Received: 7 June 2018
DOI: 10.1002/mop.31593

WILEY

RESEARCH ARTICLE

Dual-port, aperture coupled and tapered fed patch antenna for full-duplex ISM applications

Ramanand S. Sangam | **Sreeni Poolakkal** | **Ramkumar Palthiya** | **Nagarjuna Nallam** | **Rakhesh S. Kshetrimayum**

Department of Electronics and Electrical Engineering, Indian Institute of Technology Guwahati, Guwahati, Assam, India

Correspondence
Rakhesh S. Kshetrimayum, Department of Electronics and Electrical Engineering, Indian Institute of Technology Guwahati, Guwahati, Assam 781039, India.
Email: krs@iitg.ac.in

Funding information
Science and Engineering Research Board, Grant/Award Number: SB/S3/EECE/0211/2015

Abstract
Dual port, aperture coupled and tapered fed patch antenna with high isolation is proposed for full-duplex 2.4 GHz ISM applications. This antenna can achieve a measured isolation of around 60 dB at 2.4 GHz and isolation band of 2.3-2.6 GHz for more than 59.5 dB. Such a high isolation surpasses the isolation performance of dual-port antennas available in the literature.

KEYWORDS
aperture coupled feed line, dual-port patch antennas, full-duplex radios, tapered feed line

1 | INTRODUCTION

Full duplex radios allow simultaneous transmission and reception of signals with a single antenna. It has numerous advantages over the traditional frequency division duplex (FDD)/time division duplex (TDD) radios like higher spectral efficiency. One of the major issues with in-band full duplex radios is the cross-talk of the transmitter and receiver ports when employing a single antenna. This can be tackled by employing dual-port antenna with high isolation between port 1 and port 2. Few such antennas have been proposed in the literature.[1–5] The reported maximum measured isolation for those antennas are 55 dB, 64 dB, 42 dB, 50 dB, and 48 dB, respectively. An ACS-fed dual-band antenna for 2.4/5.8 GHz WLAN applications have been proposed,[6] which size is very compact and has omnidirectional radiation patterns.

Diplexer with high isolation[7] is used in conjunction with a single antenna for transmission and reception of radio signals. But the transmission and reception frequency bands are different. Isolation improvements for patch antenna are reported in Refs. [8,9] But such isolation improvements are meant for reducing mutual coupling in antenna arrays. To the best of the authors' knowledge, there are no reported dual-port antennas with single patch of isolation more than 64 dB.

In this paper, we will report a dual-port antenna whose port 1 is aperture coupled fed and port 2 is microstrip tapered fed. Such a compact antenna can achieve maximum measured isolation of 67.5 dB around 2.3 GHz. It has measured isolation bandwidth of 2.3-2.5 GHz with isolation more than 59.5 dB. This antenna can be used for full duplex ISM operation. In section 2, we will present the antenna geometry, we will provide the antenna simulation and experimental results in section 3 and conclusion is drawn in section 4.

2 | ANTENNA GEOMETRY

The geometry of the proposed antenna is shown in Figure 1A,B. From Figure 1A, we can see that the port 1 is aperture coupled fed, which gives better isolation and port 2 is microstrip tapered fed for better impedance matching. Note that we have not used inset fed microstrip antenna since the cross-polar components will be higher for such feed lines. For edge fed antenna, the antenna impedance at the edge is much higher than 50 Ω, hence the width of the rectangular microstrip feed line is so thin, thereby, it was not possible to connect and match the impedance to the SMA connector properly. Hence, a tapered feed line[10,11] has been used for matching such high impedance at the edge to 50 Ω

