Microstrip-Fed Microstrip Second Higher Order Leaky-Mode Antenna

Tai-Lee Chen, Yu-De Lin, and Jyh-Wen Sheen

***Abstract*—With the appropriate placement of the slots and via holes, the microstrip second higher order leaky-mode antenna fed by a microstrip is presented. Two main beams with titled angles from the strip are measured in the predicted radiation leaky band. The leaky band of the microstrip second higher order mode is deduced from the characteristics of the propagation constants that are calculated by the spectral domain analysis. The proposed feeding method provides a direct connection with the circuits based on the microstrip line.**

***Index Terms*—Antenna feeds, leaky-wave antennas, microstrip.**

I. Introduction

BASED on the investigation of the leaky mode of the planar transmission structures, the applications of printed leaky-wave antenna have gradually attracted attention recently [1]–[5]. The planar leaky-wave antenna is a better candidate in microwave and millimeter-wave applications owing to its advantages such as broad-band, higher gain, and frequency-scanning properties. Especially in the applications of multi-beam requirement, such as multipoint communications and surveillance systems, the leaky-wave antenna can reduce the complexity of the feeding network design [4], [5].

Based on the first higher order leaky mode of the microstrip, several microstrip leaky-wave antennas were developed. However, there is little literature utilizing the characteristics of the second higher order leaky mode as the radiation source [6], [7]. A microstrip line combined with a coplanar waveguide (CPW) underneath the strip as a leaky-wave antenna was proposed in [6]. With the CPW running under the strip, the microstrip second higher order leaky mode would not be purely excited because the guiding wavelength of the leaky mode is not necessarily the same as that of the equivalent conductor-backed CPW. In [7], two kinds of short-end CPW feeding structures of the microstrip second higher order leaky mode antenna were developed, one of which arranges the short-end CPW on the strip and another on the ground plane. However, to connect with circuits based on the microstrip line, extra CPW-to-microstrip transition circuits must be applied to these CPW feeding structures. These transition circuits are usually narrow-band in nature and might affect the radiation pattern of the antenna. To overcome these defects, the microstrip line feeding structure for the microstrip second higher order leaky mode is proposed in this paper.

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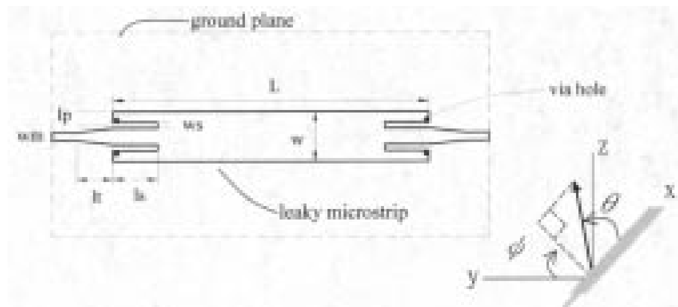

Fig. 1. Microstrip-fed microstrip second higher order leaky-wave antenna and the coordinate system. $\varepsilon_r = 10.2, h = 0.635, L = 65, w = 5.2, ws = 0.2, wm = 0.62, ls = 9.1, lp = 1.3, lt = 7.4$ (mm).

II. Microstrip Feeding Structure for the Microstrip Second Higher Order Leaky-Mode Antenna

The microstrip second higher order leaky-mode antenna with the microstrip feeding structure on both ends of the antenna is depicted in Fig. 1. To design the leaky-wave antenna, the radiation region of the microstrip must be identified first. The normalized propagation constants of the second higher order leaky mode are shown in Fig. 2. They are obtained by the spectral domain analysis (SDA) with the appropriate inverse transform integral path and the moment method technique [8]. The inverse transform integral path includes part of the real axis, the surface wave poles, and a leaky portion that locates on the second Riemann sheet with a vertically exponentially growing wave [8], [9]. The phase constant β along the strip is smaller than the freespace wavenumber k_0, which indicates the possibility of radiating into space. This is different from the covered stripline structure of which the phase constant is larger than k_0 and the wave radiates laterally when the leakage occurs [10], [11]. The fast-wave radiation region is located before the frequency point $\beta \approx k_0$ and after $\beta \approx \alpha$ [9].

