Reconfigurable BeFoL Antenna

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1. Introduction

An antenna composed of two leaf-like bent conducting strips, designated as the BeToL, has been investigated in [1]. This antenna is excited from the bottom end of one leaf strip, with the other leaf strip shorted to the ground plane and acting as a parasitic element. Investigation shows that the BeToL exhibits a unidirectional radiation beam.

An extended version of the BeToL is found in [2], where the number of bent leaves is increased to four and the antenna is designated as the BeFoL. The BeFoL is used as an element in a mobile communication array antenna. The radiation characteristics for the BeFoL array antenna are analyzed and discussed in detail in [2].

This paper is a sequel to [2], presenting a novel design for a reconfigurable antenna [3]-[6]. First, a BeFoL with a conducting ground plane of infinite extent is briefly summarized. Second, the radiation characteristics for a BeFoL with a finite-size ground plane are analyzed. Lastly, the finite-ground plane is bent and the beam direction from the BeFoL with the bent ground plane is discussed.

2. Configuration

Fig. 1 shows the BeFoL above a conducting ground plane of side length s_{GP}. The four leaves are bent at height h and have the same configuration parameters. The leaves are placed around the z-axis, in order to obtain a reconfigurable radiation pattern. The bottom ends of the leaves (a, c) and (b, d) are on the x- and y-axes, respectively. The distance between a pair of leaves on the x-axis equals that on the y-axis: $d_x = d_y$. The top triangular leaf section, which is connected to the vertical section of width w_v, is specified by the bottom length Δ_{btm} and height Δ_h. Only one leaf is excited and the other three are shorted to the ground plane (GP). The configuration parameters used throughout this paper are shown in Table I.

3. Discussion

A frequency range of 3 to 6 GHz is selected and analysis is performed using computer programs we developed based on the finite-difference time-domain method (FDTDM) [7]. The antenna characteristics are calculated using the electric and magnetic fields, **E** and **H**, obtained from the FDTDM analysis. Note that the electric and magnetic currents on any surface are obtained from **E** and **H**, respectively, and used to calculate the radiation pattern.

First, we assume the ground plane to be of infinite extent ($s_{GP} = \infty$) and consider a situation where only end a is excited, while ends b, c, and d, are shorted to the ground plane; this situation is expressed as [a]. Fig. 2 shows the radiation pattern for [a]. It is found that the maximum radiation is in the positive x-direction, where the half-power beam width (HPBW) in the x-y plane is more than 90^o.

Because the difference in orientation between adjacent leaves is 90 degrees, the radiation is in the negative x-direction for [c] (only end c is excited), in the positive y-direction for [b], and in the negative y-direction for [d]. Thus, a reconfigurable radiation pattern is obtained by specifying how the leaf ends are connected. Note that the selection of whether a leaf end is excited or shorted is realized using a switching circuit with diodes or RF-MEMS.

Next, we replace the infinite ground plane with a finite-size ground plane. This replacement causes a change in the radiation pattern. Fig. 3 shows the radiation pattern for [a], where s_{GP} = 1.86 wavelengths (at 4.5 GHz). The radiation pattern is found to be tilted upward. Additional analysis reveals that, as s_{GP} is decreased from $s_{GP} = \infty$ (within $\infty > s_{GP} \geq$ one wavelength at 4.5 GHz), the maximum beam direction in the x-z plane, θ_{max} (measured from z-axis), decreases.

A question arises as to whether the radiation for [a] can be confined, using a finite-size ground plane, to the space around the positive x-axis. Note that, as the ground plane is further decreased from s_{GP} = one wavelength, the radiation is, in fact, confined; however, the front-to-back ratio (F/B ratio) decreases undesirably. To solve this issue, we consider a structure where the ground plane is bent at b_{GP}, as shown in Fig. 4, where the bend angle with respect to the horizontal plane (x-y plane) is α.

The effect of the bend angle α on the radiation is analyzed for a fixed length b_{GP}. It is found that there is an optimum angle of α for realizing confined radiation with a high F/B ratio. Fig. 5 shows this for [a]. Note that this confined radiation leads to a high antenna gain in the x-direction, compared with the gain for the flat ground plane, as shown in Fig. 6.

4. Conclusions

The four conducting leaves of the BeFoL are placed around the antenna axis (z-axis) to realize a reconfigurable radiation pattern. When the ground plane is of infinite extent, the BeFoL for [a] (only leaf end a is excited and the other ends are shorted to the ground plane) has maximum radiation in the positive x-direction. It is also found that, as the ground plane size is decreased (within the range of $\infty >$ side length $s_{GP} \geq$ one wave length at 4.5 GHz), the direction of the maximum radiation shifts upward. This means that the beam direction in the elevation plane is controlled by the ground plane size. Further analysis reveals that, when the ground plane is bent at an appropriate bend angle α, the radiation from the BeFoL for [a] is confined to a space around the positive x-axis, with a high F/B ratio.