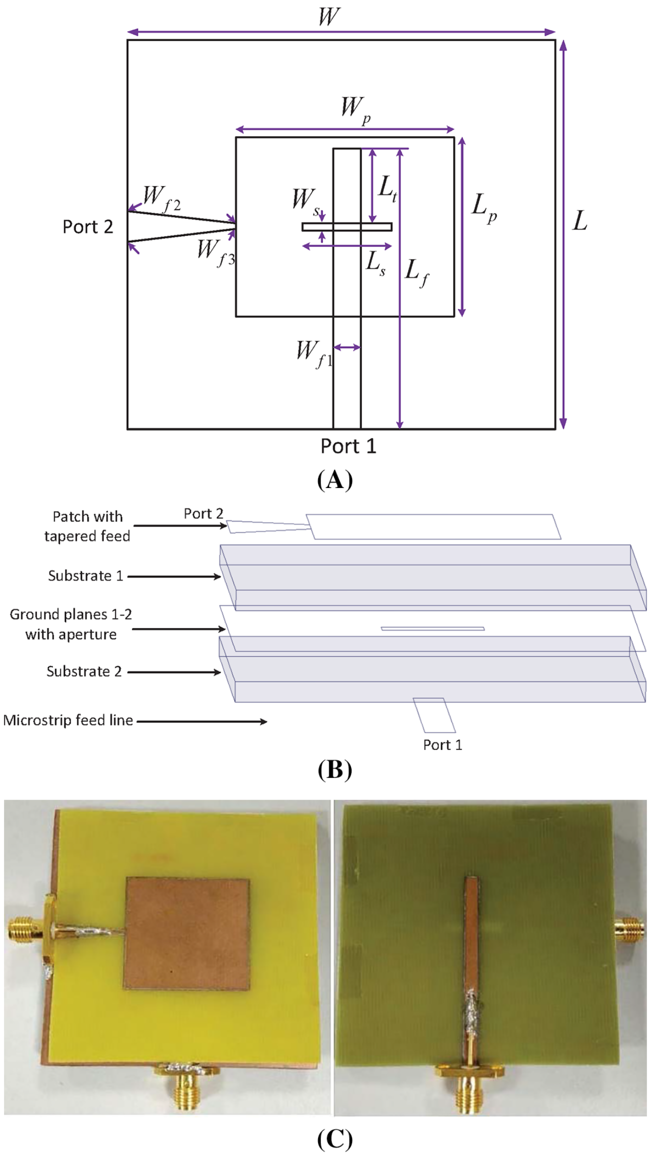

FIGURE 1 Geometry of the proposed antenna: (A) top view, (B) side view (layer wise for easier illustration), and (C) fabricated prototype [Color figure can be viewed at wileyonlinelibrary.com]

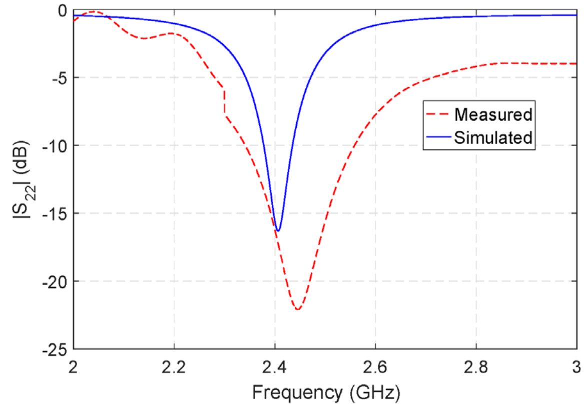

FIGURE 3 $|S_{22}|$ versus frequency of dual-port patch antenna [Color figure can be viewed at wileyonlinelibrary.com]

line as shown in Figure 1. Basically, two orthogonal polarizations are excited viz. horizontal and vertical polarizations for better isolation. Besides, the two feed lines are separated by two ground planes of the two FR4 boards. As usual, ground plane reflects the wave incident on it. Double ground planes of two FR4 boards will reflect even better than a single ground plane. Hence a very high isolation can be achieved.

