Design Feature

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LOW-COST SUBSTRATE Supports Multiband Patch Antenna

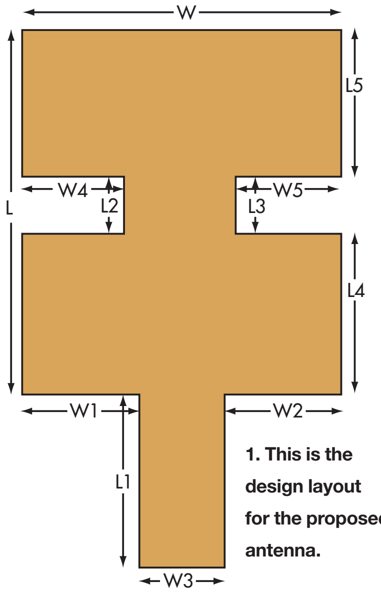
Built on reinforced fiberglass polymer resin substrate, this antenna provides the broad bandwidth and high gain required for multiband wireless applications.

Cost-effective antenna designs can be fabricated on low-cost materials, such as a durable reinforced fiberglass polymer resin material substrate. By recruiting such tools as OriginPro 8.5 software from OriginLab (www.originlab.com) and the three-dimensional (3D), electromagnetic (EM) High-Frequency Structure Simulator (HFSS) from ANSYS Corp. (www.ansys.com), a compact microstrip-line-fed, H-shaped printed-circuit-board (PCB) patch antenna was designed for multiband applications.

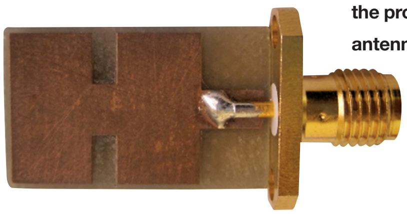
The antenna offers outstanding measured impedance bandwidth (with VSWR of less than 2.0:1) covering 3.25 GHz, from 9.75 to 13.0 GHz, with 8.5-dBi peak gain. The prototype antenna offers 0.63-dBi gain with 96% efficiency at 10.3 GHz and 6.03-dBi gain with 84.2% efficiency at 12.5 GHz. The almost steady radiation pattern makes the proposed antenna design suitable for X- through Ku-band applications.

The growing use of wireless technology is spurring the need for practical antenna designs.[1,2] The demand for low-profile compact antennas with multiband compatibility has encouraged the development of various types of patch antennas, monopole antennas, and planar inverted-F antennas (PIFAs). Planar patch antennas, for example, are desirable for their low profiles and light weight.

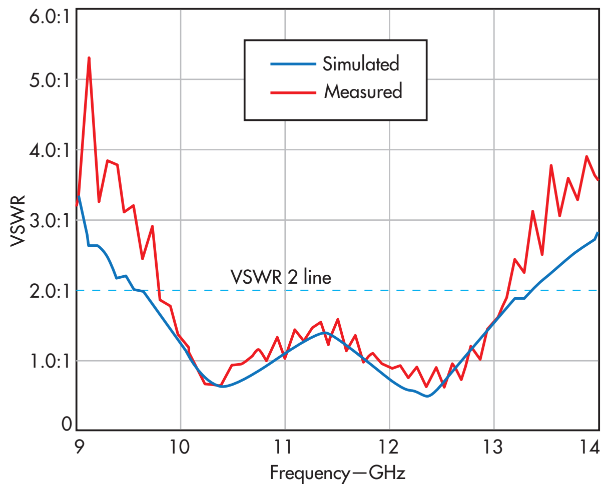
Various dual-band antennas have been developed to save space, including circle slot antennas,[3] stacked patch antennas,[4] metamaterial branch line coupled antennas,[5] dual-band dipole antennas,[6] and slotted patch antennas on ceramic substrate material.[7] Unfortunately, most of



1. This is the design layout for the proposed antenna.



2. This photograph shows the proposed multiband antenna prototype.



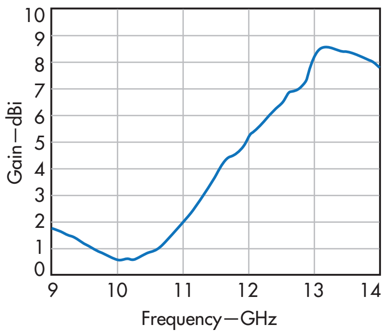
3. The plots trace the simulated and measured VSWR of the proposed antenna prototype.

