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MICROSTRIP LINE-FED BASED QUAD-PORT WIDEBAND MIMO ANTENNA FOR K BAND APPLICATION

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Abstract

In this communication, a compact (30×30×1.6 mm^3) microstrip line fed loaded quad-port and T-shaped wideband MIMO (Multiple-Input Multiple-Output) antenna for K band (18-27GHz) application is introduced. Here three simulated antennas (Antenna-1, Antenna-2 and Antenna-3) are analytically inspected in expressions of simulated gain, return loss (|S_{11}|, |S_{22}|, |S_{33}| and |S_{44}|), total active reflection coefficient (TARC), isolation (mutual coupling), diversity gain (DG), radiation efficiency, radiation pattern and envelope correlation coefficient (ECC). Antenna 3 disclaimers have been elevated for chosen antenna considerations and performance. The proposed antenna has |S_{11}|, |S_{22}|, |S_{33}| and |S_{44}| not more than -10 dB and the percentage impedance bandwidth is 19.54% (19.48-23.70GHz), 18.74% (19.58-23.63), 16.31% (19.54-23.01GHz) and 18.27% (19.39-23.29GHz) at ports 1, 2, 3 and 4 respectively. Simulated isolation is < -15 dB, ECC obtained between ports 1-2, 1-3 and 1-4 is not more than 0.06, DG originated among the ports 1-2, 1-3 and 1-4 is in the range of 9.969-9.999 (dB), TARC < 0 dB and radiation efficiency of 60% is obtained. The proposed design model of antenna has been analyzed with HFSS simulation tool by ANSOFT version 13.

Keywords:
Patch Antenna, MIMO, Isolation, ECC and TARC

1. INTRODUCTION

The rapid advancement of wireless communication technology has raised the demand of excessive data transmission rate along with the need for enhanced channel capability and as well as excellent consistency. These desires have led to the MIMO system grasping more consideration in the recent years [1]. Multiple-Input Multiple-Output (MIMO) method is worked instantaneously on behalf of communication through a wireless. MIMO structures employ multipath in achieving advanced data rates and improved accuracy. Advanced data rate is required for various services such as 4G and 5G purposes [2]-[4]. In MIMO expertise, enormous procedures are consumed to decline the mutual coupling influence or else widen the isolation among the inflexibly employed antenna fundamentals [5].

MIMO antenna classifications are accomplished in providing a decent feature of mobile communication while it has anticipated isolation and envelope correlation coefficient (ECC) concerning antenna foundations [6]. Intended for the execution of reduced mutual coupling as well as decline of multi-fading consequence, assimilation of multiple antennas is there essential which steer decent execution in the MIMO organization [7]. The micro-strip antenna is mostly targeted for X, Ku and as well as K bands; the X band consumes several applications such as in satellite broadcasting, mobile and wireless communication, etc. [8]; Ku/K band is used for radar and satellite broadcasting. Frequently X/Ku/K band micro-strip patch antennas proposed aimed at wide-band; ultra-wideband and dual-band operations. Triple band antenna used for the same frequency range is infrequent [9]. The goal of MIMO technology is toward harvesting an improved isolation amid the multi antenna fundamentals that continue finished in the communications; consequently, the channel capability of the communication is improved in a limited space without growing bandwidth. [10-11].

In this paper, a compact (30×30×1.6 mm^3) microstrip line fed based quad-port and T-shaped wideband MIMO (Multiple-Input Multiple-Output) antenna using FR-4 substrate aimed at K band (18-27GHz) uses is obtainable. Quad-port T-formed MIMO antenna is anticipated and is simulated using electromagnetic simulation tool High Frequency Structure Simulator (HFSS) software by ANSOFT version 13. T-shaped patch is accessible orthogonally between the center positions of elements to provide better isolation between the ports and it covers wide impedance bandwidth. The reason behind of the rectangular and circular slot cutting has been implemented to increase the bandwidth, gain and other antenna characteristics. The overall geometry, results, and conclusion of which is discussed in the forthcoming sections.

