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Focus and Scope

International Journal of Electrical and Computer Engineering (IJECE), ISSN 2088-8708, e-ISSN 2722-2578 is the official publication of the Institute of Advanced Engineering and Science (IAES). The IJECE is open to submission from scholars and experts in the wide areas of electrical, electronics, instrumentation, control, telecommunication, and computer engineering from the global world. The journal publishes original research papers, review papers, and short communications in the field of electrical & power engineering, circuits & electronics, power electronics & drives, automation, instrumentation & control engineering, digital signal, image & video processing, telecommunication system & technology, computer science & information technology, internet of things, big data & cloud computing, and artificial intelligence & soft computing which covers, but not limited to, the following scope:

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Electric power generation sources; Electric traction; Electric usage; Electrical and automation; Electrical apparatus connected to such systems; Electrical engineering materials; Electrical equipment, electrical capacitors, wires and cables; Electrical insulators; Electrical machinery; Electrical measurements; Electricity and electricity energy; Electrification and automation of agriculture; Electromagnetic compatibility; Electro-magnetic transients (EMT); Electro-mechanical transients; Electro-mechanics and electric transportation; Electrotechnology; Energy conversion and electric machines; Energy efficiency methods; Energy management; Energy storage technologies and system operation and planning; Environmental protection; Establishment of open market environment, risk management and electrical energy trading; Flexible alternating current transmission system (FACTS); Future power distributions systems in ships and aircrafts; Generation planning and control; Green facilities and industries; Harmonics and power quality; High voltage apparatuses; High voltage DC transmission and low voltage DC distribution networks; High voltage engineering; High voltage insulation technologies; Household electrification; Industrial electric power distribution and utilization systems; Industrial power systems; Information and communication infrastructure for future power systems; Instrumentation and novel sensor technology for advanced monitoring of power systems; Integration of consumer-side resource systems; Integration of unconventional sources into existing power systems; Interaction and integration of electricity with other energy vectors and sectors (heat, cooling, gas, hydrogen, or transport); Lighting and electroradiative technique; Lightning detection and protection; Mathematical modelling of power plants components and subsystems; Metering technologies; Methodologies and technologies for testing power system components, as well as complex protection and control schemes; Mixed AC-DC transmission networks, their interaction and technologies for their optimal operation; Nanogrids, microgrids, DC microgrids, autonomous, islanded and remote networks; New concepts of robust, secure, reliable, self-healing and resilient power systems; New power system technologies; New technologies and techniques for power transmission, distribution, protection, control and measurement; Off-line and real-time simulators, hybrid simulation (stability and EMT) of large-scale systems; Optimization methods applied to power systems; Power conversion equipment; Power economic; Power generation; Power industry; Power plants automation and control; Power quality; Power system analysis, economics, operation, planning, metering, control, protection and stability; Power system dynamic performance (system stability analysis and controls); Power transmission and distribution; Primary and secondary plant in modern EHV/HV/MV/LV substations; Prosumer resource systems; Protection of electrical devices and systems; Reactive power control; Reliability theory; Renewable energy technologies (wind, solar/photovoltaic, hydro, tidal, geothermal, biomass), clean fossil fuel technologies (e.g., carbon capture) and their integration in modern power systems; Semiconducting, superconducting, conductor, dielectric, insulating materials; Simulation of power systems transients and power electronics; Smart buildings, district and cities; Smart distribution networks; Standardisation and new energy policies in using novel technologies for future power systems; Substation automation and control; Supervisory control and data acquisition (SCADA); System integrity protection schemes (SIPS); Technologies and new solutions for ancillary services support in power systems; Technologies for real-time dynamic security assessment, situational awareness, prevention of power system blackouts and approaches for power system restoration; Technologies to enhance flexibility in future energy systems; Theoretical electrical engineering (physical basis of electrical engineering, electromagnetic field theory, the theory of electric and magnetic circuits); Theory of power systems control; Transformers and power reactors; Transient processes in power systems (slow, fast and very fast transients); Transmission and distribution; Utilization of electric power; Wide area monitoring, protection and control (WAMPAC) in power system; etc.

Circuits and Electronics: Amplifiers; Amplifying electronic signals; Analog, digital and mixed-mode circuits; Application-specific polymer optical fibres and devices; Application-specific silica optical fibres and devices; Bioelectronics; Biomechanics and rehabilitation engineering; Biomedical circuits, transducers and instrumentation; Building blocks and systems; Circuit models; Circuit theory and applications; Circuit theory and modelling; Circuits and electronics for data conversion and modulation; Circuits and systems; Circuits; Complementary metal-oxide-semiconductor (CMOS); Computer-Aided Design (CAD); Consumer electronics; Cryptographic circuits; Design and implementation of application specific integrated circuits (ASIC); Digital electronics; Digital filters; Electromagnetic theory; Electronic components, devices, and systems; Electronic instrumentation; Electronic materials; Electronic sensors; Electronic systems; Electronics for space exploration; Embedded and CMOS integrated circuit systems; Filters; Hardware/software codesign; High level synthesis; High levels design languages; Integrated circuits; Interface circuits; Laser and optical systems; Materials for state-of-the-art transistors, nanotechnology, electronic packaging, detectors, emitters, metallization, and superconductivity; Measurement and acquisition of physical quantities; Medical electronics; Memristors and Memristive circuits; Microcircuits; Microcontrollers; Microelectronic system; Microelectronics; Microprocessor; Mixed signal circuits; Molecular electronics; MOSFET; Nanostructures and nanotechnologies; Network analysis and synthesis; Neuromorphic circuits; Nonlinear circuits; Non-linear circuits; Optoelectronic devices; Organic and inorganic circuits and devices; Organic field-effect transistor; Oscillators; Phase-locked loop (PLL); Printed electronics; Programmable logic chips; Programmable logic devices; Prototype devices and measurement; RF circuits; Science and technology of electronic materials; Semiconductor devices, magnetic alloys, insulators, and optical and display materials; Silicon devices; Silicon thin-film cell; Solid state electronics; Superconductivity circuits; System-on-a-chip (SoC); Thin film electronics; Thin film technologies; Thin-film diode; Thin-film memory; Thin-film solar cell; Thin-film transistor; Transform to electrical signals; Transistor; Very large scale integration systems (VLSI); VLSI Design; Voltage-controlled oscillator (VCO); etc.

Power Electronics and Drives: Adjustable speed drives; Advanced power converter topologies; All types of converters, inverters, active filters, switched mode power and uninterruptible power supplies; Application of control methods to electrical systems; Applications of power semiconductor technology; Batteries and Fuses; Batteries and management systems (BMS); Contactless power supply; Control and conversion of electric power in electric machine drives; Current control for shunt active power filters using predictive control; Current control of AC/DC or AC/DC/AC converters using predictive control; Current control of three-phase inverters using predictive control; Current control of three-phase source rectifiers using predictive control; Current control; Distributed power supplies; Efficient predictive control strategies; Electric propulsion system; Electrical machines; Electro-mobility (E-mobility); Electronic ballasts and solid-state lighting; EMC and noise mitigation; Energy conversion and conditioning technologies in physics research and related applications; Energy conversion and conditioning technologies in the industry; Estimation and identification methods for power converters; EV's battery chargers: contact and contact-less, standards and regulations; Fault coordination and protection of DC grids; Hard and soft switching techniques; High performance drives; High-voltage direct current (HVDC); Industrial scale power conditioning; Measurements techniques, sensors, standard and advanced

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Bandwidth enhancement and miniaturization of circular-shaped microstrip antenna based on beveled half-cut structure for MIMO 2×2 application