The dimensions of the antenna are $L = 60$ mm, $W = 62$ mm, $L_p = 26.5$ mm, $W_p = 29$ mm, $L_f = 42.75$ mm, $L_t = 12$ mm, $W_{f1} = 3$ mm, $W_{f2} = 3$ mm, and $W_{f3} = 0.2$ mm. The slot length and width are chosen as $L_s = 13$ mm and $W_s = 0.9$ mm, respectively. Layer by layer illustration of the proposed antenna is shown in Figure 1B. From bottom to top, the layers are: microstrip feed line (1st layer), FR4 substrate (2nd layer), ground planes 1-2 with slot (3rd layer), FR4 substrate (4th layer) and radiating patch with microstrip feed line (5th layer). The fabricated antenna on FR4 substrate of $\epsilon_r = 4.4$, loss tangent = 0.02, and thickness h = 1.6 mm is shown in Figure 1C. Since there are two FR4 layers, the total thickness of the proposed antenna is 3.2 mm. This antenna is very compact and its overall size is $60 \times 62 \times 3.2$ mm^3.

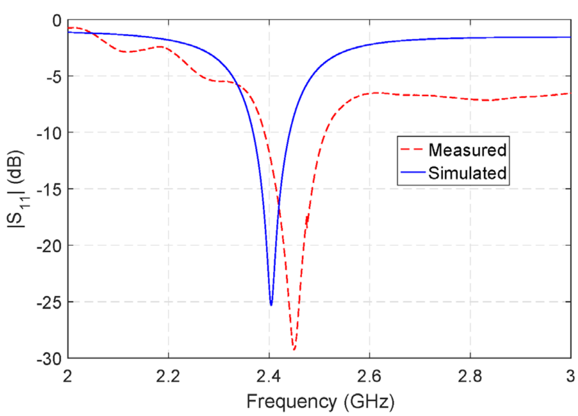

FIGURE 2 $|S_{11}|$ versus frequency of dual-port patch antenna [Color figure can be viewed at wileyonlinelibrary.com]

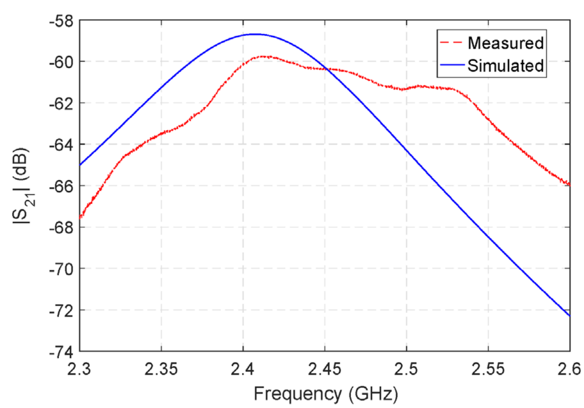

FIGURE 4 $|S_{21}|$ versus frequency of dual-port patch antenna [Color figure can be viewed at wileyonlinelibrary.com]