The slots are etched where the longitudinal currents along the strip are small. The slot length is chosen to be about a quarter of the guided wavelength of the leaky mode. Two via holes are placed at about a quarter width from the edge of the strip (the fringing effect is taken into account) near the slots to match the boundary condition of the second higher order leaky mode on the feeding interface. In this way, the vertical electric fields

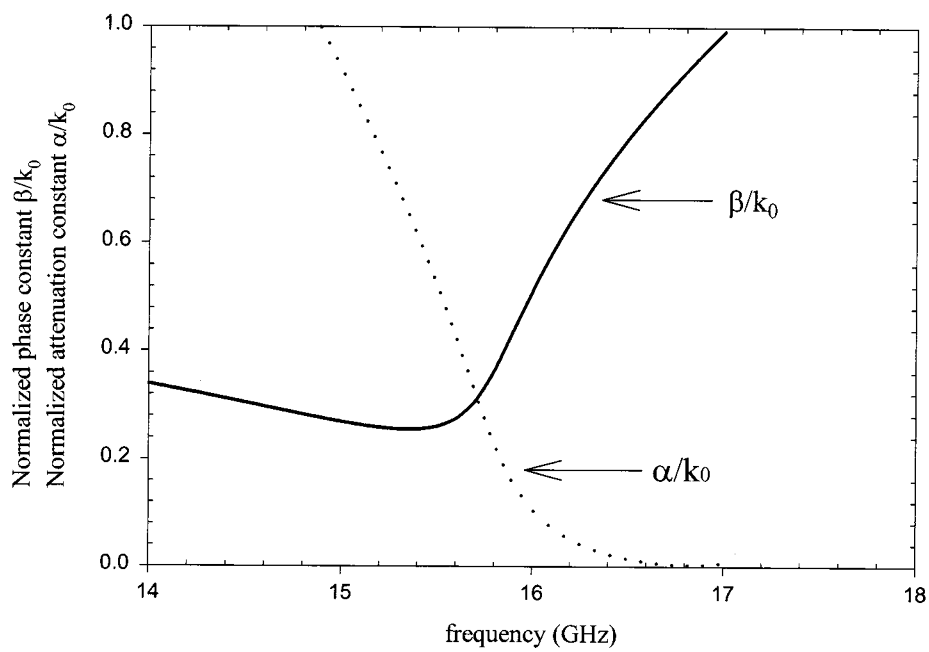

Fig. 2. The normalized phase constant and attenuation constant of the microstrip second higher order leaky mode with the specification in Fig. 1.

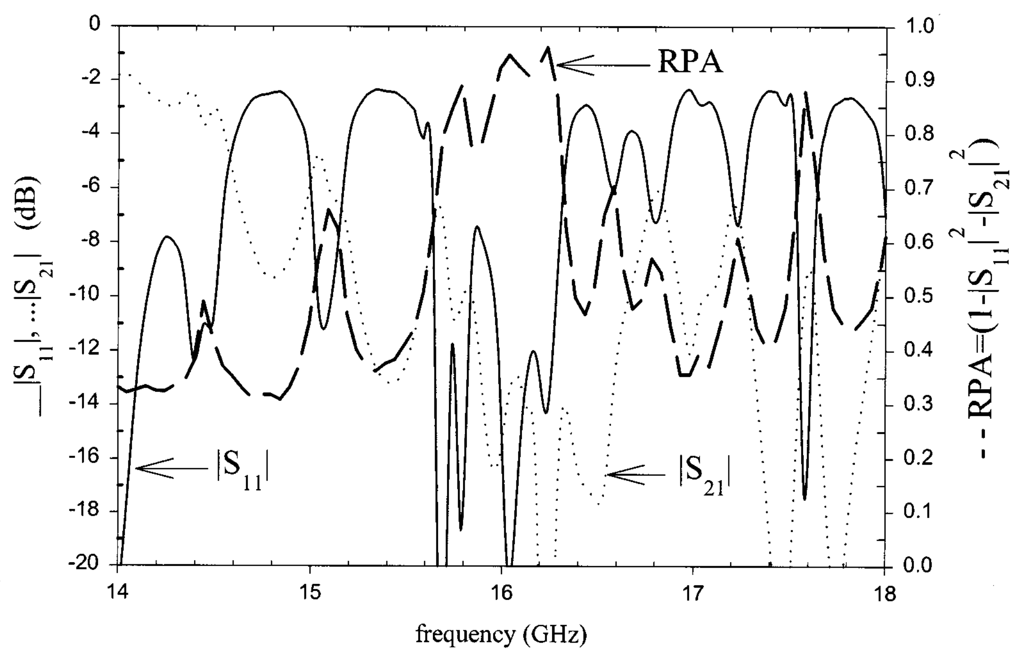

Fig. 3. Measured S-parameters and the RPA of the second higher order leaky-wave antenna in Fig. 1.

under the strip at the via holes are shorted and the microstrip dominant mode can be suppressed.