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MIMO

ABSTRACT

In this paper, circular-shaped microstrip antenna was simulated, fabricated, and measured accordingly. As the novelty, to enhance bandwidth and reduce antenna size, beveled half-cut microstrip structure is proposed. Further, this proposed antenna structure will be applied to multiple input multiple output (MIMO) antenna 2×2. Therefore, this research was investigated conventional circular shape antenna (CCSA), circular shaped beveled antenna (CSBA), and MIMO circular shaped beveled antenna (MIMO-CBSA) as Model 1, Model 2, and Model 3, respectively. An FR4 substrate with $\epsilon_r=4.4$, thickness $h=1.6$ mm, and $\tan \delta=0.0265$ was used. The simulation has been conducted using Advanced Design System (ADS). The antenna CCSA/CSBA/MIMO-CBSA achieve 1.831GHz/2.265 GHz/2.256 GHz, -15.13dB/-17.37dB/-17.25 dB, 1.42/1.31/1.33, and 1.474/2.332/2.322 for center frequency, reflection coefficient, VSWR, and bandwidth, respectively. This antenna has a size 63x90 mm and 51.5x90 mm for CCSA (Model 1) and CSBA (Model 2), respectively. After the structure of MIMO 2×2 was applied, the size of antenna MIMO-CBSA (Model 3) became 180 mm x 180 mm with a mutual coupling (S_{21})=-26.18 dB and mutual coupling (S_{31})=-26.41 dB. The result showed that proposed antenna CSBA (Model 2) has wider-bandwidth of 58,2% and smaller-size of 18.2%. Furthermore, after CSBA (Model 2) structure was applied to MIMO 2×2 (Model 3) and the MIMO antenna obtain good mutual coupling (<-15dB). Moreover, the measured results are good agreement with the simulated results. In conclusion, all of these advantages make it particularly valuable in multistandard antenna applications design such as GSM950, WCDMA1800, LTE2300, and WLAN2400.

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1. INTRODUCTION

In recent years, microstrip patch antenna technology is widely used. The microstrip patch antenna has advantages such as low fabrication cost, light in weight, capable of supporting multiple frequency bands, easily etched on any PCB and integrated them with MICs or MMICs [1-3]. However, it has disadvantages such as low gain, large PCB structure, and narrow bandwidth due to conductor losses, surface wave losses,

and dielectric losses [4, 5]. Several studies investigating bandwidth enhancement of microstrip antenna have been carried out by [6, 7]. The proposed methods include defected ground structure (DGS) [6], electromagnetic band gap (EBG) [7, 8], parasitic patch [9, 10], metamaterial [11], metamaterial bilayer substrates (MBS) [12], monopole slot [13], T-shaped slot [14], cylindrical dielectric slot (CDS) [15], polymeric grid [16], spiral split ring (SSR) [17], Jerusalem cross-shaped [18], and characteristic modes [19].

The DGS method was proposed by Marotkar [6], it is realized by etching the ground plane so the current distribution in the ground plane is disturbed. As the results, the antenna has a wide bandwidth of 302 MHz with center frequency of 2.4 GHz, and reflection coefficient of -23.26 dB. Furthermore, Gupta [7] and Hadarig [8] investigated bandwidth enhancement of microstrip patch antennas by implementing EBG structures. This proposed antenna has a center frequency of 10 GHz and 2.4 GHz for X-band Radar and VHF RFID, respectively. Then, to reduce the size of the antenna, Rothwell and Raoul O [21] proposed a metamaterial structure. The metamaterial microstrip structure has advantages such as compact size and broadband. However, the structure has complex geometry, and it is difficult to fabricate. Then, H. Mosallaei and K. Sarabandi [22] proposed bandwidth enhancement by using a reactive impedance substrate (RIS). This method succeeds to increase the bandwidth of the antenna and reduce antenna size.

Moreover, a fascinating method was proposed by Mohamadi [18]. It investigated the bandwidth enhancement of antenna for Long Term Evolution (LTE) technology with multiple input multiple output (MIMO) application. He introduced the basic modes method, this method successfully to enhance the bandwidth of the antenna, but it was still a drawback such as complex microstrip structure. Other methods include, G-shaped band-notched antenna [23], dielectric resonator antenna (DRA) [24], and U-shaped slot antenna [25]. The DRA antenna that is proposed by [24] has good bandwidth. However, the antenna structure is still large.

As the novelty, to enhance bandwidth and reduce antenna size, beveled half-cut microstrip structure is proposed in this paper. Further, this proposed antenna structure will be applied to multiple input multiple output (MIMO) antenna 2×2. Therefore, this research was investigated conventional circular shape antenna (CCSA), circular shaped beveled antenna (CSBA), and MIMO circular shaped beveled antenna (MIMO-CBSA) as Model 1, Model 2, and Model 3, respectively. An FR4 substrate with $\epsilon_r=4.4$, thickness $h=1.6$ mm, and $\tan \delta=0.0265$ was used. In brief, Table 1. provides the research position of this paper compare to another research of bandwidth enhancement and miniaturization of the antenna.

Table 1. The Research Position of Bandwidth Enhancement and Miniaturization of the Antenna

Ref. no	Method	Center Freq.	Wireless Technology	Bandwidth Enhancement	Miniaturization	MIMO Application
[6]	DGS	2.4 GHz	WLAN	yes	-	-
[7]	EBG	10 GHz	X-band Radar	yes	-	-
[8]	EBG	2.4 GHz	RFID	yes	-	-
[9]	Parasitic Patch	8.5 GHz	X-band	yes	-	-
[10]	Parasitic Patch	120 MHz	VHF RFID	yes	-	-
[11]	Metamaterial	1.9 GHz	GSM	yes	-	-
[12]	Metamaterial Bilayer	2.6 GHz	LTE	yes	-	-
[13]	Monopole Slot	4.4 GHz	WiMAX	yes	-	-
[14]	T-shaped Slot	6.7 GHz	UWB	yes	-	-
[15]	Dielectric Slot	11.25 GHz	X-band	yes	-	-
[16]	Polymeric Grid	26.8 GHz	5G	yes	-	-
[17]	Spiral Split Ring	5.8 GHz	WLAN	yes	-	-
[18]	Jerusalem Cross-Shaped	5.8 GHz	WLAN	yes	-	-
[19]	Characteristic Modes	1.9 GHz	LTE	yes	-	yes
[20]	Parasitic Patch	2.6 GHz	LTE	yes	-	yes
[21]	Metamaterial	2.6 GHz	LTE	-	yes	-
[22]	RIS	1.9 GHz	WCDMA	yes	yes	-
[23]	G-shaped band-notched	7.75 GHz	UWB	-	-	yes
[24]	DRA	30 GHz	5G	-	-	yes
[25]	U-shaped Slot	3 GHz	Selular	-	-	yes
This paper	Circular-Shaped with Beveled Halfcut Structure	2.175 GHz	GSM, WCDMA, LTE, and WLAN	yes	yes	yes

This rest of this paper is detailed as follows. In Section 2, the proposed circular shaped beveled antenna and MMO circular shaped beveled antenna are presented. The detail of numerical simulation was also described in Section 2. Furthermore, the measurement results of the fabricated antenna and the comparison with simulation result was explained in Section 3. Finally, Section 4 concludes this research.

2. RESEARCH METHOD

In this section, the proposed circular shaped beveled antenna and MMO circular shaped beveled antenna were designed. Figure 1(a), Figure 1(b), Figure 1(c), Figure 1(d), and Figure 1(e) show conventional circular shape antenna (CCSA) [Model-1], front view of CCSA, circular shaped beveled antenna (CSBA) [Model-2], front view of CSBA, MIMO circular shaped beveled antenna (CSBA) [Model-3], respectively.