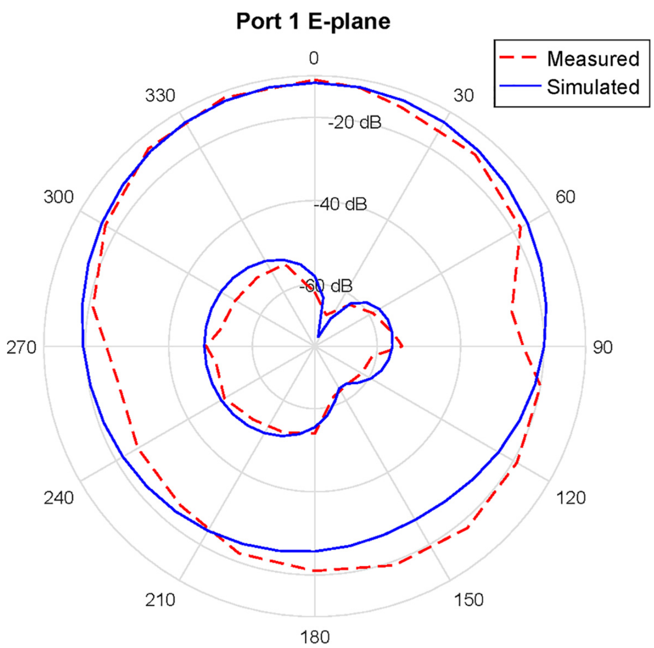

FIGURE 5 E-plane radiation pattern (port 1) of the dual-port patch antenna at 2.4 GHz [Color figure can be viewed at wileyonlinelibrary.com]

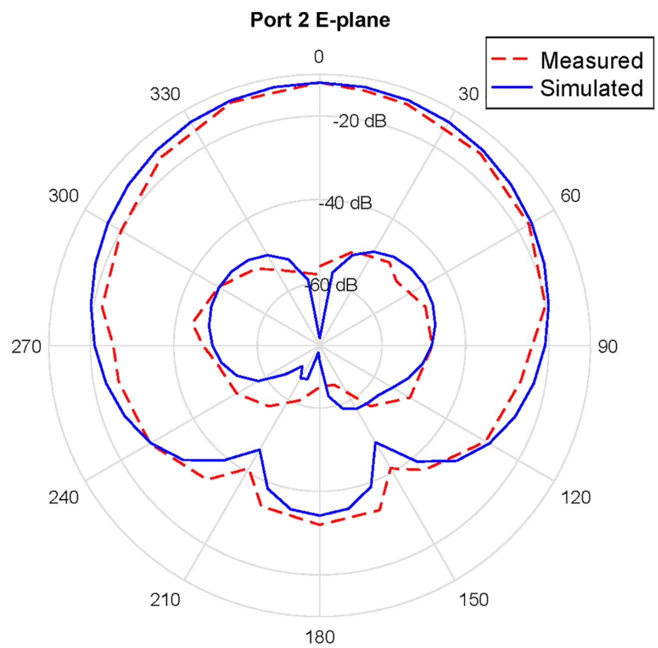

FIGURE 7 E-plane radiation pattern (port 2) of the dual-port patch antenna at 2.4 GHz [Color figure can be viewed at wileyonlinelibrary.com]

3 | RESULTS AND DISCUSSION

The HFSS simulated and measured results of $|S_{11}|$ versus frequency and $|S_{22}|$ versus frequency are depicted in Figures 2 and 3, respectively. The measured 10 dB bandwidth for $|S_{11}|$ and $|S_{22}|$ are approximately 2.4-2.5 GHz and 2.33-2.55 GHz, respectively. There is a minor frequency shift between the HFSS simulated and measured results. This is mainly due to imprecise calibration set-up for measurement, connector losses and fabrication tolerances which were not included in the HFSS simulation. Besides, the ground plane size has been slightly increased in order to connect the SMA connectors to the two ports (see Figure 1C).

The measured and HFSS simulated results of $|S_{21}|$ versus frequency are shown in Figure 4. There are some differences

