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A DUAL-PORT ANTENNA FOR WIDE AND NARROWBAND APPLICATIONS

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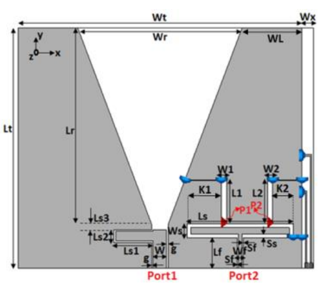
Graphical abstract



Abstract

This paper presents a study on a dual port antenna with wide and narrowband functionality. The proposed structure incorporates two antennas into a single substrate by sharing same ground plane. In this structure, two ports are used. One port is used for wideband function that works from 1 to 3.7 GHz. The other one is used for reconfigurable narrowband operation, which supports single, dual and triple-band modes. Reconfiguration of the narrowband antenna is achieved by means of PIN diode switches. The single-band operates at 2 GHz. The dual-band provides two center frequencies at 1.8 GHz and 2.4 GHz, while the triple-band operates at 1.4, 1.8, and 2.6 GHz. The coupling between the two ports is signified by the S12 and S21 parameters. The coupling is below -10dB across the full operating range of the antenna measured in S12 and S21 parameter. These features are potentially useful for Cognitive Radio systems.

Keywords: Dual port, slot antenna, reconfigurable, PIN diode switches

Abstrak

Kertaskerja ini membentangkan rekaan antena tatasusunan alur mampu kendali berasaskan pengganding talian cabang yang beroperasi pada jalur frekuensi 28GHz bagi pengunaan wayarles generasi kelima (5G). Tatasusunan ini direkabentuk menggunakan substrat Rogers RT/duroid 5880 yang ketebalan 0,254 mm dan pemalar dielektrik 2.2. Rekabentuk Antena ini mempunyai enam elemen tatasunan dan disuapkan oleh pengganding talian cabang yang berfungsi sebagai pengimbas alur bagi mendapatkan julat imbasan antara -16 hingga 16 darjah. Gandaan maksimum 14.4dBi dan jalurlebar yang meliputi 25.2 GHz hingga 32 GHz dicapai melalui pengukuran. Antena yang direkabentuk dapat diaplikasikan pada jalur frekuensi 28 GHz yang dicadangkan untuk komunikasi wayarles 5G. Semua keputusan simulasi dan pengukuran dibentangkan dengan jelas.

Kata kunci: Antena tatasusunan, pengganding talian cabang , gelombang milimeter , antena mampu kendali

1.0 INTRODUCTION

A cognitive radio (CR) system functions to sense spectrum and dynamically changes its operation based on any changes in the communication channel. In general, the CR systems use reconfigurable antennas which can be tuned based on any changes in the environment with a fast response time. With regard to this, antenna designers have adopted various techniques for antenna reconfiguration. According to [1], the antenna for the CR system must have combined wideband and narrowband characteristics. In CR systems, the necessity is to sense the spectrum environment within a wideband and at the same time maintain communication with a relatively narrow bandwidth. In general, the directional wideband element is used for sensing the dynamic spectrum, while for communication purpose; bi-directional narrowband element is used. In [2, 3], the original concept of combined narrowband and wideband is presented and in [4-7], both the narrowband and wideband antennas are combined in the same volume.

A single pair of ring slot resonators is incorporated to obtain a reconfigurable wideband to narrowband Vivaldi antenna in [2]. In [3], a notch band at a specific frequency and variation in the input matching of the antenna are obtained in a reconfigurable tapered slot antenna using the following two ways. Firstly, incorporating a resonator parasitic structure, which is electrically coupled to the antenna secondly, altering the length of a stub line extended from a small additional part of the ground, on the back side of the antenna. A frequency reconfigurable antenna in [4] is combined of a disc monopole with dual port which is excited at the opposite edges. Wideband with CPW feed is from first port and tunable narrowband with microstrip feed line consisting defected slots in its ground plane relates to the other port. In [5] and [6], wideband and narrowband operations were obtained simultaneously from two antennas on the same structure using dual ports.

Due to lack of particular agreed scheme for various operations and spectrum sensing techniques in cognitive radio, a possible solution is to use two antennas, one with its front-end used for continuous sensing and the other one for the operation [7]. It is therefore necessary to combine both antennas in the same structure to save some space. In a dual-port antenna system, both the ports need to be isolated by having a very low mutual coupling between them.

