F-Shape Dual-Band MIMO Antenna System for Next-Generation Smartphone Applications

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Abstract. In this paper, a new F-shape 6-element dual-band multiple-input multiple-output (MIMO) antenna operating in a 5G band for smartphone mobile is presented. The antenna contains six antenna elements covering a dual-frequency range including 3.42-3.77 GHz and 5.30-5.63 GHz of sub 6 GHz 5G spectrums. The elements are fed by F-shaped microstrip feeding lines while the ground is cut in L shape with every antenna element. Fundamental characteristics of the proposed design are investigated. It offers good S-parameters, acceptable isolation, sufficient radiation coverage, and efficiency. At 3.6 GHz the Ant 3 has a maximum return loss of -35dB while Ant 5 and Ant 6 has a maximum return loss of -38dB at 5.4 GHz of the proposed dual-band frequency of 5G smartphones.

Keywords: 5G communication, dual-band antenna, smartphone compact antenna array.

1 Introduction

Since the announcement of 5G New Radio (NR) designs in June 2018, the fifth-generation (5G) communication technique is now anticipating an explosive evolution, and a great need for a new 5G antenna design is projected [1-2]. As mobile and communication technology is established more swiftly so the practise of wireless technology and its applications has been growing very fast as well. This significant development in wireless communication is principally due to the applications of the internet of things (IoT), artificial intelligence and mobile video streaming [3-4]. Fifth-generation mobile networking is the latest vital solution for the bandwidth and improves the advancement of wireless communication technologies and the mounting requirement for cell phone communication configurations throughout the subsequent phase pending 6G arrives [5-8]. To accomplish the superior data rate and low latency 5G is the definitive answer for wireless communication technology [9-10].

Presently, the 5th generation of cellular phone communication (5G) of the band is recognized as dual frequency bands in 3.42 – 3.77 GHz and 5.30 – 5.63 GHz. The aggregate of 700 MHz bandwidth can be achieved [11-13]. Then in communication systems, multiple-input multiple-output (MIMO) techniques can substantially enhance range operation and channel capability without increasing transmit power and increasing extra transmission bandwidth. Nevertheless, as the miniaturization and probability of wireless gadgets turn out to be the typical mainstream, the accessible spaces for the antenna are further inadequate [14-16]. Hence, it is extremely crucial to project an efficient MIMO antenna. To adopt the frequently utilized wireless machines, publishing MIMO antenna is additional alternatives. Though, there is powerful mutual coupling when the space amongst MIMO antenna components is very close together. It is perverse to the aspiration for sharper isolation and lowers envelop correlation coefficients. Therefore, it is crucial to diminish the mutual coupling among the antenna components [17-18].

However, as the miniaturization and portability of wireless devices become mainstream, the available space for antennas is more limited. Therefore, it is very necessary to design a compact MIMO antenna. In order to adapt to the commonly used wireless devices, printing MIMO antennas is a necessary choice[19]. However, there is strong mutual coupling when the distance between MIMO antenna elements is very close. It is contrary to the desire for higher isolation and lower envelope correlation coefficients. Hence, it is indispensable to reduce the mutual coupling between the antenna elements[20].

In the proposed design, a dual-band 6 elements MIMO antenna array is accessible which covers 3.42 – 3.77 GHz and 5.30 – 5.63 GHz. The modernization of the decoupling proposal anticipated in this editorial does not simply increase the separations efficiently, but moreover creates a new booming theme in an alternative frequency band, which covers 5.30 – 5.63 GHz to attain a dual-band working performance, thus it can efficiently develop space use in mobile devices [21-23]. The particulars of the presented MIMO compact antenna array are designated, and the results of S-parameter, maximum gain, user effects, radiation and total efficiency of MIMO antenna array are also presented.

2 Design and Configuration

The design of this compact mobile MIMO 6-terminal antenna array is established via CST Microwave Studio electromagnetic simulation software [24]. The proposed design was developed on an FR4 substrate with relative permittivity ε_r=4.3 and dielectric loss tangent δ=0.019. The size of the main substrate is 140×70 mm^2 shown in Figs. 1 and 2 show the Front Side and BackSide respectively, which is almost the identical measurement of today's smart mobile phone. Table 1 shows the detailed dimensions of the antenna parameters.

