Surface Wave Enhanced Broadband Planar Antenna for Wireless Applications

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***Abstract*—This letter explores the development of a new class of broadband antenna in which TE_0 surface-wave is used as the primary source of free space radiation. We demonstrate that antennas based on this concept can be designed to operate over a broad bandwidth, be extremely compact, and can be easily integrated with MIC and MMIC technology. Measurement of return loss and radiation pattern characteristics of the antenna described in this letter indicate a 47% operating bandwidth, covering a large part of the frequency spectrum assigned for U.S. as well as European high-speed wireless local area network (WLAN) applications, making it ideal for integration with WLAN modules.**

***Index Terms*—Antennas, microstrip antennas, wireless LAN.**

I. Introduction

Advantages of wireless networks such as user mobility, low maintenance, and easy addition of new users have brought upon an expanding interest in the possibility of replacing existing wired systems with wireless systems. Recently, the United States Federal Communications Commission (FCC) has allocated new frequency bands in the 5–6 GHz range under the Unlicensed National Information Infrastructure (U-NII) for high-speed wireless LAN [1]. The European Telecommunications Standards Institute (ETSI) has dedicated a 150 MHz band, from 5.15–5.3 GHz for wireless LAN applications. These large frequency bands can easily accommodate the spectrum requirements of wireless systems with higher than 100 Mbps data rate.

For system flexibility and feasibility, the ability to operate at any or all of the specified frequency bands is highly desirable. Size compactness and cost-effectiveness of WLAN transceiver modules are also issues of concern. Meeting these design challenges requires not only the development of broadband circuits, but also compact, broadband antennas as well.

Planar antennas offer many attractive features for use in conjunction with WLAN modules, including compactness, lightweight construction, low-cost, and ease of fabrication. In order to achieve extreme size compactness as well as high circuit compatibility it is often times necessary to fabricate such antennas on high dielectric constant substrates. However, this often presents several disadvantages. For example, microstrip patch antennas printed on high dielectric constant substrates are typically narrowband and have relatively low-efficiency due to the excitation of undesired substrate modes [2].

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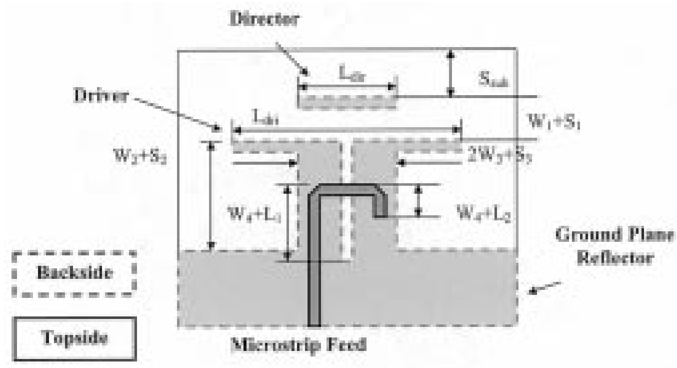

Fig. 1. Schematic diagram of proposed antenna.

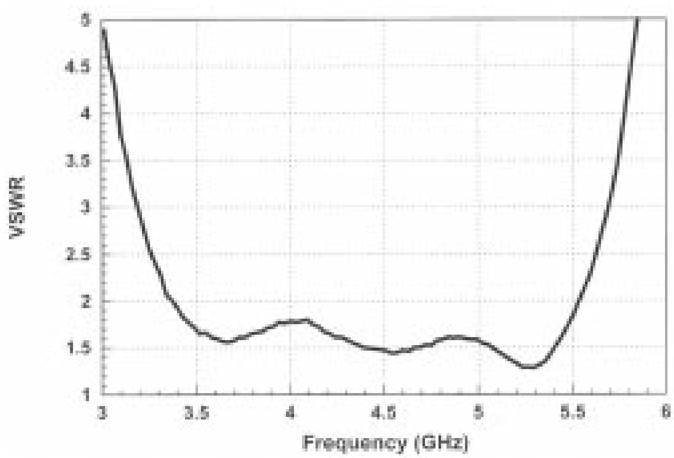

Fig. 2. Measured input VSWR.

Recently, a novel "quasi-Yagi" printed antenna has been proposed [3], [4], which in fact takes advantage of the generation of surface-waves. The antenna configuration is similar to the classic Yagi-Uda dipole type antenna. However, in this case the driver dipole element is used mainly to excite TE_0 surface-wave. The truncated microstrip ground plane then acts as a surface-wave reflecting element, resulting in unidirectional radiation. Moreover, this eliminates the need for any separate reflector elements.

The antenna proposed in this letter utilizes the same concept of the ground plane reflector element. The broadband microstrip balun for dipole feeding reported by Edward and Rees [5] is employed to further reduce the size of the antenna as well as

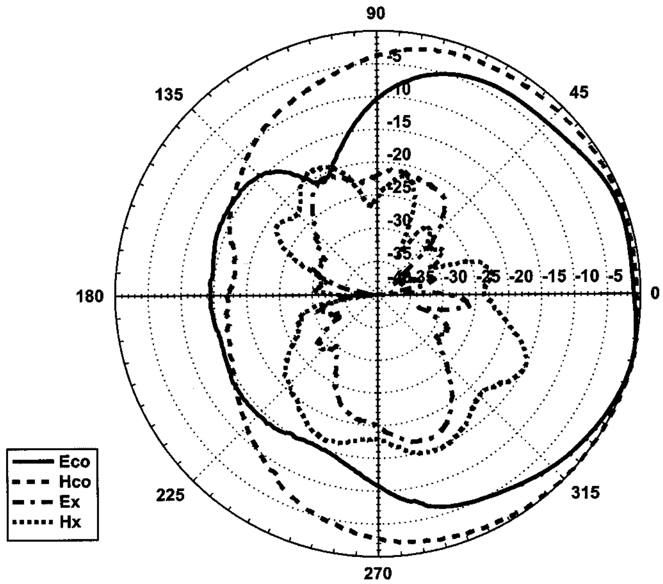

Fig. 3. Measured radiation patterns at 3.5 GHz.