In this paper, a dual-port wide and narrowband slot antenna is presented. It consists of two different antennas and both are CPW feed. The narrowband antenna is integrated within the ground plane of the wideband antenna. The advantage of the proposed antenna is that, wideband operation along with multi-band modes is achieved contrary to the wideband and single narrowband modes as presented in [4-7].

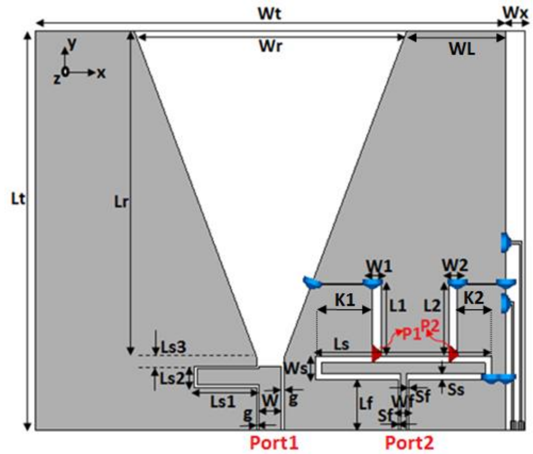


Figure 1 Configuration of the proposed antenna

2.0 ANTENNA CONFIGURATION

Fig. 1 shows the configuration of the proposed antenna, including the switch biasing circuit. It consists of a wideband tapered slot antenna and narrowband slot antenna. The combined antenna is fabricated on an FR4 substrate with a thickness of 0.8 mm, permittivity of 4.3 and loss tangent of 0.0019. The size of the substrate is 168.6 ×141mm^2. The antenna dimensions are illustrated in Table 1. The tapered slot antenna in port1 was based on [8], and has been scaled to operate at a wideband from 1 to 3.7 GHz. The antenna is fed with a CPW line with an offset length. This offset length is used as a delay line to obtain wideband matching. The narrower end part function determines the high frequency range, while the wider end part determines the low frequency range.

To improve low band matching, the ground plane is extended W_L= 35 mm horizontally at the wider end part. The principal design of the slot antenna in port 2 is based on [9] and used to operate in several narrowband modes between the wideband frequency ranges. Two identical vertical slots with size denoted as $L_1 \times W_1$ and $L_2 \times W_2$ are placed in specific positions to obtain dual and triple-band operation. By changing the position of vertical slot, different input impedance and, wavelength steer multi frequency mode to be operated. The $L_1 \times W_1$ slot is positioned nearly at the center to achieve dual band operation. The $L_2 \times W_2$ slot is positioned nearly at the end of the horizontal slot to achieve triple-band operation. In order to achieve frequency reconfiguration, the vertical slot is coupled and also decoupled from the horizontal slot by means of PIN diode switches, model BAR 50-02V. The narrowband antenna is integrated within the ground plane of the wideband antenna. Radiation characteristics, i.e co- and cross-polar, and coupling factor of the antennas has been taken into account in choosing the best position within the limited space available.

In order to separate the ground plane, small slits with a width of 0.3 mm have been introduced. The RF PIN diode is biased with the help of the slits. RF wave connection through the ground plane is achieved by surface mounted RF capacitances of 100 pF value. Two inductors and six capacitors have been used in this design. Fig. 2 shows the prototype of the proposed antenna. At the right side of the prototype, biasing lines have been placed. To simulate the designed antenna, Computer Simulation Technology (CST) software is used [10].

Table 1 Antenna dimensions

Parameters	Dimensions (mm)	Parameters	Dimensions (mm)
Wt	166.2	g	0.9
Wr	103.14	Wf	1.97
Wx	6.9	W1=W2	3
Lt	141	Ws	8
Lr	115.5	Lf	17.9
W	7.8	Ls	62
Ls1	22.5	L1=L2	25.84
Ls2	5.7	Sf	0.7
Ls3	3	Ss	2
WL	35	K1	20.015
K2	11.985		

