. 1(b), a quasi-cutoff region with the height of less than $\lambda_0/2$ is provided as the air region of the truncated side in which no leaky wave modes generated. The effect of this quasi-cutoff region will be demonstrated and discussed in the next section.

III. SIMULATED RESULTS

FDTD simulations were performed to demonstrate the effect of quasi-cutoff region at the design frequency of 10 GHz (λ_0=30 mm), with wide tilt angle of θ_p=60 degree. Fig. 2 shows the fundamental geometry of LWADS with dielectric

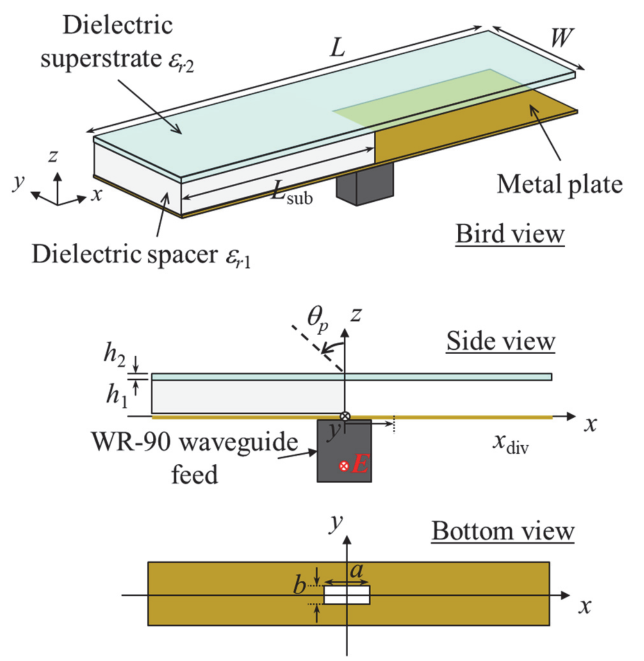

Fig. 2. Fundamental geometry of the LWADS with dielectric superstrate on asymmetric dielectric spacer.

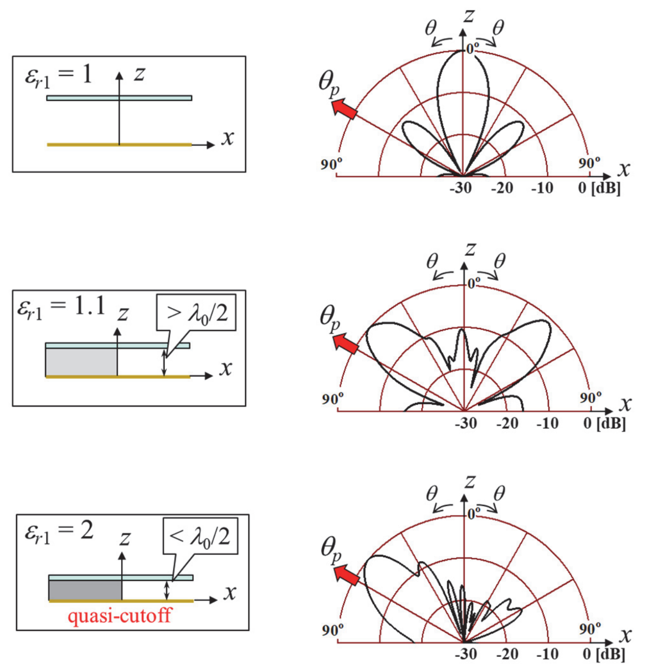

Fig.3. Three geometries of LWA and simulated directivity gain pattern to show the effect of cutoff region.

superstrate on asymmetric dielectric spacer. The dielectric superstrate is made of soda glass plates (ε_{r2} = 6.8) with thickness of h_2 = 3 mm which is obtained by (2) for n=1. Left side of Fig. 3 show the three geometries of LWA and right side of Fig. 3 show the simulated radiation pattern to show the effect of cutoff region. When θ_p=60 deg and ε_{r1}=1, the height h_1 becomes 30 mm in mode m=1 of (1), but this mode also corresponding to the case of mode m=2 of θ_p=0 deg and strong broad side radiation was observed. Directivity gain was 14.6 dBi.

When θ_p=60 deg and ε_{r1}=1.1, the height h_1 becomes 25.4 mm in mode m=1 of (1), and a beam toward θ_p=52 deg, ϕ=180 deg direction was observed, but this height h_1 with ε_{r1}=1 also corresponding to the radiation direction of θ_p=53.8 deg of (1), result in two beams with different tilted angles described in Fig. 1(a). Directivity gain was 10.1 dBi.

When θ_p=60 deg and ε_{r1}=2, the height h_1 becomes 13.4 mm in mode m=1 of (1), and a beam toward θ_p=52 deg, ϕ=180 deg direction was observed, and this height h_1 with ε_{r1}=1 having no mode, we call it as quasi cutoff and a high gain, single, wide angle tilted beam was obtained. Directivity gain was 13.4 dBi.

It is known that the directivity gain G_d of LWADS increases proportional to the ratio of the relative permittivity of the dielectric superstrate to that of the dielectric spacer in the case of an infinite structure as

$$G_d \propto \frac{\varepsilon_{r2}}{\varepsilon_{r1}}. \quad (3)$$

Therefore, high permittivity ε_{r2} is effective for the superstrate, but permittivity of ε_{r1}=1 for the spacer cannot be selected, it should be larger than 1 to construct quasi cutoff region to avoid unwanted radiation toward ϕ=0 deg direction.

Due to page limitations, the experimental data were not presented in this paper, please check reference [10] which include comparisons between simulated and measured results.

IV. CONCLUSION

In this paper, a LWA with a non-radiative dielectric superstrate has been proposed and the wide-angle tilted beam of over 50 degree was demonstrated. It is shown that the conical beam of the LWADS were successfully converted to the unidirectional high gain beam by the presence of quasi-cutoff leaky wave guide.

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