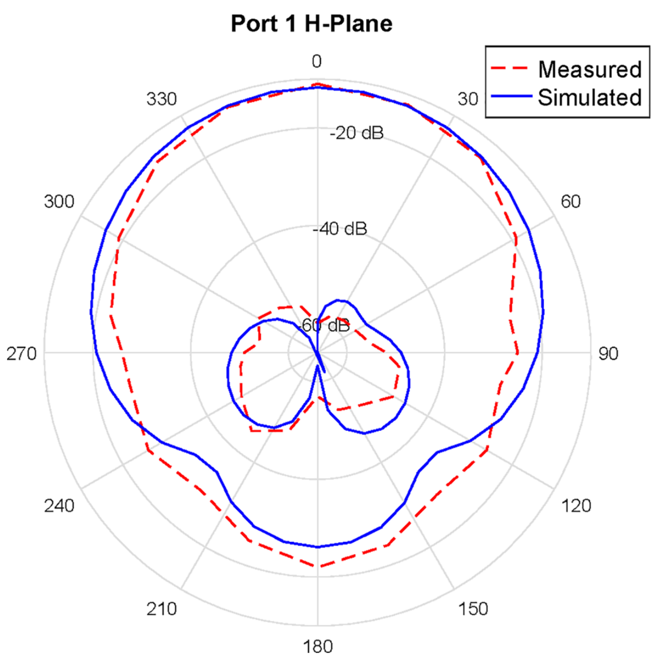

FIGURE 6 H-plane radiation pattern (port 1) of the dual-port patch antenna at 2.4 GHz [Color figure can be viewed at wileyonlinelibrary.com]

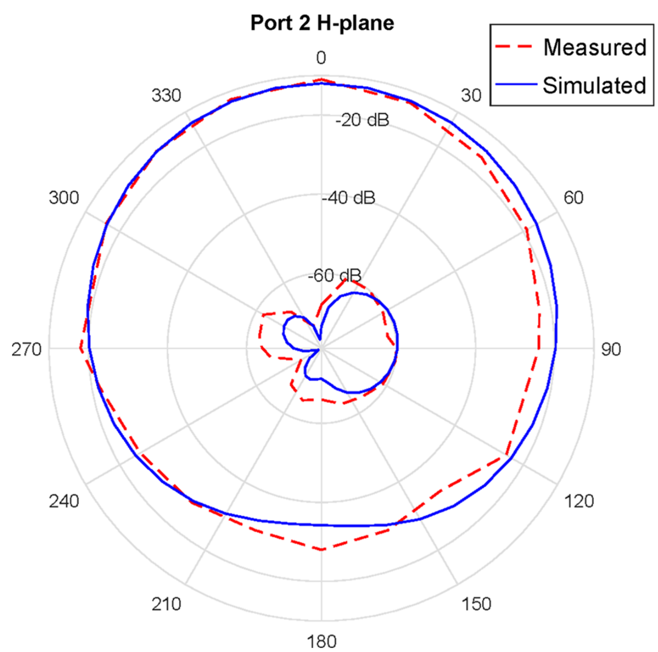

FIGURE 8 H-plane radiation pattern (port 2) of the dual-port patch antenna at 2.4 GHz [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Performance comparison (experimental) of the proposed antenna with the antennas available in the literature

Reference	Matching band (RL > 10 dB)	Isolation band	Maximum isolation	Size
[3]	2.33-2.52 GHz	2.34-2.5 GHz (isolation >28 dB)	42 dB at 2.4 GHz	$80 \times 80 \times 5.1$ mm^3 =32 640 mm^3
[4]	2.15-2.72 GHz	2.15-2.72 GHz (isolation >40 dB)	50 dB at 2.4 GHz	$120 \times 120 \times 25$ mm^3 =3,60 000 mm^3
Proposed antenna	2.4-2.5 GHz	2.3-2.6 GHz (isolation >59.5 dB)	67.5 dB at 2.3 GHz	$60 \times 62 \times 3.2$ mm^3 =11 904 mm^3

between the simulation and experimental results. Such differences are due to measurement performed in a real laboratory environment, where interference from nearby signals, reflections and scattering from surroundings and addition of ambient noises is more pronounced at such low values of $|S_{21}|$ as also reported in Ref. [1] The isolation ($|S_{21}|$) is greater than 59.5 dB from 2.3 to 2.6 GHz in experimental results which is suitable for ISM band antennas for full duplex operations. The maximum measured isolation ($|S_{21}|$) is 67.5 dB at 2.3 GHz. $|S_{12}|$ versus frequency has very similar performance. The E-plane (port 1), H-plane (port 1), E-plane (port 2), and H-plane (port 2) radiation patterns (both simulation and experimental) of the dual-port antenna at 2.4 GHz are shown in Figures 5–8, respectively. It can be seen that co-polar radiation patterns are mostly oval in shape and the cross-polar components are well below −40 dB for all of the above cases. Hence, the cross-polarization components are sufficiently low. The radiation patterns are plotted for given input power of 1 mW. The experimental and simulation results are approximately matching.