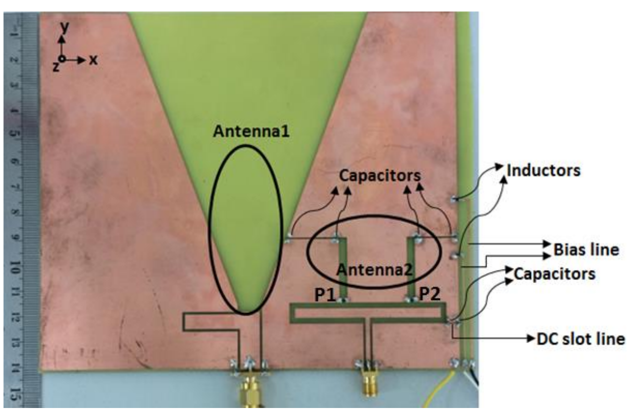


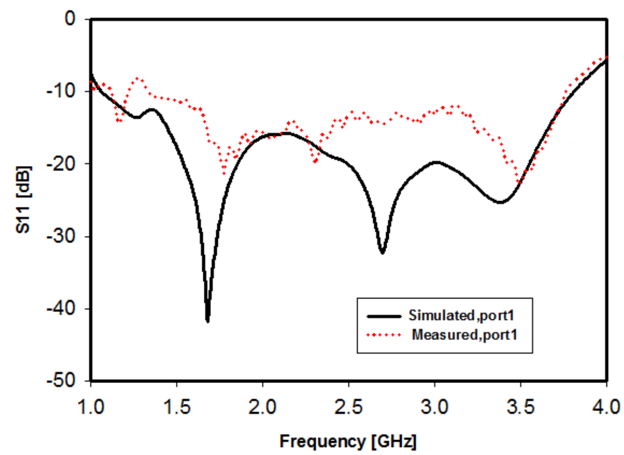
Figure 2 Prototype of the proposed antenna

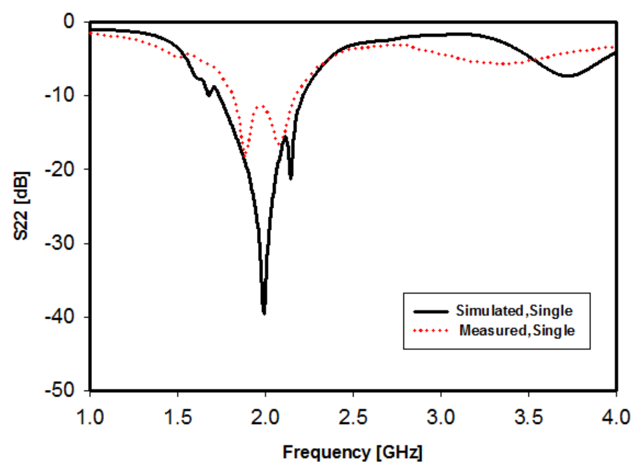
3.0 RESULTS AND DISCUSSION

Fig. 3 and Fig. 4 show the simulated and measured return losses of the designed antenna. The wide bandwidth is obtained when port 1 is used. By this, good agreement between measured and simulated is achieved, as shown in Fig 3 and 4. Meanwhile, single, dual and triple-band is achieved through port 2. Overall, the agreement between measured and simulated results is good. The switching states to create single, dual and triple-band mode are shown in Table 2. Single-band mode is operated at 2 GHz. The dual-band provides two center frequencies at 1.8 GHz and 2.4 GHz, while the triple-band operates at 1.4, 1.8, and 2.6 GHz.

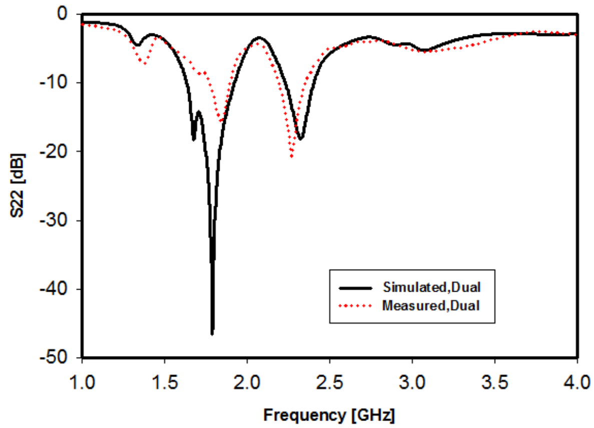
Table 2 Different states of the PIN diodes and corresponding bands.

Bands / Switches	Single	Dual	Triple
P1	ON	OFF	OFF
P2	ON	ON	ON





(a)



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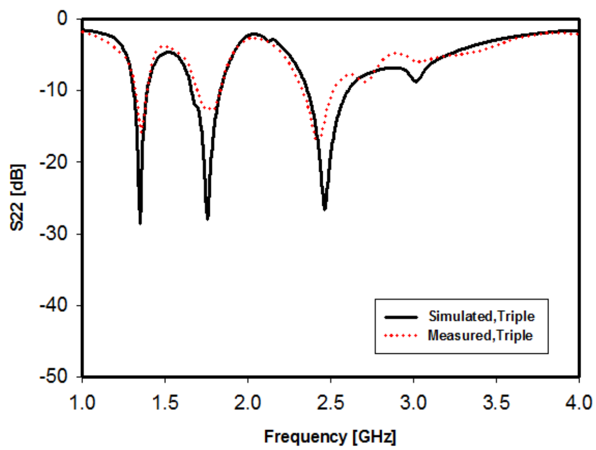


(c)

Figure 4 Simulated and Measured S22 of Port 2: (a) Single (b) Dual (c) Triple-band.