2. PROPOSED ANTENNA EVOLUTION AND DESIGN

A Patch (green-color) and ground (orange-color) interpretation of the Antenna 1, Antenna 2 and Antenna 3 (Proposed design) is presented in Fig.1, the intended antenna (Antenna 3) geometry in which patch is on the side (green color-front outlook), ground on the side (orange color-back outlook) as well as disclaimers or sizes is presented in millimeter scales (mm) and displayed in Fig.2.

The systematic growth of Antenna 1, Antenna 2 and Antenna 3 is shown in Fig.1. Ground geometry (orange color-back view) of all these antennas (Antenna 1, Antenna 2 and Antenna 3) is the same.

Antenna 1 is initiated by four symmetrical rectangular radiating elements (green-color) with ground (orange-color) structure (cf. fig.1).

Antenna 2 is obtained from Antenna 1, in which two symmetrical parallel rectangular slots (2 × 1 mm2) are there cut in the radiating elements (cf. Fig.1). Antenna 3 is further obtained from Antenna 2, in which one circular slot of diameter (2 mm) is etched in the inside section of the radiating elements (cf. Fig.1 and Fig.2).

The entire Antenna configuration is deliberate with FR4 epoxy material (ε = 4.4, h = 1.6 mm). The reason behind of rectangular and circular slots in radiating element is to improve the isolation, inclusive of good antenna gain and as well as operating bandwidth.

Rectangular slot as well as circular slots is constantly cut in the patch so that T shape is formed for improving operating impedance bandwidth, returns loss, surface current and inclusive gain. Moreover, MIMO appearances bordering on total active reflection coefficient (TARC), inclusive diversity gain (DG) as well as inclusive envelope correlation coefficient (ECC) is evaluated by resources of ANSOFT HFSS version 13 as deliberated earlier.

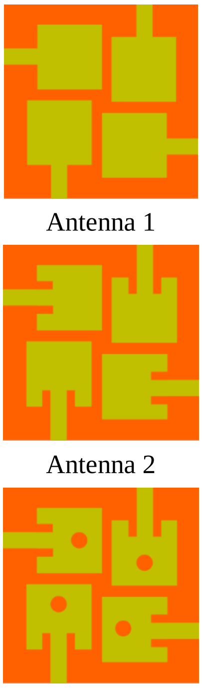

Fig.1 Step-wise evolution of the Antenna-1, Antenna-2 and Antenna-3 (Proposed)

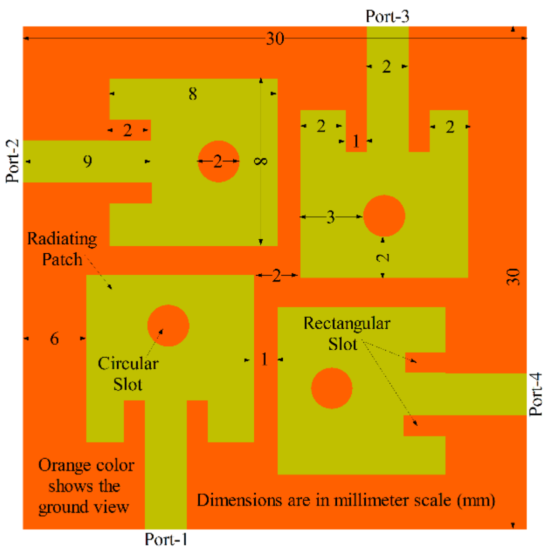

Fig.2. A, Patch (green-color) and ground (orange-color) outlook of the proposed design

3. RESULTS AND DISCUSSION

The proposed antenna is inspected for radiation efficiency, gain, isolation (mutual coupling), radiation patterns, reflection coefficient, ECC, DG as well as TARC.

The Table.1 signifies the data of Antenna 1, Antenna 2 and Antenna 3 correspondingly by the side of entirely ports to be precise 1, 2, 3 and 4 respectively for ready reference. The Table.1 describes the performing bands and percentage impedance bandwidth, resonant frequency (in GHz), reflection coefficient (in dB) and peak gain (in dBi). $|S_{11}|$, $|S_{22}|$, $|S_{33}|$ and $|S_{44}|$ (in dB) vs. frequency are tabularized in Table.1; gain (in dBi) as well as mutual coupling (in dB) is illustrated in Fig.3 – Fig.8 separately.