these are either relatively large or lack sufficient bandwidth. Antenna researchers have explored the development of compact, low-profile multiband planar antennas to meet the ever-increasing demands of smart multiple-technology wireless equipment.[8]

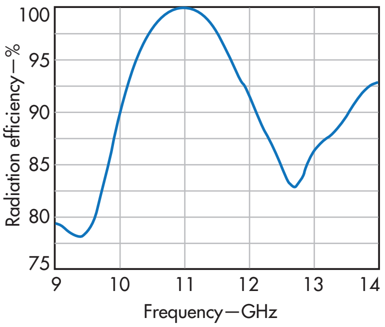
As an example, a dual-band, dual-linearly polarized proximity-coupled patch antenna was designed with dimensions of 12.45 × 16 mm^2.[9] In addition, a 10- ×-16 mm^2 dual-band-notched square monopole antenna was proposed for ultrawideband (UWB) applications[10] and a diamond dual-band antenna was designed for radio-frequency-identification (RFID) applications[11]; the RFID antenna features overall dimensions of 190 × 190 mm^2. Yet all of these antennas were relatively large in size, or else their performance levels were limited.

To provide broad bandwidth in smaller antenna size, a 5-mm-long, microstrip-line-fed, inverted-H-shape, slotted patch antenna is proposed for dual-band use. Its compact size of 12 × 15 mm^2 is significantly smaller than that of the other reported broadband antennas. Measurements of this proposed antenna design reveal an impedance bandwidth ranging from 9.75 to 13.00 GHz (3.25 GHz), with peak gain of 8.5 dBi. The gain ranges from 0.63 dBi with 96% efficiency at the lower band at 10.3 GHz to 6.03 dBi with 84.2% efficiency at the upper band at 12.5 GHz.

The antenna has been designed and analyzed with the aid of the 3D, finite-element-method (FEM) High Frequency Structure Simulator (HFSS) electromagnetic (EM) simulation software from ANSYS Corp.[12] *Figure 1* shows the



4. This is the gain of the proposed multiband antenna prototype.



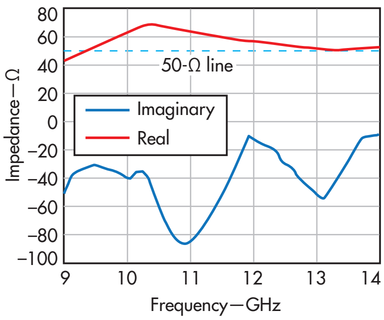
5. The traces show the radiation efficiency of the proposed antenna.

design layout for the slotted radiating patch of the proposed antenna, with the optimized parameters for the proposed antenna listed in the *table*.

The inverted-H-shaped radiating patch antenna was obtained by cutting slots from the conventional rectangular shape. The radiating patch takes a longer path around the slots for flowing current to reach the opposite edge. The desired resonant frequency and bandwidth are achieved by introducing slots on the radiating patch.

DESIGN PARAMETERS FOR THE PROPOSED PATCH ANTENNA

Parameter	Value (mm)	Parameter	Value (mm)
L	15	W	12
L1	5	W1	4.5
L2	2	W2	4.5
L3	2	W3	3
L4	6.5	W4	4
L5	6.5	W5	4

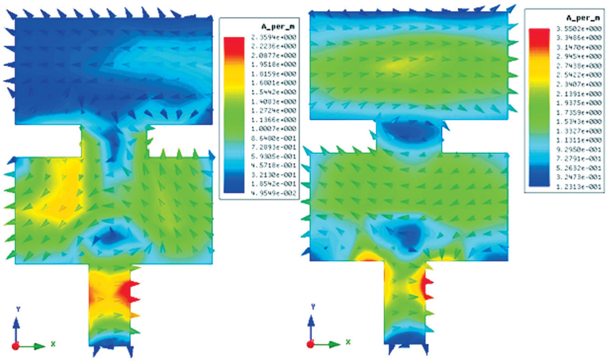


6. This is the real and imaginary input impedance of the proposed antenna.

The proposed antenna *(Fig. 2)* was fabricated on low-cost, durable, 1.6-mm-thick reinforced fiberglass polymer resin substrate material. The relative permittivity of the substrate material is 4.6 with a loss tangent of 0.023. The material consists of an epoxy matrix reinforced by woven glass. Such composites can be shaped and reshaped repeatedly without losing their material properties.[13]

The performance of the antenna was analyzed and optimized with the aid of FEM software and the HFSS EM simulator. It was plotted with the help of the OriginPro 8.5 software from OriginLab. The antenna prototype's performance was measured in a standard far-field anechoic measurement chamber.