Table 1 compares the performance of the proposed dual-port antenna with antennas available in the literature in terms of matching band ($|S_{11}| < -10$ dB), isolation band, maximum isolation, and size. It can be seen that the proposed antenna can achieve the best isolation in terms of maximum isolation and isolation band. Besides, the size of the proposed antenna is much smaller than the other reported antennas. It may be noted all the antennas compared in Table 1 are fabricated on FR4 substrate. Hence the size comparison is a fair comparison.

4 | CONCLUSION

A dual-port, compact patch antenna with high isolation has been designed, fabricated and tested. This antenna can achieve a maximum isolation of 67.5 dB at 2.3 GHz and over 59.5 dB isolation from 2.3 to 2.6 GHz. Such antenna can be used for in-band full-duplex ISM operation. The same antenna geometry with the two feed lines (tapered feed and aperture coupled feed) can be tuned and used for designing antennas for in-band full-duplex radios such as for WiMAX applications.

ORCID

Rakhesh S. Kshetrimayum https://orcid.org/0000-0002-3383-2028

REFERENCES

[1] Sim CYD, Chang CC, Row JS. Dual-feed dual-polarized patch antenna with low cross polarization and high isolation. *IEEE Trans Antennas Propag*. 2009;57:3321-3324.

[2] Chung Y, Jeon S-S, Ahn D, Choi J-I, Itoh T. High isolation dual-polarized patch antenna using integrated defected ground structure. *IEEE Microw Wireless Compon Lett*. 2004;14:4-6.

[3] Wang B, Zhuang Y, Li X. Compact dual ports handheld RFID reader antenna with high isolation. *Int J RF Microw Comput Aided Eng*. 2015;25:548-555.

[4] Li B, Yin YZ, Zhao Y, Ding Y, Zou R. Dual polarised patch antenna with low cross-polarisation and high isolation for WIMAX applications. *Electron Lett*. 2011;47:952-953.

[5] Acimovic I, McNamara DA, Petosa A. Dual-polarized microstrip patch planar array antennas with improved port-to-port isolation. *IEEE Trans Antennas Propag*. 2008;56:3433-3439.

[6] Li Y, Li W, Ye Q. A compact asymmetric coplanar strip-fed dual-band antenna for 2.4/5.8 GHz WLAN applications. *Microw Opt Technol Lett*. 2013;55:2066-2070.

[7] Heshmati H, Roshani S. A miniaturized lowpass bandpass diplexer with high isolation. *AEU-Int J Electron C*. 2018;87:87-94.

[8] Emadeddin A, Shad S, Rahimian Z, Hassani HR. High mutual coupling reduction between microstrip patch antennas using novel structure. *AEU-Int J Electron C*. 2017;71:152-156.

[9] Panda PK, Ghosh D. Isolation and gain enhancement of patch antennas using EMNZ superstrate. *AEU-Int J Electron C*. 2018;86:164-170.

[10] Pozar DM. *Microwave Engineering*. John Wiley & Sons (Asia) Pvt. Ltd., Singapore. 2005.

[11] Manohar M, Kshetrimayum RS, Gogoi AK. Printed monopole antenna with tapered feed line, feed region and patch for super wideband applications. *IET Microw Antennas Propag*. 2014;8:39-45.

How to cite this article: Sangam RS, Poolakkal S, Palthiya R, Nallam N, Kshetrimayum RS. Dual-port, aperture coupled and tapered fed patch antenna for full-duplex ISM applications. *Microw Opt Technol Lett*. 2019;61:542–545. https://doi.org/10.1002/mop.31593