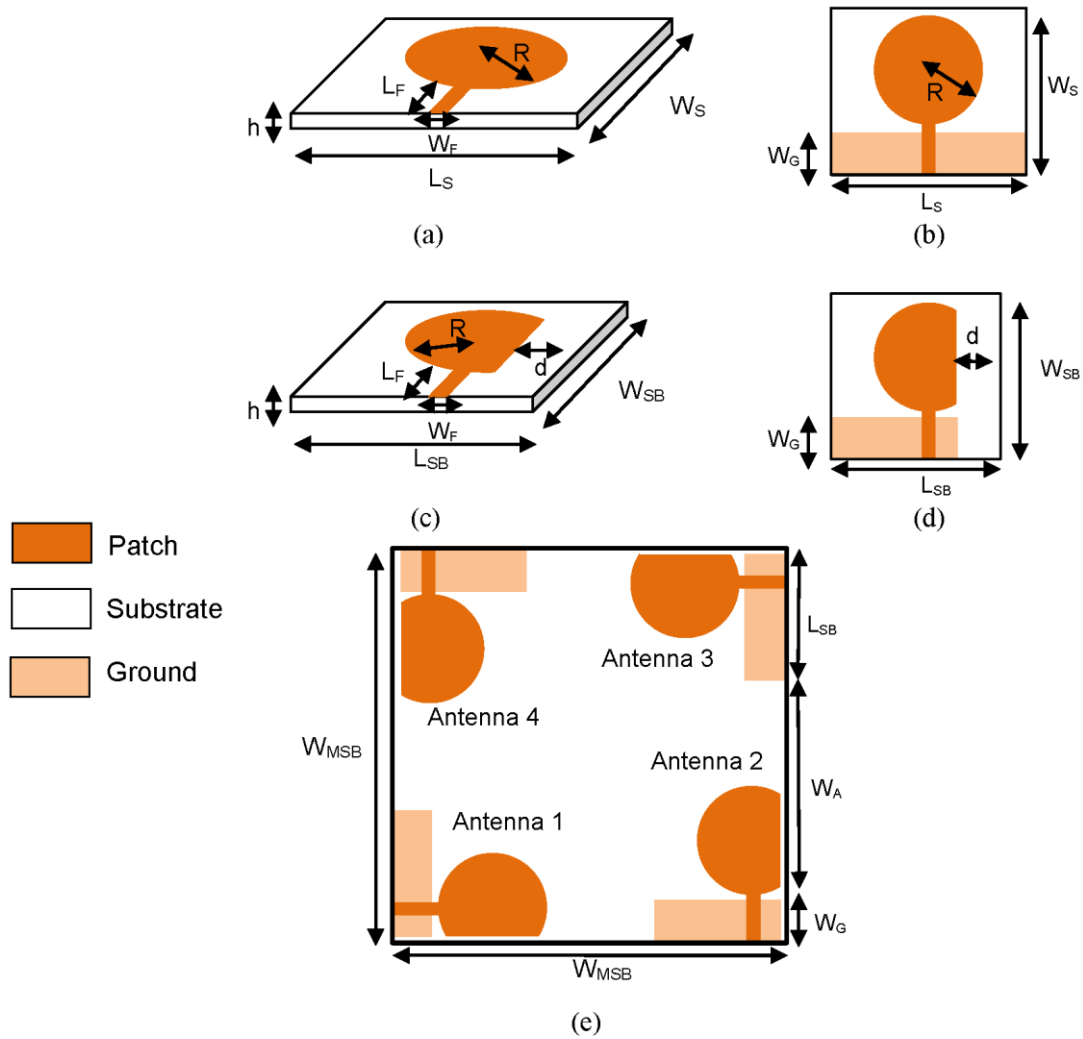


Figure 1. (a) Conventional Circular Shape Antenna (CCSSA) [Model-1], (b) Front view of Conventional Circular Shape Antenna, (c) Circular Shaped Beveled Antenna (CSBA) [Model-2], (d) Front view of Circular Shaped Beveled Antenna, (e) MIMO Circular Shaped Beveled Antenna (MIMO-CSBA) [Model-3]

The radius of circular-shaped microstrip patch antenna is formulated by [26], [27]:

$$R = \frac{F}{\sqrt{1 + \frac{2h}{\pi\epsilon_r} \left[\ln\left(\frac{\pi F}{2h}\right) + 1.7726 \right]}} \tag{1}$$

Where

$$F = \frac{8.791 \times 10^9}{f_r \sqrt{\epsilon_r}} \tag{2}$$

with h =thickness of substrate (cm), ϵ_r =permittivity of substrate, and f_r =resonant frequency (Hz). A direct feeding method was used in this paper. Moreover, the impedance characteristic (Z_0) can be determined by the ratio of a thickness of substrate (h) and its width (W) [28].

When $Z_0\sqrt{\epsilon_{re}} > 89.91$, W/h ratio is given by [29], [30]:

$$W/h = \frac{8 \exp(A)}{\exp(2A) - 2} \quad (3)$$

when $Z_0\sqrt{\epsilon_{re}} \leq 89.91$, W/h ratio is given by [29], [30]:

$$W/h = \frac{2}{\pi} \left\{ B - 1 - \ln(2B - 1) + \frac{\epsilon_r - 1}{2\epsilon_r} \left[\ln(B - 1) + 0.39 - \frac{0.61}{\epsilon_r} \right] \right\} \quad (4)$$

where

$$A = \frac{Z_0}{60} \left\{ \frac{\epsilon_r + 1}{2} \right\}^{1/2} + \frac{\epsilon_r - 1}{\epsilon_r + 1} \left\{ 0.23 + \frac{0.11}{\epsilon_r} \right\} \quad (5)$$

$$B = \frac{60\pi^2}{Z_0\sqrt{\epsilon_r}} \quad (6)$$

$$\epsilon_{re} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} F \left(\frac{W}{h} \right) \quad (7)$$

Furthermore, the conductivity loss (α_c) of microstrip transmission line feeding is given by [29], [30];

$$\alpha_c = \begin{cases} 1,38D \frac{R_s}{hZ_0} \frac{32 - (W/h)^2}{32 + (W/h)^2} & \left(\frac{W}{h} \leq 1 \right) \\ 6,1 \times 10^{-5} D \frac{R_s Z_0 \epsilon_{re}(f)}{h} \left[W_e/h + \frac{0,667 W/h}{W_e/h + 1,444} \right] & \left(\frac{W}{h} \geq 1 \right) \end{cases} \quad (8)$$

where

$$D = 1 + \frac{h}{W} \left\{ 1 + \frac{1,25}{\pi} \ln \frac{4\pi W}{t} \right\} \quad (9)$$

with

$$R_s = \sqrt{\pi f \mu_0 \rho_c},$$

ρ_c = resistivity of the conductor,

f = frequency (Hz), and

$\mu_0 = 4\pi \times 10^{-7} \text{ N}\cdot\text{A}^{-2}$ is the magnetic permeability of free space,

The numerical simulation of the antenna parameters has been conducted by using Advanced Design System (ADS). The FR4 substrate with $\epsilon_r=4.4$, thickness $h=1.6$ mm, and $\tan \delta=0.0265$ was used. Figure 2(a) shows the extracted reflection coefficient with varied R . The data shows that by modifying the radius (R), the reflection coefficient can be tuned. However, for $R=22$ mm and $R=24$ mm, the antenna is not resonance. Furthermore, Figure 2(b) shows the voltage standing wave ratio (VSWR) value by varied radius (R). The simulation result shows that VSWR value is better than 2 at $R=28$ mm and $R=30$ mm.

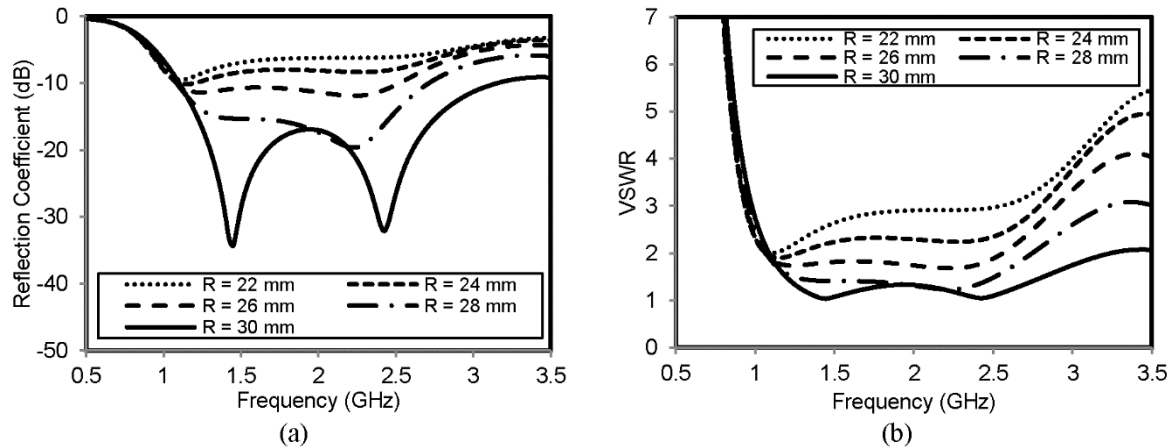


Figure 2. (a) The extracted reflection coefficient with varied R (mm); (b) The extracted voltage standing wave ratio (VSWR) with varied R (mm)

Figure 3(a) and Figure 3(b) illustrate the reflection coefficient with varied W_G and voltage standing wave ratio (VSWR) with varied W_G , respectively. From the data in Figure 3(a), we can see that the W_G is essential parameters to make the antenna resonate. The Figure 3(a) shows that by increasing the W_G (mm), the antenna will be more resonate. Moreover, Figure 3(b) shows clearly trend that the VSWR of the antenna is better than 2 (two) for W_G is longer than 28 mm. However, the dimension of this antenna is large. The next step explains the miniaturization process.