Acknowledgments

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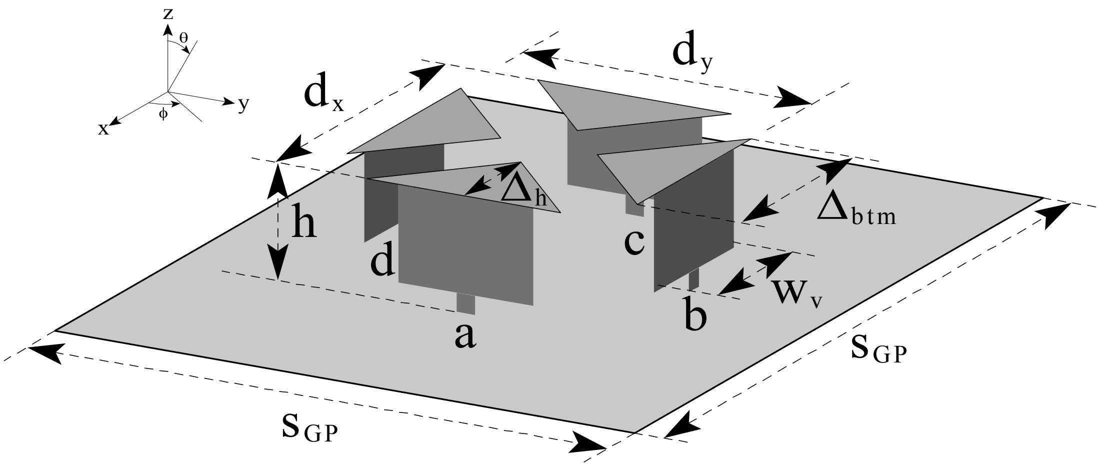

Fig. 1 BeFoL above a ground plane.

Table I Configuration Parameters.

Symbol	Value
d_x	$0.45\lambda_{4.5}$
d_y	$0.45\lambda_{4.5}$
h	$0.18\lambda_{4.5}$
w_v	$0.21\lambda_{4.5}$
Δ_{btm}	$0.3\lambda_{4.5}$
Δ_h	$0.15\lambda_{4.5}$
$\lambda_{4.5}$	66.7 mm

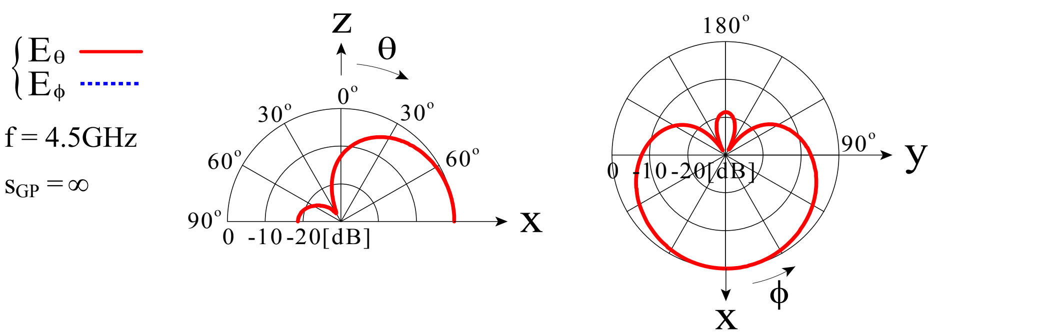

Fig. 2 Radiation pattern for situation [a] at 4.5 GHz, where the ground plane is of infinite extent.

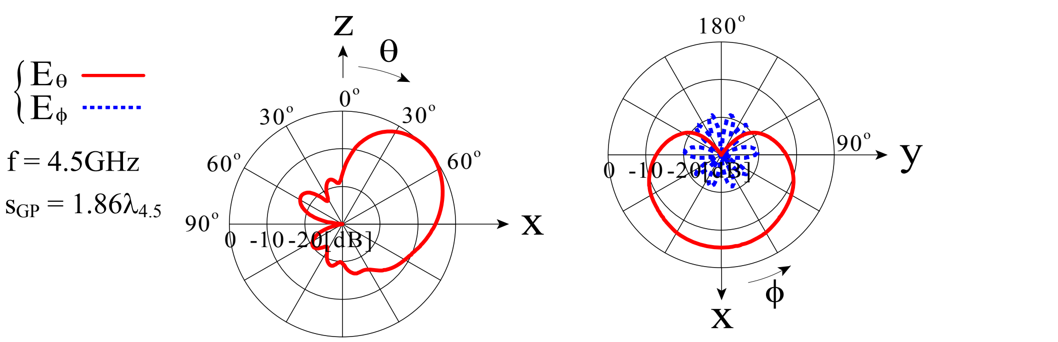

Fig. 3 Radiation pattern for situation [a], where the ground plane has a side length of s_{GP} = 1.86 wavelength at 4.5 GHz.