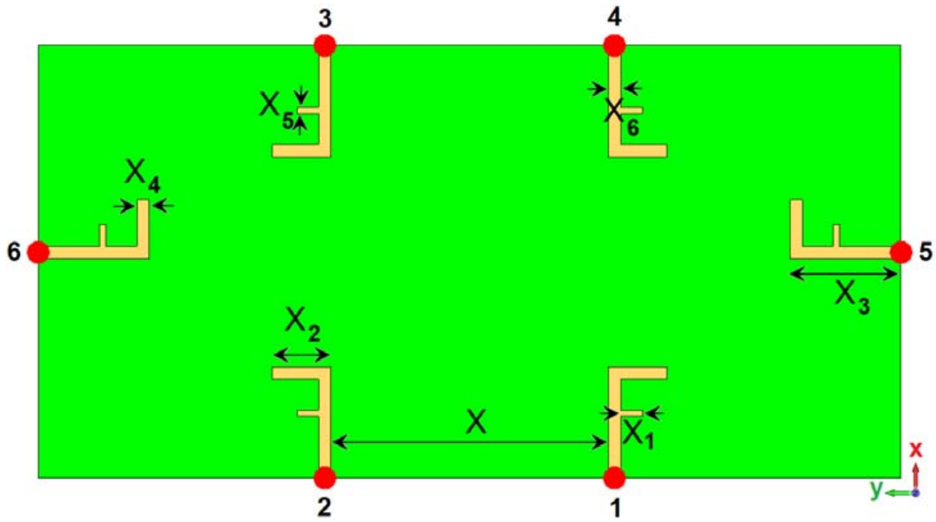

Fig. 1. Front View of Schematic structure of the designed MIMO smartphone antenna.

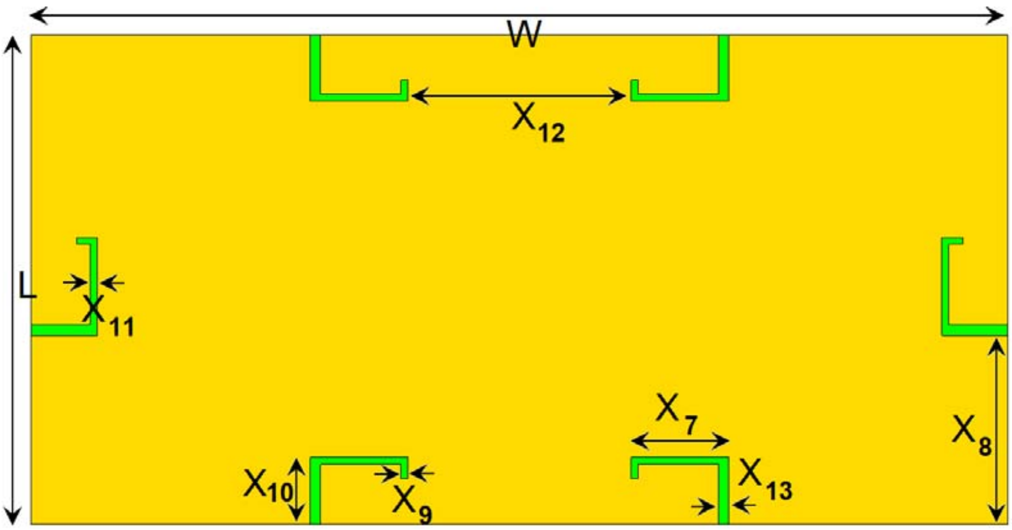

Fig.2. Bottom View of Schematic structure of the designed MIMO smartphone antenna

Table 1. Final dimensions of the antenna parameters.

Parameter	**W**	**L**	h_{sub}	**X**	X_1	X_2	X_3	X_4	X_5
Value (mm)	140	70	0.8	48	4	8	18	2	1
Parameter	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	
Value (mm)	2	11.5	41.5	1	9.5	1	32	1.5	

3 Results and Discussions

In this paper, the parameters and performance of the suggested 6-terminal MIMO antenna arrays are investigated using CST software[28]. Every element is attached to a 50-ohm SMA connector to attain adequate S-parameters and the antenna was focused on attaining the detailed polarization return loss, radiation pattern, resonant frequency, and gain are the constraints that will be discussed in this paper.

The proposed 6-elements MIMO array operates at the dual-band from 3.42 – 3.77 GHz and 5.30 – 5.63 GHz covering the sub 6 GHz frequencies for the 5G mobile communications. Fig. 2 shows the return loss (S_{nn}) of the proposed antenna while Fig. 4 shows the mutual coupling (S_{mn}) of the proposed antenna. As shown, the simulated S_{55} and S_{66} are smaller than -20dB at 3.6 while the simulated S_{11}, S_{22}, S_{33}, and S_{55} are less than -21dB at 5.45 GHz, respectively. However, for antenna elements including 1, 2, 3 and 4 the S_{nn} results are less than -35 dB at 3.6 GHz while for antenna elements 5 and 6 the S_{nn}. Results are less than -40dB. At 5.45GHz. This is mainly due to the placement of the antenna elements [29-33]. As illustrated in Fig. 4, the antenna elements exhibit good mutual coupling results better than -15 dB and -12 dB at two operation bands.