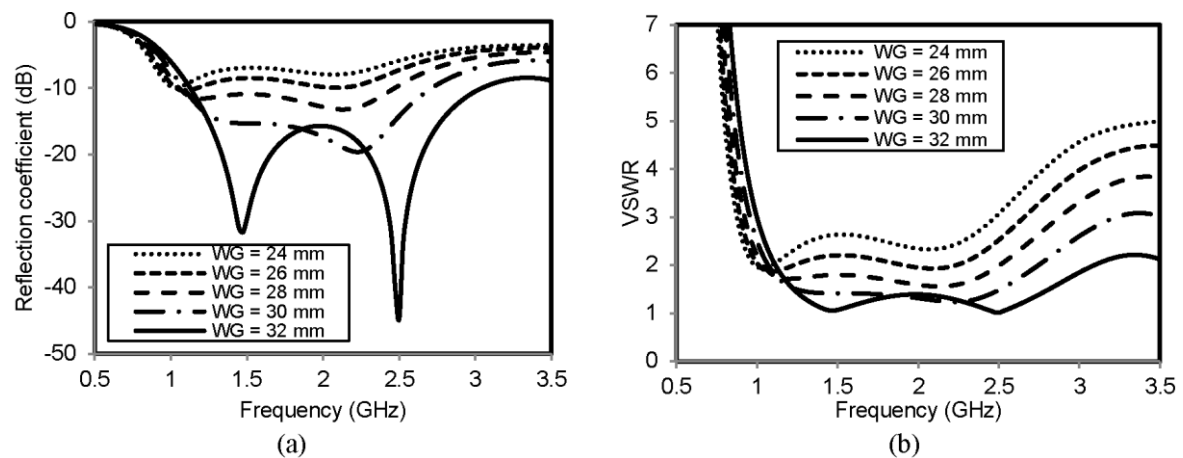


Figure 3. (a) The extracted reflection coefficient with varied W_G (mm); (b) The extracted voltage standing wave ratio (VSWR) with varied W_G (mm)

In this paper, the bandwidth enhancement and miniaturization of the antenna is obtained by the beveled method as shown in Figure 1(b) and Figure 1(c). The beveled method was applied by cut one side of the antenna, partially. Furthermore, the size of the antenna will be reduced by d (mm). Moreover, the result of numerical simulation based on the beveled method is depicted in Figure 4(a) and Figure 4(b). Figure 4(a) illustrates the extracted reflection coefficient with varied d (mm). Base on Figure 4(a), the data shows that at $d=10$ mm produce large bandwidth. However for $d=10$ mm at the frequency of 2.8 GHz, the reflection coefficient is higher than -10 dB. Therefore, the value $d=10$ mm is not chosen because the reflection coefficient is too high. Therefore, the data shows that the largest bandwidth is generated at $d=8$ mm. This result is also indicated in Figure 4(b) which presents the extracted center frequency and bandwidth with varied d (mm). For instance, the circular shaped beveled antenna (CSBA) [Model-2] is represented by the antenna with $d=8$ mm and the conventional circular shape antenna (CCSA) [Model-1] is represented by the antenna with $d=0$ mm.

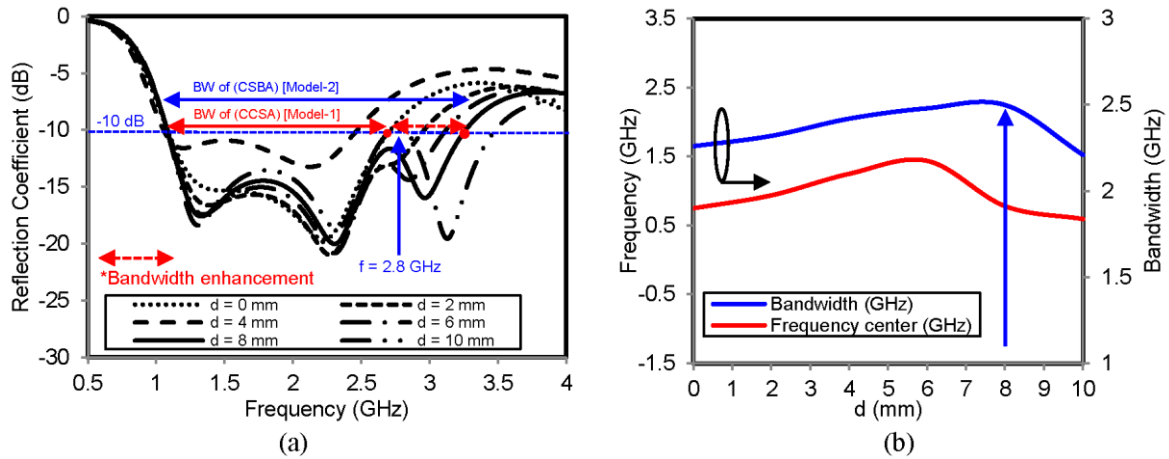


Figure 4. (a) The extracted reflection coefficient with varied d (mm); (b) The extracted frequency center and bandwidth with varied d (mm)

The next step is to apply the CSBA [Model-2] to MIMO-CSBA [Model-3] antenna as shown in Figure 1(e). Furthermore, Figure 5(a) shows the extracted reflection coefficient with different W_{SMB} (mm) and Figure 5(b) illustrates the extracted voltage standing wave ratio (VSWR) with varied W_{SMB} (mm). Figure 5(a) shows a clear illustration that the reflection coefficient is stable for the different length of W_{SMB} and it shows that the reflection coefficient values are lower than -10 dB. However, the reflection coefficient for $W_{SMB}=180$ mm generates lower bandwidth than others. Furthermore, it appears from Figure 5(b) that the VSWR values are still lower than 2 (two). This data shows that the antenna is working properly with good performance.