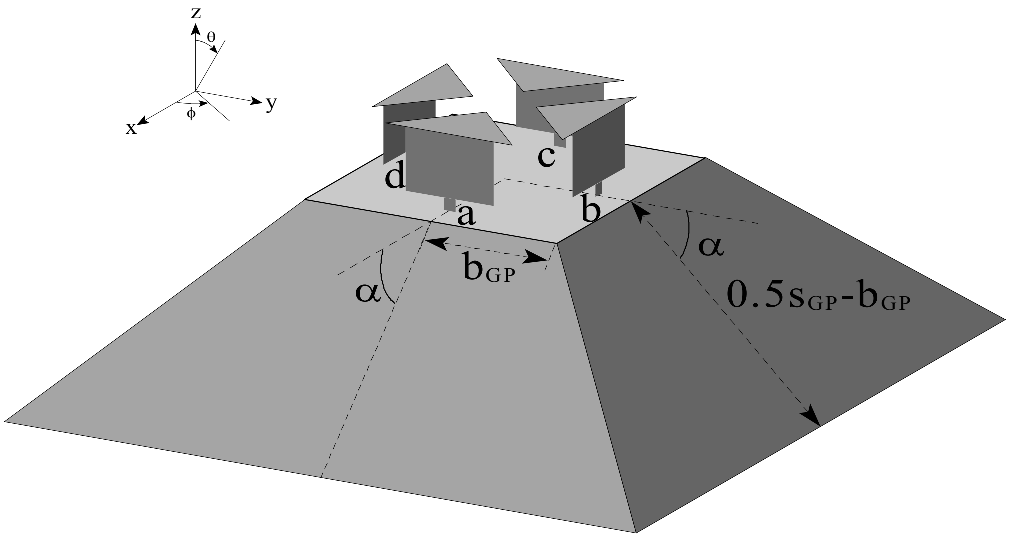

Fig. 4 BeFoL above a bent ground plane.

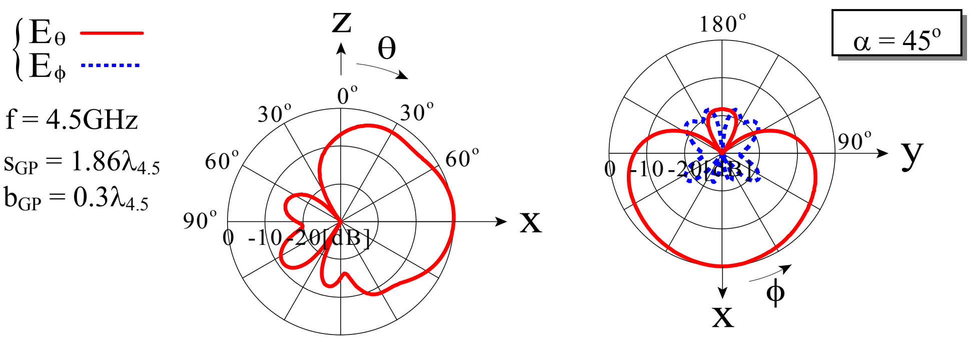

Fig. 5 Radiation pattern for situation [a], where the finite-size ground plane is bent.

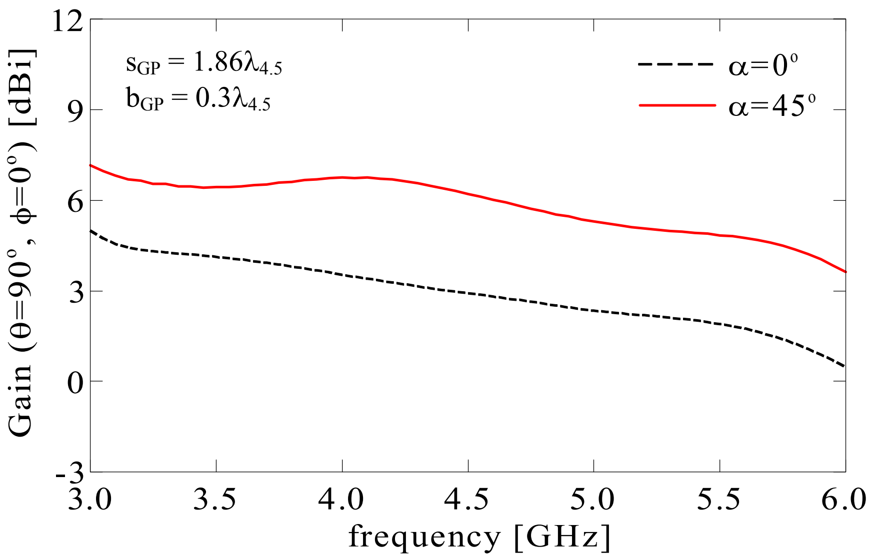

Fig. 6 Gain for situation [a].