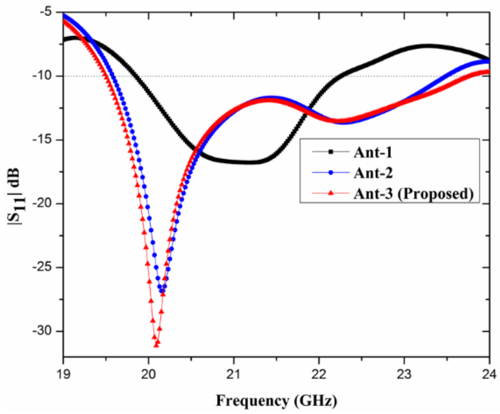

Fig.3. Simulated $|S_{11}|$ curve of the Antenna 1, Antenna 2 and Antenna 3

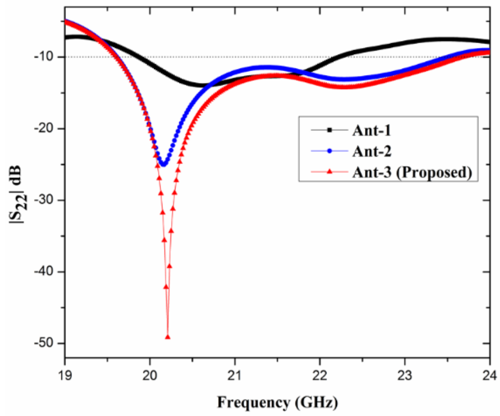

Fig.4. Simulated $|S_{22}|$ curve of the Antenna 1, Antenna 2 and Antenna 3

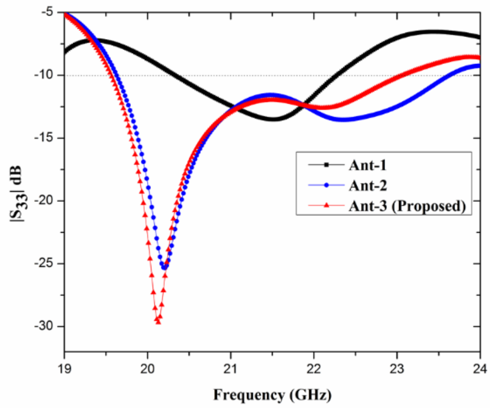

Fig.5. Simulated $|S_{33}|$ curve of the Antenna 1, Antenna 2 and Antenna 3

Table.1. Port Individualities of the Antenna-1, Antenna-2 and Antenna-3

Antenna	Port Representation	Performing band (GHz)/ Impedance BW (%)	Isolation (in dB)	Resonant frequency (in GHz) / Reflection Coefficients (dB)	Peak Gain (dBi)
Ant-1	Port-1	19.83-22.26/11.45	≤ -13	21.23/-16.62	4.07
	Port-2	19.85-22.23/11.31	≤-13	20.60/-13.87	4.1
	Port-3	20.32-22.27/9.1	≤ -13	21.52/-13.38	4.07
	Port 4	20.19-22.46/10.64	≤ -13	21.47/-14.69	4.05
Ant-2	Port-1	19.57-23.45/18.03	≤ -14	20.14/-26.71	4.58
	Port-2	19.59-23.48/18.06	≤-14	20.14/-24.85	4.53
	Port-3	19.61-23.58/18.38	≤-14	20.19/-25.04	4.98
	Port 4	19.59-23.54/18.34	≤-14	20.13/-27.30	4.11
Ant-3 (Proposed)	Port-1	19.48-23.70/19.54	≤-15	20.08/-30.53	5.23
	Port-2	19.58-23.63/18.74	≤-15	20.18/-48.40	5.23
	Port-3	19.54-23.01/16.31	≤-15	20.11/-29.01	5.22
	Port 4	19.39-23.29/18.27	≤-15	20/-41.39	5.23