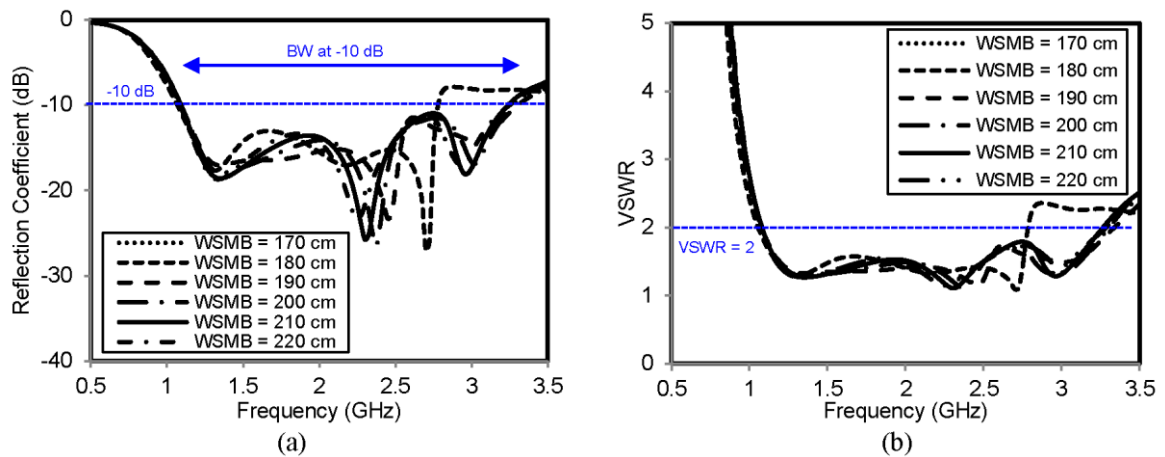


Figure 5. (a) The extracted reflection coefficient with varied W_{SMB} (mm); (b) The extracted voltage standing wave ratio (VSWR) with varied W_{SMB} (mm)

The numerical simulation result of mutual coupling MIMO antenna is shown in Figure 6(a) and Figure 6(b). Figure 6(a) exhibits the extracted mutual coupling (S_{21}) with varied W_{SMB} (mm) and Figure 6(b) illustrates the extracted mutual coupling (S_{31}) with varied W_{SMB} (mm). The mutual coupling value of S_{21} (dB) and S_{31} (dB) demonstrate the coupling between Antena 1 to Antena 2 and Antena 1 to Antena 3, respectively. The coupling coefficient is lower than -15 dB almost over the whole band which shows a good isolation performance. However, the coupling coefficient for $W_{SMB}=180$ mm is higher than -15 dB at the frequency of 2.8 GHz. So, the $W_{SMB}=180$ mm cannot be chosen. The distance between antenna effects on mutual coupling. The mutual coupling can be decreased by increasing the distance between the MIMO antennas. However, the size of the antennas cannot be made too large.

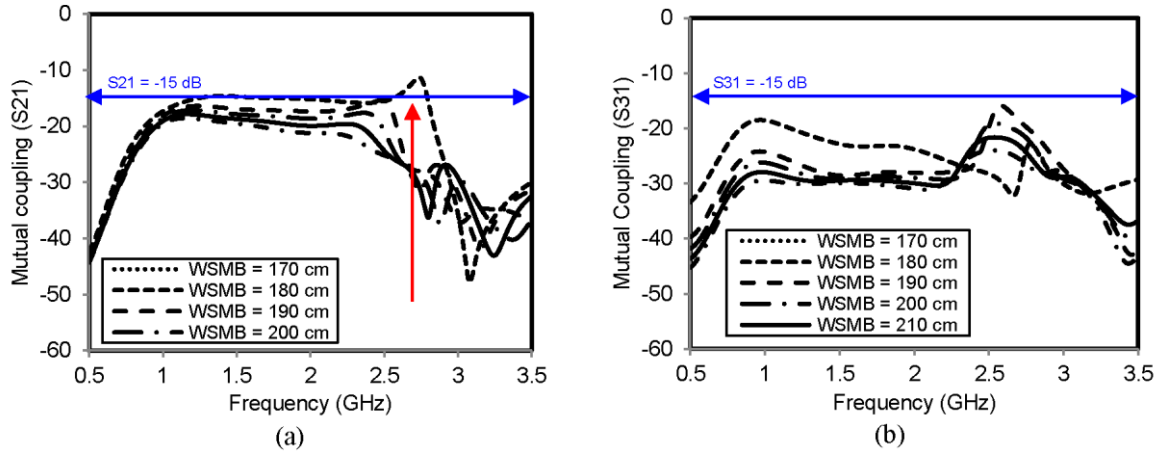


Figure 6. (a) The extracted mutual coupling (S_{21}) with varied W_{SMB} (mm); (c) The extracted mutual coupling (S_{31}) with varied W_{SMB} (mm)

3. RESULTS AND ANALYSIS

To verify the simulation result, the measurement of the antenna prototype must be carried out. The photograph of the fabricated proposed antenna is depicted in Figure 7(a), Figure 7(b), and Figure 7(c). Figure 7(a) shows the photograph of conventional circular shape antenna (CCSA) [Model-1], and Figure 7(b) illustrates the photograph of circular shaped beveled antenna (CSBA) [Model-2]. Furthermore, Figure 7(c) presents the photograph MIMO circular shaped beveled antenna (MCSBA) [Model-3]. The FR4 substrate with $\epsilon_r=4.4$, thickness $h=1.6$ mm, and $\tan d=0.0265$ was used. The simulation and optimization has been conducted using Advanced Design System (ADS). The detailed geometric parameters are $R=28$ mm, $L_S=63$ mm, $W_S=90$ mm, $W_G=30$ mm, $L_F=34$ mm, $W_F=3$ mm, $d=8$ mm, $L_{SB}=51.5$ mm, $W_{SB}=90$ mm, $W_{MSB}=190$ mm, and $W_A=98.5$ mm, Moreover, the full size of the PCB board is 190×190 mm².

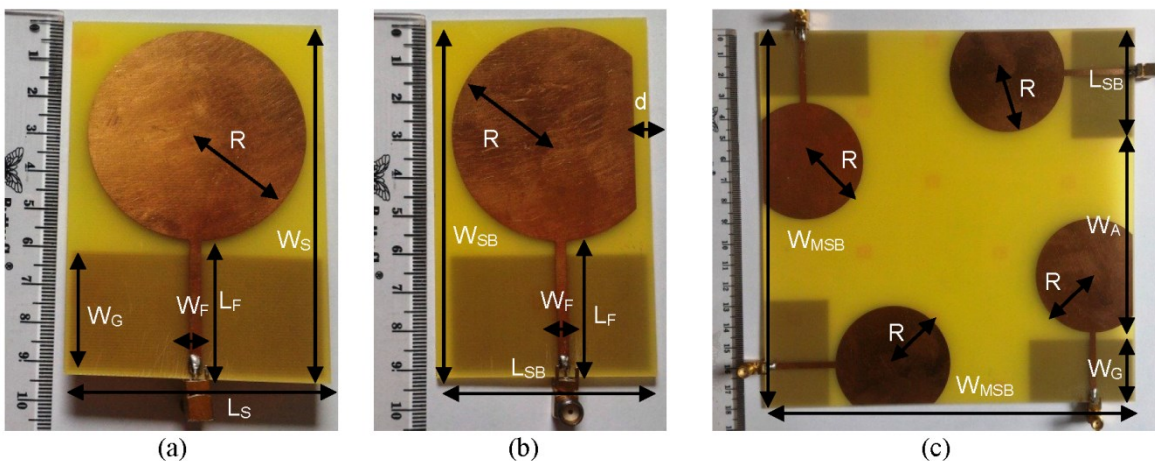


Figure 7. Photograph of (a) conventional circular shape antenna (CCSA) [Model-1], (b) circular shaped beveled antenna (CSBA) [Model-2], (c) MIMO circular shaped beveled antenna (MCSBA) [Model-3]

Figure 8(a) shows the comparison between simulated and measured of reflection coefficient of CCSA antenna dan CSBA antenna. The simulated/measured of CCSA antenna [Model-1] achieves lower frequency=1.093 GHz/1.094 GHz, upper frequency=2.719 GHz/2.568 GHz, center frequency=1.906 GHz/1.831 GHz, bandwidth=1.626 GHz/1.474 GHz, and reflection coefficient=-16.39 dB/-15.13 dB with the size of CCSA antenna has 63x90 mm. Furthermore, the simulated/measured of CBSA antenna [Model-2] achieves lower frequency=1.051 GHz/1.090 GHz, upper frequency=3.299 GHz/3.422 GHz, center frequency=2.175 GHz/2.265 GHz, bandwidth=2.248 GHz/2.332 GHz, and reflection

coefficient=-17.99 dB/17.37 dB with the size of CSBA antenna has 51.5x90 mm. Moreover, Figure 8(b) shows the comparison between simulated and measured of VSWR. The simulated/measured of CCSA antenna [Model-1] achieves VSWR=1.35/1.42, and the simulated/measured of CSBA antenna [Model-2] achieves VSWR=1.28/1.31. Base on the measurement performance, both antennas can work as expected. However, the comparison result showed that proposed antenna CSBA [Model 2] has wider-bandwidth of 58,2% and smaller-size of 18.2%.