Figure 3 shows the simulated and measured VSWR of the proposed antenna. The impedance bandwidth (for a VSWR of less than 2.0:1) is 3.25 GHz, extending from 9.75 to 13.00 GHz. This shows that the lower resonance shifted from 10.5 to 10.3 GHz and the upper resonance shifted from 12.3 to 12.5 GHz. *Figure 4* presents the gain achieved for the proposed antenna, from 0.6 to 6.03 dBi. *Figure 5* highlights its radiation efficiency.

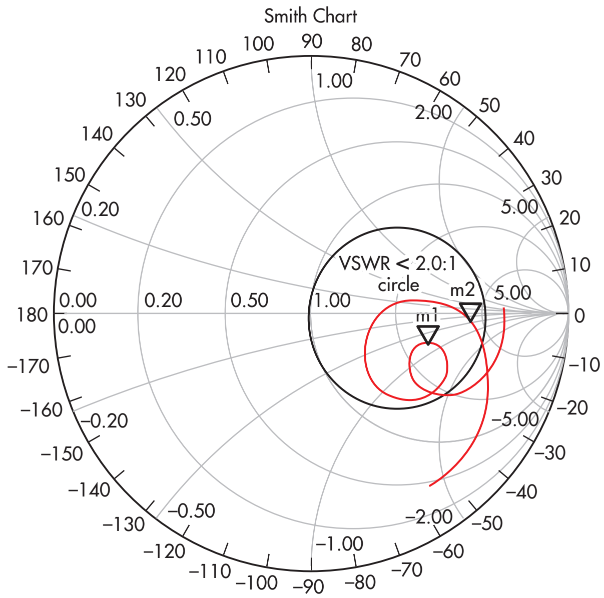


7. This is the current distribution along the radiating patch of the proposed multiband antenna.

Figure 6 provides a plot of the antenna's input impedance, with the real part of impedance optimized to be as close as possible to 50 Ω. *Figure 7* shows the current distribution along the antenna's radiating patch, revealing that the intensity of the current distribution is higher at the upper resonant frequency than at the lower resonant frequency.

Figure 8 offers a Smith chart of the proposed antenna, validating the design's input impedance and VSWR. The VSWR of the proposed antenna is within the circle. *Figure 9* offers the E- and H-plane radiation patterns for the proposed antenna, with the almost steady radiation patterns at both 10.3- and 12.3-GHz resonant frequencies marking the antenna design as suitable for X- and Ku-band satellite-communications (satcom) applications.

As the results for this low-profile antenna reveal, it is capable of a 3.25-GHz impedance bandwidth with VSWR of less than 2.0:1 from 9.75 to 13 GHz using a low-cost, durable, reinforced fiber-glass polymer resin material substrate. With peak gain of 8.5 dBi, the compact slotted patch antenna measures just 15 ×12 mm and boasts excellent performance. mw



Name	Freq.	Ang.	Mag.	Rx
m1	10.3	–12.15	0.95	1.02–0.89i
m2	12.5	–6.568	1.02	1.18–0.94i

8. The Smith chart plots the behavior of the proposed multiband antenna prototype.

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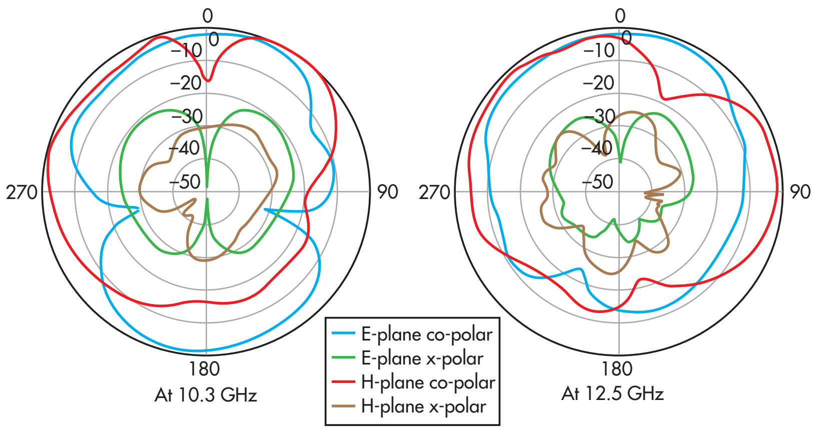

9. This is the measured radiation pattern for the multiband antenna prototype.