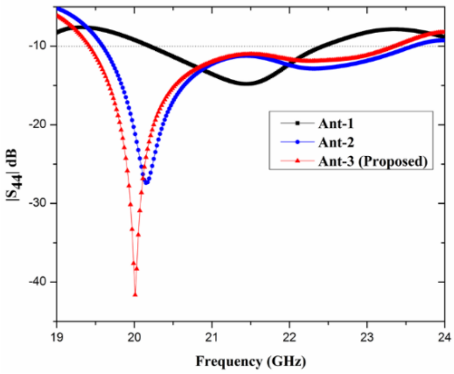

Fig.6. Simulated $|S_{44}|$ curve of the Antenna 1, Antenna 2 and Antenna 3

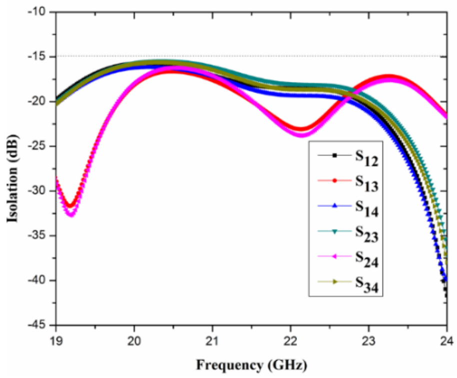

Fig.8. Isolation vs. frequency plot of the proposed antenna (Antenna 3)

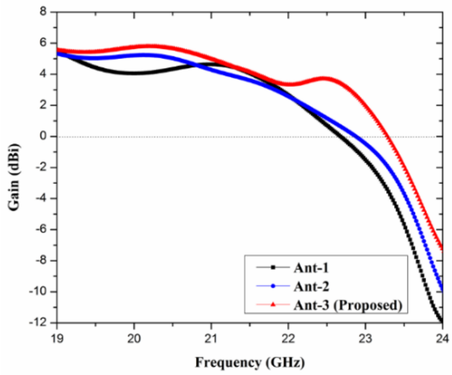

Fig.7. Plot of gain vs. frequency of the Antenna 1, Antenna 2 and Antenna 3

A read-through of Table.1 as well as Fig.3 - Fig.8 clearly show that the performing band, gain and further isolation parameters of Antenna 3 keep on matching by both side of ports through marginal deviations while for Antenna 2 as well as Antenna 3 the deviation in band, gain and also isolation is enhanced for instance equated to Antenna 1 and 2.

Several of the essential accomplishment factors of MIMO structures are ECC as deliberate with Eq.(1) - Eq.(4). The Fig.9 drafts the ECC curvature of the anticipated antenna vs. frequency, the ECC value for ports i.e. 1-2, 1-3 and 1-4 respectively is less than 0.06.

Diversity gain specifies the broadcasting power. DG has been evaluated by using Eq.(5). Diversity gain by the side of several designated frequencies is detected as well as it is originating that the grown values are happening the preferred range i.e. ECC is not more than 0.05 as well as DG nearby towards to 10. Fig.10 displays the significance of DG gotten among ports i.e. 1-2, 1-3 and 1-4 respectively in vary between of 9.969-9.999 (dB).

The Fig.11 demonstrates the TARC along with curve of radiation efficiency vs. frequency. The radiation efficiency exceeds 60% intended for the resonating band of curiosity. On behalf of the effective broadcast of MIMO antenna not more than 0 dB TARC significance is mandatory as well as this one is deliberated via Eq.(6). The TARC is several of the animated factors, which are analyzed proficiently the bandwidth as well as the inefficiency of the MIMO structures. On behalf of the N-component MIMO classification, this one is construed as per the proportion of the sum-up of the square root of the returned signal power to the square root of the power served to the antenna. MIMO methods ensure the bi as well as a_i individualities of the returned power also the occurrence power served just before the antenna then they be presented as $b=[S]a$. The proportion of the TARC targeted at the MIMO structure is obtained by Eq.(6). The isolation significance is ≤-15 dB Fig.8 intended for the perceived bandwidth.