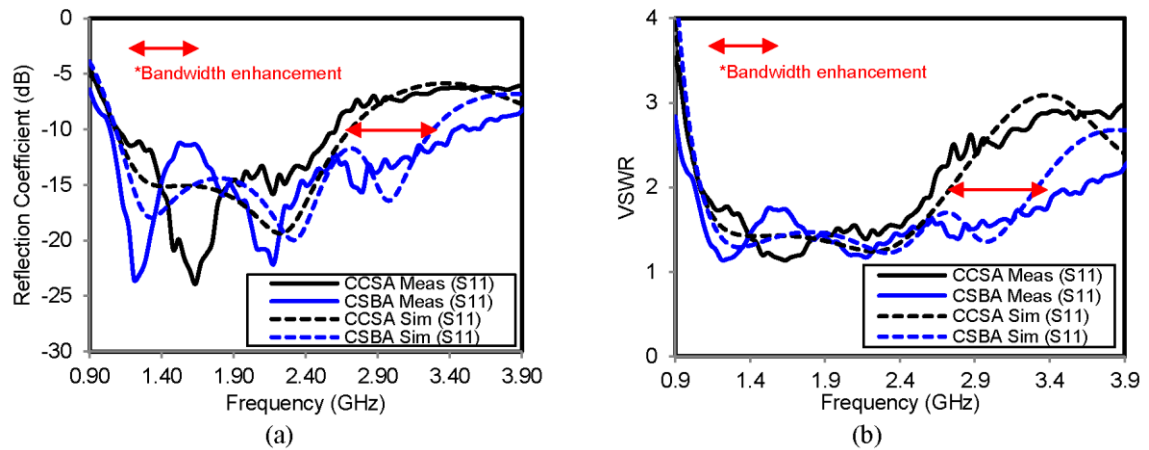


Figure 8. (a) The comparison between simulated and measured of reflection coefficient; (b) The comparison between simulated and measured of VSWR

Figure 9(a) exhibits the comparison of gain (dBi), directivity (dBi), efficiency (%). The gain of CCSA [Model 1]/CSBA [Model 2] antenna has 1.58 dBi/1.56 dBi, 3.61 dBi/2.29 dBi, 2.44 dBi/2.27 dBi, and 2.47 dBi/2.34 dBi for frequency of 0.95 GHz, 1.85 GHz, 2.35 GHz, and 2.45 GHz, respectively. Furthermore, the directivity of CCSA [Model 1]/CSBA [Model 2] antenna has 2.34 dBi/2.32 dBi, 2.36 dBi/3.54 dBi, 3.99 dBi/3.74 dBi, and 4.09 dBi/3.84 dBi for frequency of 0.95 GHz, 1.85 GHz, 2.35 GHz, and 2.45 GHz, respectively. The efficiency of CCSA [Model 1]/CSBA [Model 2] antenna has 83.99 %/83.92%, 75.12 %/74.92%, 70.10%/71.25%, and 68.95%/70.89% for frequency of 0.95 GHz, 1.85 GHz, 2.35 GHz, and 2.45 GHz, respectively. Moreover, Figure 9(b) shows the comparison between simulated and measured of mutual coupling (S_{21}) and (S_{31}). The simulated/measured of mutual coupling of MIMO-CBSA [Model-3] antenna are -16.15 dB/-26.18 dB and -27.11 dB/-26.41 dB for mutual coupling (S_{21}) and mutual coupling (S_{31}), respectively. The MIMO antenna obtain very good mutual coupling (<-15dB). Moreover, the measured results are in a good agreement with the simulated results.

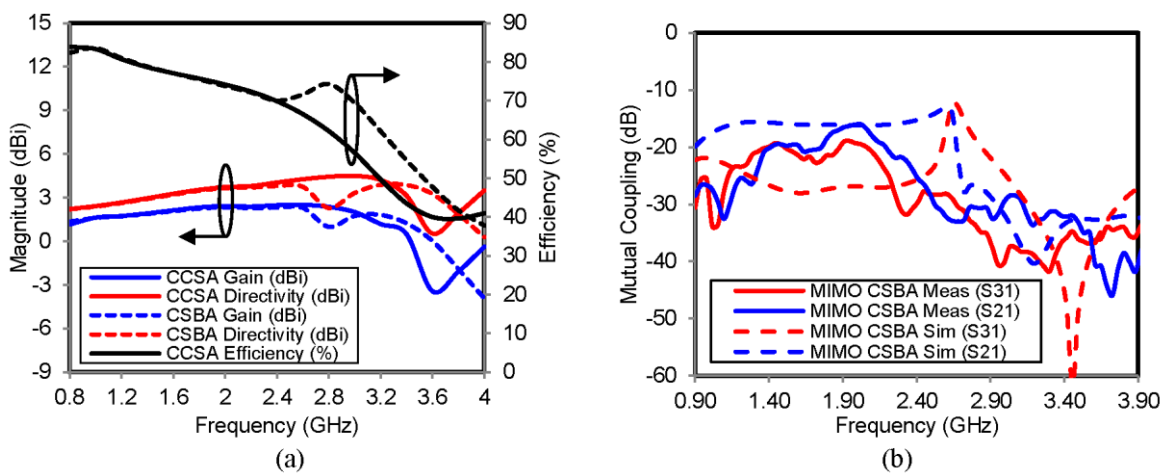
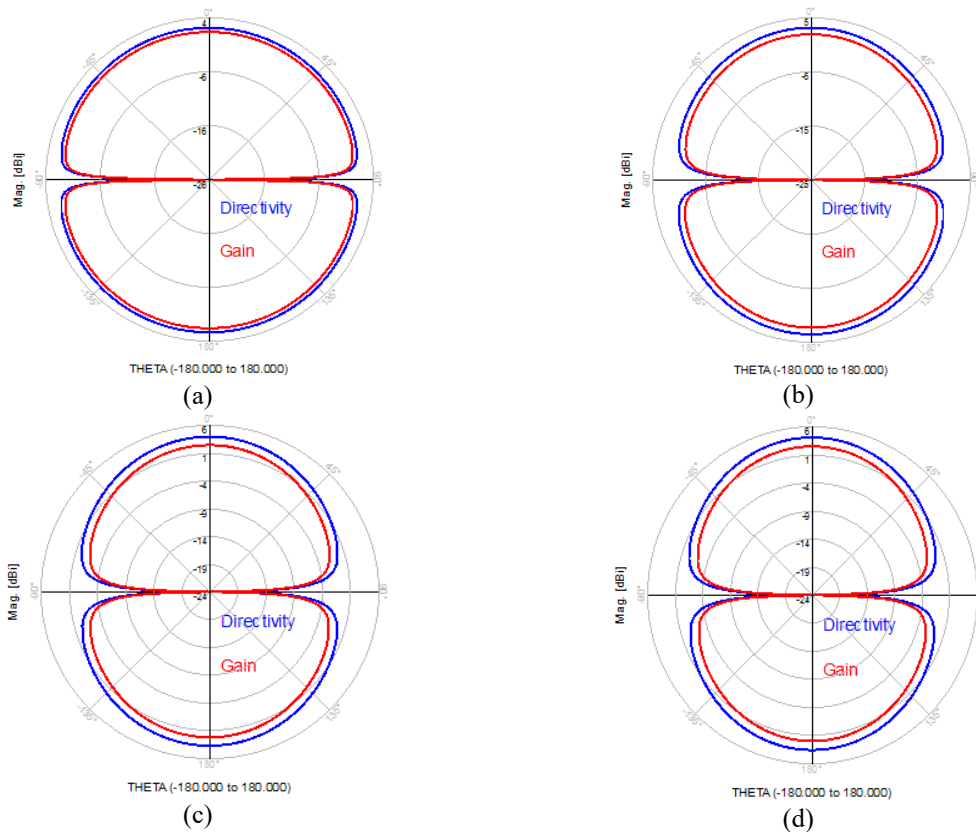


Figure 9. (a) The comparison gain (dBi), directivity (dBi), Efficiency (%), (b) The comparison between simulated and measured of mutual coupling (S_{21}) and (S_{31})

Table 2 summarizes the comparison of simulated and measured data of CCSA [Model-1] antenna, CSBA [Model-2] antenna, and MIMO CSBA [Model-3] antenna, in brief. Moreover, the radiation patterns of the proposed antenna are shown in Figure 10(a)-(h). In conclusion, all of these advantages make it particularly valuable in multistandard antenna applications design such as GSM950, WCDMA1800, LTE2300, and WLAN2400.