Fig. 5 shows the isolation between port1 and port 2 when port 2 runs the triple-band operation. At these operating frequencies, isolation, small than -10 dB are obtained.

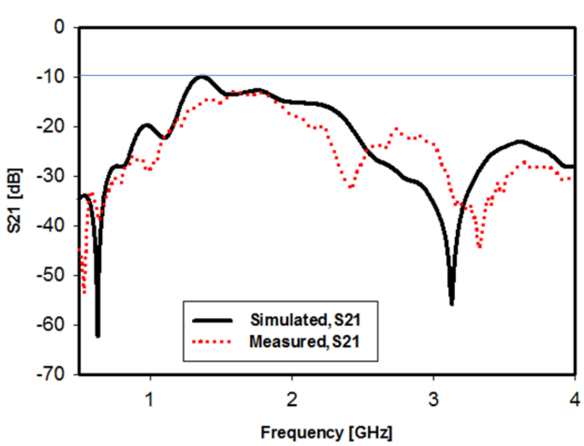
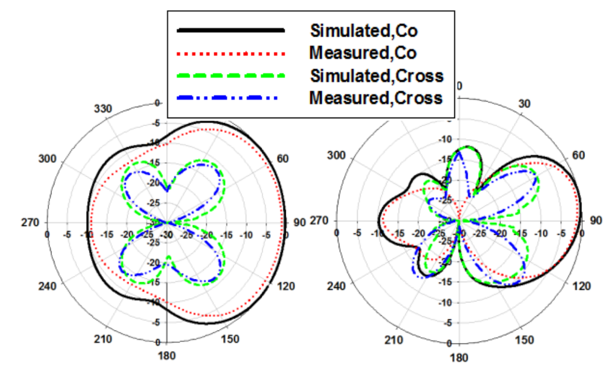


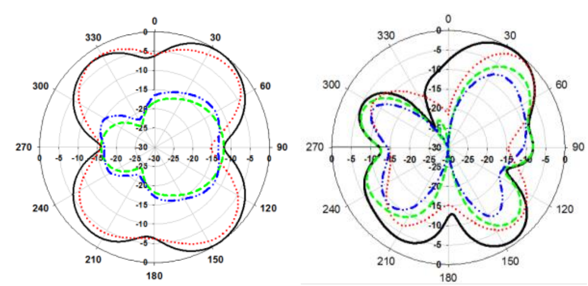
Figure 5 Simulated and measured S21

The simulated and measured radiation patterns in the E plane (x-y plane) and H plane (y-z plane) are shown in Fig 6 and 7, which are measured in an Anechoic Chamber. All radiation patterns for port1 at 1.8 GHz, port 2 for dual and triple-band at 1.8 GHz and for single-band at 2 GHz are simulated and measured. Only one port is connected to the Vector Network Analyzer during each measurement, while the other port is terminated by 50 Ω. The pattern of wideband operation is found to be uni-directional, while the pattern of narrow bands operation is observed to be multi-directional. This pattern is useful for communication purposes. The cross-polar of wideband operation is radiated low compared with co-polar on desired direction. Due to the asymmetrical structure of the antenna, the cross-polar of narrowband operations is high.

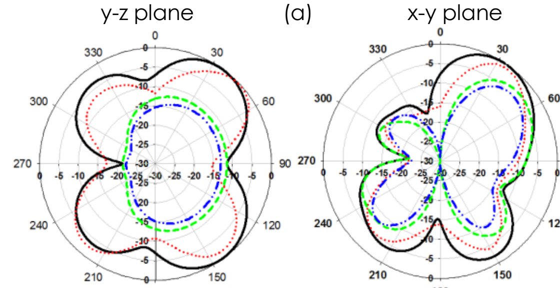


y-z plane x-y plane

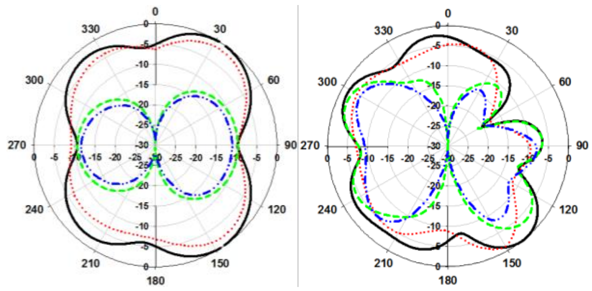
Figure 6 Simulated and measured radiation patterns of port 1