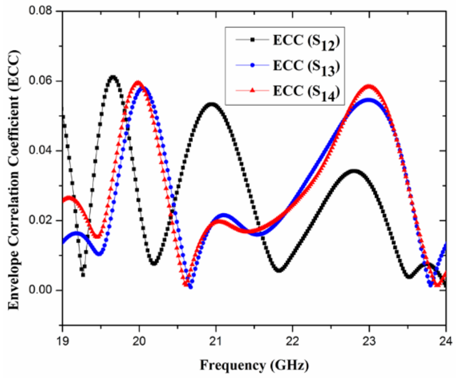

Fig.9. Simulated plot of ECC vs. frequency of the proposed antenna (Antenna 3)

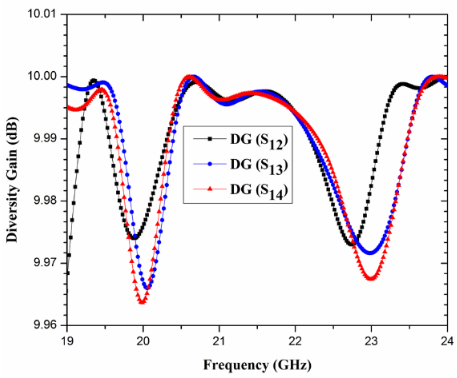

Fig.10. Simulated plot of Diversity gain in competition with frequency of the Antenna 3

$$ECC=\frac{\left|\int_{4\pi} F_1(\theta,\varnothing)\cdot F_2(\theta,\varnothing)\,d\Omega\right|^2}{\int\int_{4\pi}\left|F_1(\theta,\varnothing)\right|^2 d\Omega\int\int_{4\pi}\left|F_2(\theta,\varnothing)\right|^2 d\Omega} \tag{1}$$

$$ECC_{12}=\frac{\left|S_{11}S_{12}+S_{21}S_{22}S_{13}S_{32}+S_{41}S_{42}\right|^2}{\left(1-\left|S_{11}\right|^2-\left|S_{12}\right|^2\right)\left(\left|S_{13}\right|^2+\left|S_{14}\right|^2\right)} \tag{2}$$

$$ECC_{13}=\frac{\left|S_{11}S_{13}+S_{21}S_{23}S_{13}S_{33}+S_{14}S_{43}\right|^2}{\left(1-\left|S_{11}\right|^2-\left|S_{12}\right|^2\right)\left(\left|S_{13}\right|^2+\left|S_{14}\right|^2\right)} \tag{3}$$

$$ECC_{14}=\frac{\left|S_{11}S_{14}+S_{12}S_{24}S_{13}S_{34}+S_{14}S_{44}\right|^2}{\left(1-\left|S_{11}\right|^2-\left|S_{12}\right|^2\right)\left(\left|S_{13}\right|^2+\left|S_{14}\right|^2\right)} \tag{4}$$

$$Diversity\ Gain=10\sqrt{1-ECC^2} \tag{5}$$

$$\Gamma_a^t=\frac{\sqrt{\sum_{i=1}^{N}\left|b_i\right|^2}}{\sqrt{\sum_{i=1}^{N}\left|a_i\right|^2}} \tag{6}$$

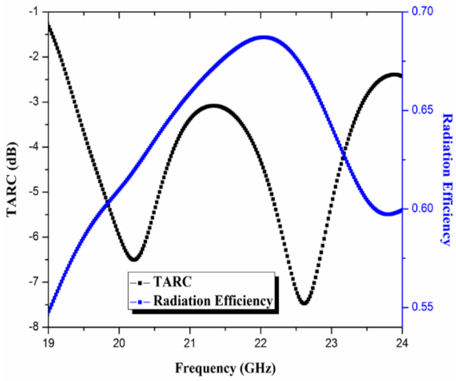

Fig.11. Plot of TARC and Radiation efficiency in competition with frequency of the Antenna 3

By the side of port 1 of the Antenna 3, we detect the surface distribution by the side of particular frequency i.e. 20.08 GHz equally displayed in Fig.12. The surface current on 20.08 GHz be there 77.01 A/m as well as is almost identical for the ports 1, 2, 3, and 4, owing to which, at the present we only display the current distribution aimed at port 1. The current strong point is in elevation as well as correspondingly spread at wholly concluded the patch. This disparate design can consume for *K* band (18-27) GHz uses through quad-port for instance recommended.