Table 2. The Comparison of Simulated and Measured Result of CCSA [Model-1] Antenna, CSBA [Model-2] Antenna, and MIMO CSBA [Model-3] Antenna

Performace	CCSA [Model-1]		CSBA [Model-2]		MIMO CSBA [Model-3]		
	Simulated	Measured	Simulated	Measured	Simulated	Measured	
Lower frequency (GHz)	1.093	1.094	1.051	1.090	1.061	1.095	
Upper frequency (GHz)	2.719	2.568	3.299	3.422	3.275	3.417	
Center frequency (GHz)	1.906	1.831	2.175	2.265	2.168	2.256	
Bandwidth (MHz)	1.626	1.474	2.248	2.332	2.214	2.322	
Reflection coefficient (dB)	-16.39	-15.13	-17.99	-17.37	-17.12	-17.25	
VSWR	1.35	1.42	1.28	1.31	1.32	1.33	
Mutual coupling (S ₂₁)	NA	NA	NA	NA	-16.15	-26.18	
Mutual coupling (S ₃₁)	NA	NA	NA	NA	-27.11	-26.41	
Gain @ f=0.95 GHz (dBi)	1.58	NA	1.56	NA	0.14	NA	
Gain @ f=1.85 GHz (dBi)	3.61	NA	2.29	NA	3.90	NA	
Gain @ f=2.35 GHz (dBi)	2.44	NA	2.27	NA	4.64	NA	
Gain @ f=2.45 GHz (dBi)	2.47	NA	2.34	NA	4.84	NA	
Directivity @ f=0.95 GHz (dBi)	2.34	NA	2.32	NA	1.47	NA	
Directivity @ f=1.85 GHz (dBi)	2.36	NA	3.54	NA	4.50	NA	
Directivity @ f=2.35 GHz (dBi)	3.99	NA	3.74	NA	5.49	NA	
Directivity @ f=2.45 GHz (dBi)	4.09	NA	3.84	NA	5.16	NA	
Efficiency @ f=0.95 GHz (%)	83.99	NA	83.92	NA	73.74	NA	
Efficiency @ f=1.85 GHz (%)	75.12	NA	74.92	NA	87.25	NA	
Efficiency @ f=2.35 GHz (%)	70.10	NA	71.25	NA	82.23	NA	
Efficiency @ f=2.45 GHz (%)	68.95	NA	70.89	NA	92.82	NA	
Size	W (mm)	63	63	51.5	51.5	190	190
	L (mm)	90	90	90	90	190	190
	H (mm)	1.6	1.6	1.6	1.6	1.6	1.6



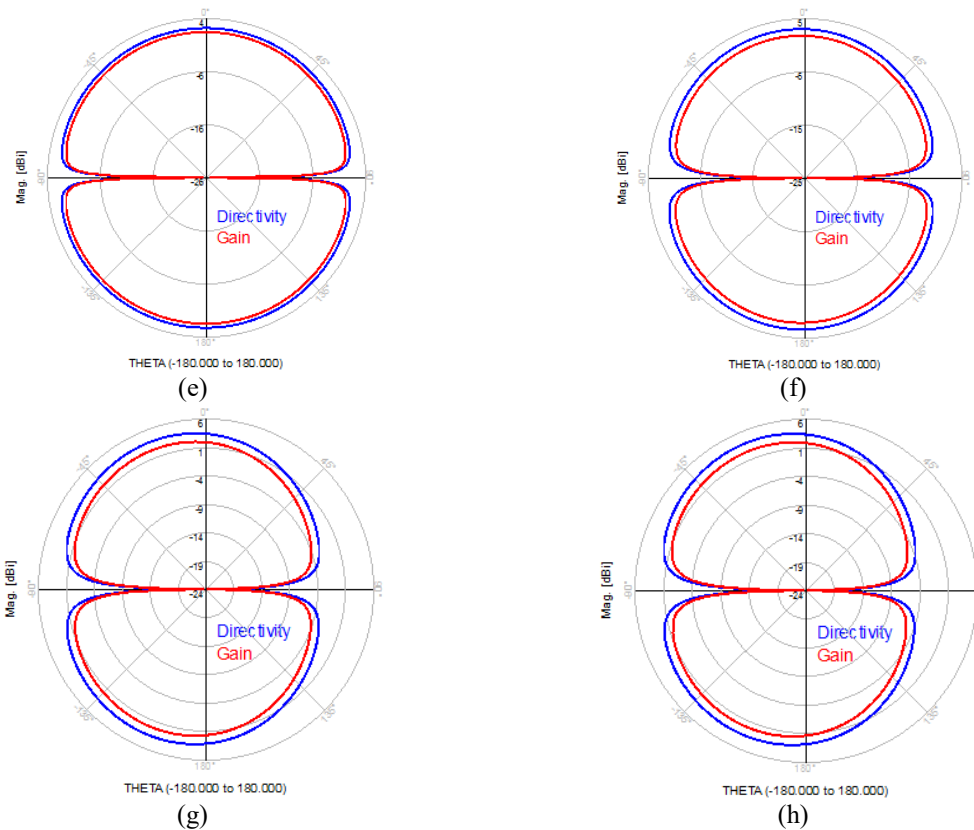


Figure 10. Gain and directivity of CCSA at frequency (a) $f=0.95$ GHz, (b) $f=1.85$ GHz, (c) $f=2.35$ GHz, (d) $f=2.45$ GHz. Gain and directivity of CSBA at frequency (e) $f=0.95$ GHz, (f) $f=1.85$ GHz, (g) $f=2.35$ GHz, (h) $f=2.45$ GHz

4. CONCLUSION

In order to reduce the antenna size and enhance the bandwidth of antenna, this paper was proposed the beveled half-cut microstrip structure. Moreover, this research was investigated conventional circular shape antenna (CCSA), circular shaped beveled antenna (CSBA), and MIMO circular shaped beveled antenna (MIMO-CBSA) as Model 1, Model 2, and Model 3, respectively. This antenna was fabricated on FR4 substrate with $\epsilon_r=4.4$, thickness $h=1.6$ mm, and $\tan \delta=0.0265$. The numerical simulation has been conducted using Advanced Design System (ADS). The measured result showed that proposed antenna CSBA [Model 2] has wider-bandwidth of 58,2% and smaller-size of 18.2% compared to CCSA [Model 1] antenna. Then, after CSBA [Model 2] structure was applied to MIMO 2×2 [Model 3], the MIMO antenna obtain very good mutual coupling (< -15 dB). Moreover, the measured results are good agreement with the simulated results. In conclusion, all of these advantages make it particularly valuable in multistandard antenna applications design such as GSM950, WCDMA1800, LTE2300, and WLAN2400.

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REFERENCES

- [1] L. Wang, Z. Weng, Y. C. Jiao, W. Zhang and C. Zhang, "A Low-Profile Broadband Circularly Polarized Microstrip Antenna With Wide Beamwidth," *IEEE Antennas and Wireless Propagation Letters*, vol. 17, no. 7, pp. 1213-1217, July 2018. doi: 10.1109/LAWP.2018.2839100
- [2] Hashim Dahri, et al. "Broadband Resonant Elements for 5G Reflectarray Antenna Design," *TELKOMNIKA Telecommunication Computing Electronics and Control*, vol. 15 (3), pp. 793-798. 2017.