y-z plane (a) x-y plane



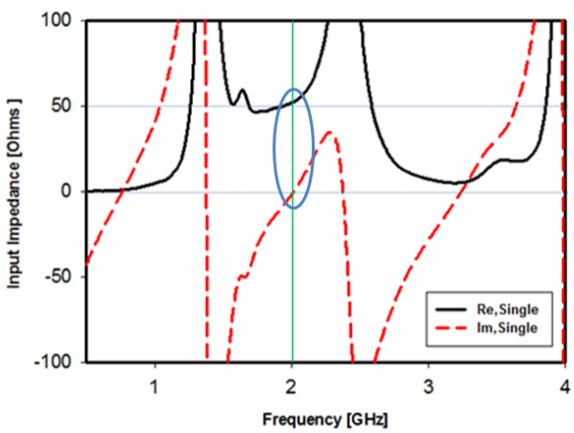
y-z plane (b) x-y plane



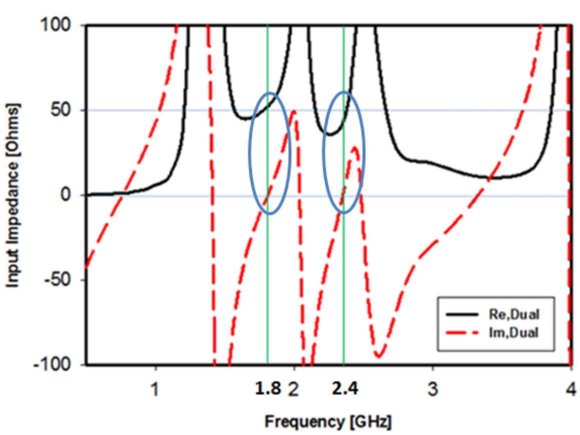
y-z plane (c) x-y plane

Figure 7 Simulated and measured radiation patterns of port 2 (a) ON-ON (b) OFF-ON (c) ON-OFF states.

For more clarification of slot antenna behavior in antenna 2, the input impedances of port 2 are shown in Fig. 8. The input impedance includes real and imaginary impedances. Resonance frequency is created when the imaginary impedance is zero and real impedance is 50 Ω. As shown in Fig. 8, each circle shows one frequency band. The simulated gains at 2 GHz of port1 and at 2 GHz of port 2 for single-band are 7.11 dBi and 4.89 dBi, respectively. The measured gains at 2 GHz of port1 and at the same resonance frequency for single-band of port 2 are 6.92 dBi and 4.56 dBi, respectively. Gain has been dropped at narrowband operations might be due to the diffraction from limited ground plane.



(a)



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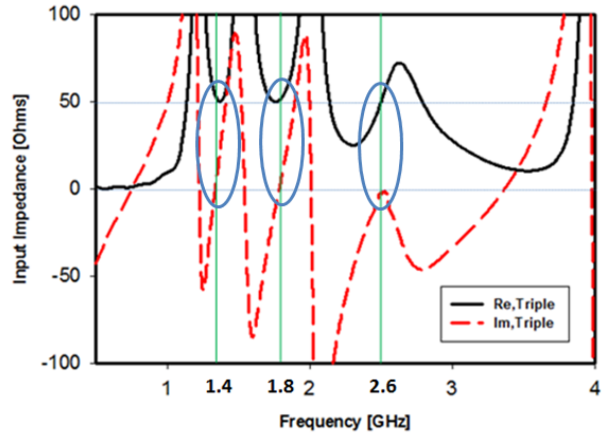

(c)

Figure 8 The input impedances: (a) Single-band (b) Dual-band (c) Triple-band.

4.0 CONCLUSION

A dual port wide and narrowband slot antenna was presented and investigated. By using two PIN diode switches, the reconfigurable narrowband slot antenna offered the single-band, dual-band and triple-band operations. Port1 was used to achieve wideband impedance bandwidth from 1 to 3.7 GHz, while port 2 gave reconfigurable narrowband functionality. The mutual coupling was low and the ports were decoupled less than 10 dB in the whole of the frequency range. Overall, the proposed combined antenna design is potential to benefit the CR systems.

Acknowledgement

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