III. Experimental Results

The measured scattering parameters and the relative power absorbed (RPA $= 1 - |S_{11}|^2 - |S_{21}|^2$) which indicates how much power is dissipated in the circuit are shown in Fig. 3. The frequency band where both $|S_{11}|$ and $|S_{21}|$ are small (RPA increases) is in the radiation region in Fig. 2. The dips of $|S_{11}|$ are caused by the bound modes resonating forward and backward on the strip. These bound modes (dominant mode and second higher order bound mode) are not matched by the feeding structure out of the leaky band. The measured three-dimensional power gain pattern of the antenna fed by one port (with another end cut flatly) is depicted in Fig. 4. The pattern is measured in an anechoic chamber with the HP85301 antenna measure system. The magnitude of the radial component is the measured power gain in dBi. In the chosen coordinate system, E_ϕ is the dominant polarization of the radiated fields. This can be deduced from the waveguide (cavity) model that assumes two magnetic side walls under the edges of the strip. The peak power gain of the tilted dual mainbeam is about 7.3 dBi ($\theta = 65°$, $\phi = 130°$) at 16 GHz. There is another smaller beam (E_θ) with lower elevation

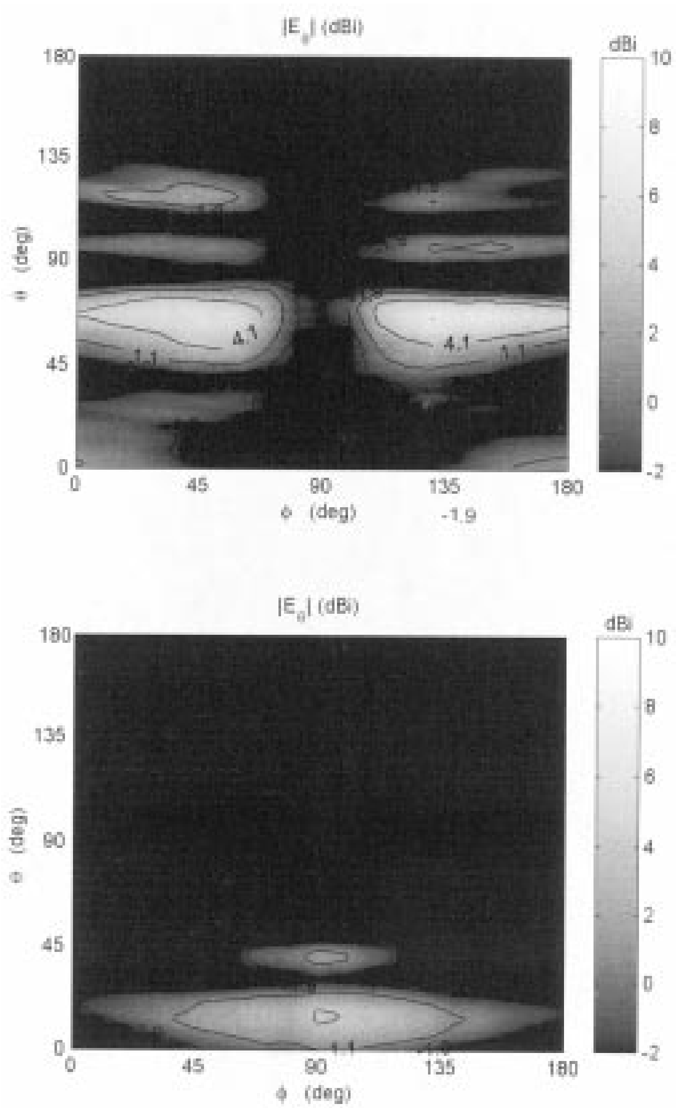

Fig. 4. Measured power gain patterns (3 dB/contour) of the truncated open end of the antenna in Fig. 1 at 16 GHz. Peak$(\theta,\ \phi) = (65^\circ,\ 130^\circ)$, peak power gain $= 7.3$ dBi.

angle along above the strip. It could be attributed to the radiation caused by the survival power on the truncated end.

IV. Conclusion

An effective exciting technique for the microstrip second higher order leaky mode is devised in this paper. To satisfy the current and field distributions of the leaky mode, the slots and the via holes are combined around the feeding structure. Antenna fed directly by the microstrip offers the advantage of easy connecting with the circuits based on the microstrip line. Measurement of scattering parameters confirms the expected leaky band that was deduced by the spectral domain analysis. Measured two tilted main beams reveals the possibility of use in multi-beam applications.

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