- [3] Raimi Dewanet., et al "Dual Band to Wideband Pentagon-shaped Patch Antenna with Frequency Reconfigurability using EBGs," *International Journal of Electrical and Computer Engineering (IJECE)*, Vol.8, No.4, pp. 2557-2563. August 2018.
- [4] E. Ragab M, "Study on Bandwidth Enhancement Techniques of Microstrip Antenna," *Journal of Electrical Systems and Information Technology*, vol. 3 (3), pp. 527-531, December 2016. doi: 10.1016/j.jesit.2015.05.003
- [5] J. F. Lin and Q. X. Chu, "Enhancing Bandwidth of CP Microstrip Antenna by Using Parasitic Patches in Annular Sector Shapes to Control Electric Field Components," *IEEE Antennas and Wireless Propagation Letters*, vol. 17, no. 5, pp. 924-927, May 2018. doi: 10.1109/LAWP.2018.2825236
- [6] D. S. Marotkar and P. Zade, "Bandwidth Enhancement of Microstrip Patch Antenna Using Defected Ground Structure," *International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT)*, Chennai, pp. 1712-1716, 2016. doi: 10.1109/ICEEOT.2016.7754978.
- [7] Gupta and M. Kumar, "Bandwidth Enhancement of Microstrip Patch Antennas by Implementing Electromagnetic Bandgap (EBG) Structures," *Fourth International Conference on Computational Intelligence and Communication Networks*, Mathura, pp. 15-18, 2012. doi: 10.1109/CICN.2012.58
- [8] R. C. Hadarig, M. E. de Cos, and F. Las-Heras., "Microstrip Patch Antenna Bandwidth Enhancement Using AMC/EBG Structures," *International Journal of Antennas and Propagation*, vol. pp. 1-6, 2012. doi:10.1155/2012/843754
- [9] M. H. Reddy, R. M. Joany, M. J. Reddy, M. Sugadev and E. Logashanmugam, "Bandwidth Enhancement of Microstrip Patch Antenna Using Parasitic Patch," *IEEE International Conference on Smart Technologies and Management for Computing, Communication, Controls, Energy and Materials (ICSTM)*, Chennai, pp. 295-298, 2017. doi: 10.1109/ICSTM.2017.8089172
- [10] Lin Peng, Fu-Man Yang and Xing Jiang, "Simple and Electrically Small EZR-MZR Resonator With Quasi-Isotropic Pattern," *IEEE Journal of Radio Frequency Identification*, vol. 1, 2017. doi: 10.1002/mop.30471
- [11] P. Ananya., et at., "Bandwidth Enhancement of Microstrip Patch Antenna Using Metamaterials," *IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)*, vol. 8 (4), pp. 5-10. Nov 2013
- [12] R. Yang , Y. Xie , D. Li , J. Zhang & J. Jiang. "Bandwidth Enhancement of Microstrip Antennas with Metamaterial Bilayered Substrates", *Journal of Electromagnetic Waves and Applications*, vol. 21(15), pp. 2321-2330, 2007. doi: 10.1163/156939307783134425
- [13] B. Sudeep, V. Dinesh Kumar., "Bandwidth Enhancement of a Planar Monopole Microstrip Patch Antenna," *International Journal of Microwave and Wireless Technologies*. vol. 8, issue 2, pp. 237-242. March 2016. doi:10.1017/S175907871400141X
- [14] S. Kun Song, Y.Ying-Zeng, Xiao-Bo Wu, and Li Zhang., "Bandwidth Enhancement of Open Slot Antenna With A T-Shaped Stub," *Microwave And Optical Technology Letters*. vol. 52,no. 2, pp. 390-393. February 2010. doi: 10.1002/mop
- [15] M. Nipun K, D. Soma, and V. Dinesh K., "Bandwidth Enhancement of Cylindrical Dielectric Resonator Antenna Using Thin Dielectric Layer Fed by Resonating Slot". *Frequenz*. Vol. 70, pp. 381–388. 2016. doi: 10.1515/freq-2015-0188
- [16] M. Wan Asilah Wan., "Bandwidth enhancement using Polymeric Grid Array Antenna for millimeter-wave application". *Appl. Phys. A*. vol. 123:69, 2017 doi: 10.1007/s00339-016-0689-0
- [17] Arora C., Pattnaik S.S., Baral R.N. (2018) Bandwidth Enhancement of Microstrip Patch Antenna Array Using Spiral Split Ring Resonator. *Advances in Intelligent Systems and Computing*, vol 672. doi:10.1007/978-981-10-7512-4
- [18] F. Mohamadi Monavar and N. Komjani., "Bandwidth Enhancement Of Microstrip Patch Antenna Using Jerusalem Cross-Shaped Frequency Selective Surfaces By Invasive Weed Optimization Approach". *Progress In Electromagnetics Research*, vol. 121, pp. 103-120, 2011.
- [19] Z. Miers, H. Li and B. K. Lau, "Design of Bandwidth-Enhanced and Multiband MIMO Antennas Using Characteristic Modes," *IEEE Antennas and Wireless Propagation Letters*, vol. 12, pp. 1696-1699, 2013. doi: 10.1109/LAWP.2013.2292562
- [20] Y. Wen, D. Yang, H. Zeng, M. Zou and J. Pan, "Bandwidth Enhancement of Low-Profile Microstrip Antenna for MIMO Applications," *IEEE Transactions on Antennas and Propagation*, vol. 66, no. 3, pp. 1064-1075, March 2018. doi: 10.1109/TAP.2017.2787542
- [21] Edward J. Rothwell and Raoul O. Ouedraogo., "Antenna Miniaturization: Definitions, Concepts, and a Review With Emphasis on Metamaterials," *Journal of Electromagnetic Waves and Applications*, doi: 10.1080/09205071.2014.972470
- [22] H. Mosallaei and K. Sarabandi, "Antenna Miniaturization and Bandwidth Enhancement Using a Reactive Impedance Substrate," *IEEE Transactions on Antennas and Propagation*, vol. 52, no. 9, pp. 2403-2414, Sept. 2004. doi: 10.1109/TAP.2004.834135
- [23] A. Toktas, "G-shaped Band-Notched Ultra-Wideband MIMO Antenna System for Mobile Terminals," *IET Microwaves, Antennas & Propagation*, vol. 11, no. 5, pp. 718-725, 2017. doi: 10.1049/iet-map.2016.0820
- [24] M. S. Sharawi, S. K. Podilchak, M. T. Hussain and Y. M. M. Antar, "Dielectric Resonator based MIMO Antenna System Enabling Millimetre-Wave Mobile Devices." *IET Microwaves, Antennas & Propagation*, vol. 11, no. 2, pp. 287-293, 1 29. 2017. doi: 10.1049/iet-map.2016.0457
- [25] H. T. Hu, F. C. Chen and Q. X. Chu, "A Wideband U-Shaped Slot Antenna and Its Application in MIMO Terminals," *IEEE Antennas and Wireless Propagation Letters*, vol. 15, pp. 508-511, 2016. doi: 10.1109/LAWP.2015.2455237

-
- [26] T Pramendra, P Sharma, T Bandopadhyay. "Gain Enhancement of Circular Microstrip Antenna for Personal Communication Systems," *International Journal of Engineering and Technology*. vol. 3(2), pp. 175-178. 2011.
- [27] Firmansyah, T. et al., "Bandwidth and Gain Enhancement of MIMO Antenna by Using Ring and Circular Parasitic With Air-Gap Microstrip Structure," *TELKOMNIKA Telecommunication Computing Electronics and Control*. vol. 15 (3), pp. 1155-1163. 2017.
- [28] Firmansyah, T. et al., "Dual-Wideband Band Pass Filter Using Folded Cross-Stub Stepped Impedance Resonator," *Microwave and Optical Technology Letters*, vol. 59 (11), pp. 2929-2934, November 2017.
- [29] Bahl, Inder, *Lumped Elements for RF and Microwave Circuits*. Norwood: Artech House, Inc, 2003.
- [30] D. Pozar *Microwave Engineering*, Fourth Edition, Wiley, 2011.