Table.2. A comparative overview of the proposed antenna (Antenna-3)

Methods	**Area of Antenna (mm^2)**	**Number of Elements**	**Substrate Material**	**Peak gain (dBi)**	**ECC**	**Isolation (dB)**	**TARC (dB)**
[1]	45×45	4	FR4 (ε_r=4.4, tanδ=0.02)	3.47	< 0.05	< -15	NA
[2]	30×35	4	FR4 (ε_r=4.4, tanδ=0.02)	2.5	< 0.01	< -10	NA
[4]	50×100	4	FR4 (ε_r=4.4, tanδ=0.02)	3.2	< 0.01	< -13	NA
[7]	35×33	4	FR4 (ε_r=4.4, tanδ=0.02)	2.9	NA	<-15	NA
[10]	40×30	2	FR4 (ε_r=4.4, tanδ=0.02)	1.7	< 0.2	< -15	NA
[11]	37.7×25	4	FR4 (ε_r=4.4, tanδ=0.02)	2.84	< 0.02	< -10	NA
Proposed	30×30	4	FR4 (ε_r=4.4, tanδ=0.02)	5.23	< 0.06	< -15	< 0

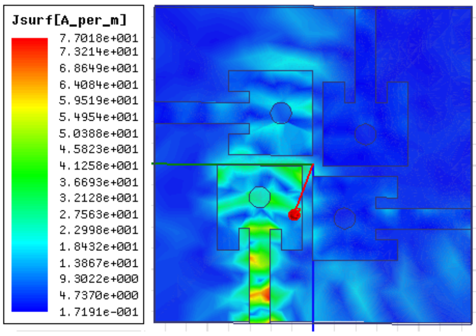

Fig.12 Surface current distribution of the proposed antenna (Antenna 3) at port-1 for 20.08 GHz

The simulated far-field radiation patterns in the E and H-planes of the proposed design (Antenna 3) at 20.08 GHz for port-1 are presented as displayed in Fig.13. The anticipated antenna aimed at entirely resonating frequencies demonstrates omnidirectional wide radiation patterns, which improves the signal acceptance ability irrespective of the polarization.

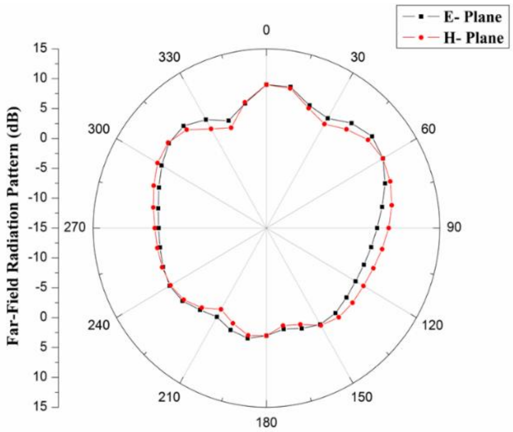

Fig.13. Far-Field radiation pattern of the Antenna 3 by port-1 aimed at 20.08 GHz

4. COMPARATIVE ANALYSIS WITH RECENT ANTENNAS

A comparative overview of the quad-port and T-shaped wideband MIMO microstrip antenna in terms of area of the antenna, number of elements used, material used, peak gain, ECC, isolation and TARC is presented in Table.2.

The proposed antenna occupies a lesser size and superior peak gain as compared to antennas reported in [1] [2] [4] [7] [10] [11]. In proposed antenna exhibited and simulated one more parameter of the TARC function is presented as compared to reported antennas in references [1] [2] [4] [7] [10] [11].

5. CONCLUSION

In this paper, a compact quad-port microstrip line fed based MIMO antenna with wideband characteristics is demonstrated which can be utilized for K band application and in particular for radar application. Proposed antenna operates from 18 GHz to 27 GHz and provides a maximum impedance bandwidth of 19.54% and maximum peak gain of 5.23 dBi.

In proposed antenna, ECC acquired among the ports i.e. 1-2, 1-3 and 1-4 respectively is not more than 0.06, diversity gain lies between 9.969-9.999 (dB), TARC < 0 dB, isolation observed at port 1, 2, 3 and 4 <-15 dB and radiation efficiency is found to be above 60% at the desired frequencies. The MIMO antenna proposed operates proficiently through a considerable reflection coefficient, elevation gain and better isolation, which is potentially effective for radar applications. The leading advantages of MIMO methods are advanced data rate and advanced consistency lacking the necessity of additional power and bandwidth.

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