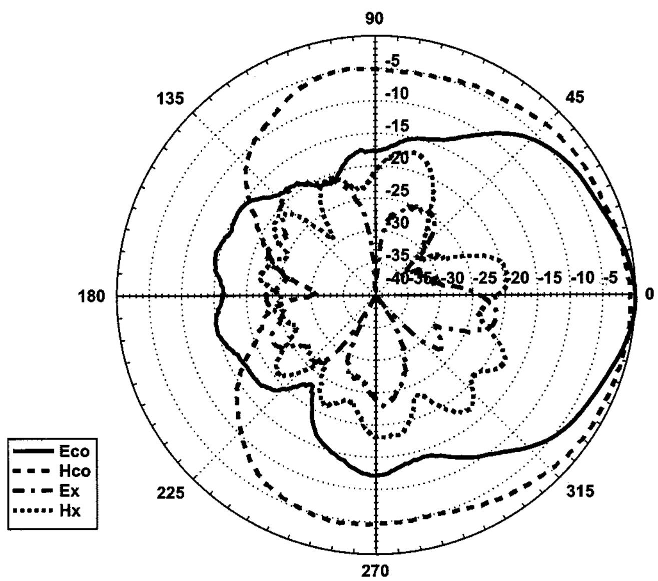

Fig. 4. Measured radiation patterns at 5.0 GHz.

to lessen the cross-pol radiation. In turn, the resulting radiation pattern is unidirectional, as opposed to a standard omnidirectional dipole antenna, resulting in a more efficient means of signal transmission for WLAN applications.

II. Antenna Design

Fig. 1 shows the schematic of the proposed antenna. The antenna consists of a driver dipole element, a parasitic director element, and the truncated ground plane acting as the antenna's reflector element. The microstrip fed antenna uses the broadband balun described in [5], which uses broad side coupling between the microstrip line printed on the top side of the substrate to the slot which is printed on the bottom of the substrate, exciting the balanced mode which is required to feed the driver dipole. Although this type of balun has already been proven to be effective in the feeding of printed dipole antennas, this newly proposed dipole antenna is able to achieve not only a broad operating bandwidth, but also a unidirectional pattern without the use of an additional metal reflector, which is necessary in [5]. Since the metal reflector must often times be electrically large, the overall antenna becomes bulky and heavy in spite of the extreme compactness of the printed dipole itself.

The end-fire nature of the proposed antenna stems from a number of factors. The antenna is printed on high dielectric material, Duorid $\varepsilon_r = 10.2$ with the optimum thickness for this operating frequency range, 1.27 mm. The choice of high permittivity substrate not only reduces the size of the antenna but also allows for proper excitation of TE_0 surface-wave [6]. The printed antenna utilizes both free space radiation of the dipole and the TE_0 surface-wave, which are reflected by the truncated ground plane to realize the desired front-to-back ratio over a broad frequency range. Simultaneously, the director sends the energy toward the endfire direction and also acts as an impedance matching parasitic element.

The antenna was optimized using an in-house FDTD code. The dimensions of the fabricated antenna are as follows: $L_{dri} = 23.4$, $L_{dir} = 10.8$, $L_1 = 4.2$, $L_2 = 4.68\, W_1 = W_2 = W_4 = S_6 = 0.6\, W_3 = 3.6\, S_1 = 6.3\, S_2 = 8.4$ and $S_{sub} = 4$, where all units are in mm. Note that this new design is much smaller than the C–band version of the "quasi-Yagi" antenna reported in [3], [4], due to the use of a more compact balun, making it more suitable for portable module integration.

III. Measurement Results

Measurement of the input VSWR (Fig. 2) of the antenna shows a broad bandwidth (VSWR < 2) of 47% from 3.4–5.5 GHz. The antenna radiates in the endfire direction, maintaining a front-to-back ratio of 15 dB and cross polarization level of less than -15 dB across the wide operation band. We observe reduced cross polarized radiation in comparison with antennas discussed in [3], [4], resulting from the simplified implementation of the feeding balun. To verify that the operating bandwidth can be specified in terms of both impedance matching as well as by radiation characteristics, antenna patterns are shown at the lower and upper edges of the operating frequency range. Radiation patterns taken at 3.5 GHz (Fig. 3) show a broad endfire pattern with 15 dB front-to-back ratio and cross polarization level measured to be less than -15 dB in both E and H planes with 4.6 dB gain. Fig. 4 depicts the measurement results of radiation patterns measured at 5 GHz, which exhibit an identical front-to-back ratio of 15 dB and cross polarization level less than -18 dB in all directions. Gain at this frequency was found to be a moderate value of 5.8 dB.

IV. Conclusion

We have presented a novel, compact, broadband printed antenna. Utilizing the truncated microstrip ground plane as a surface-wave reflector element rather than an additional metal sheet to achieve unidirectional radiation results in a significant savings in overall antenna size and weight. We believe this antenna technology is ideal for integration with WLAN modules.

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