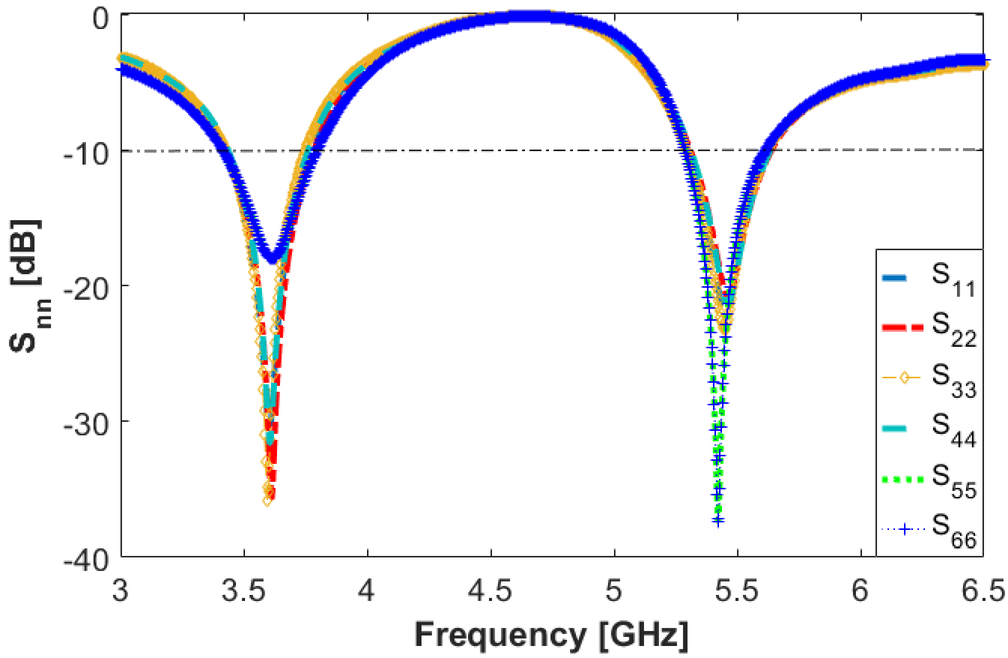

Fig. 3. Simulated return loss (S_{nn}) of the MIMO antenna array.

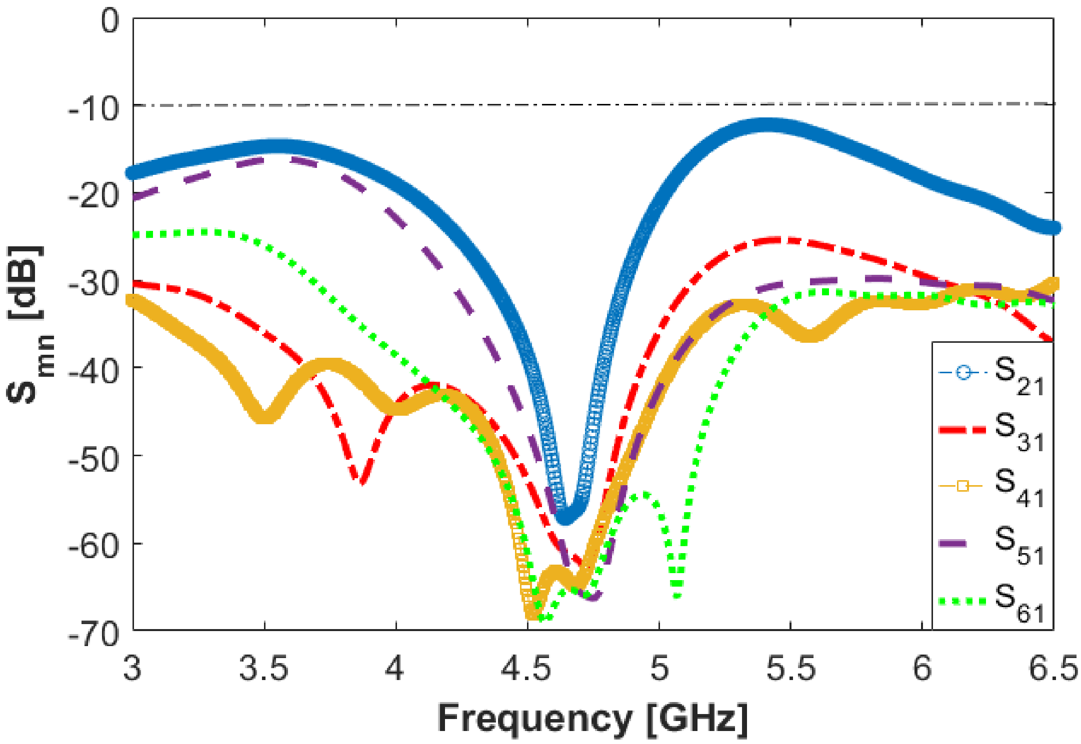

Fig. 4. Simulated mutual coupling results (S_{mn}) of the MIMO antenna array.

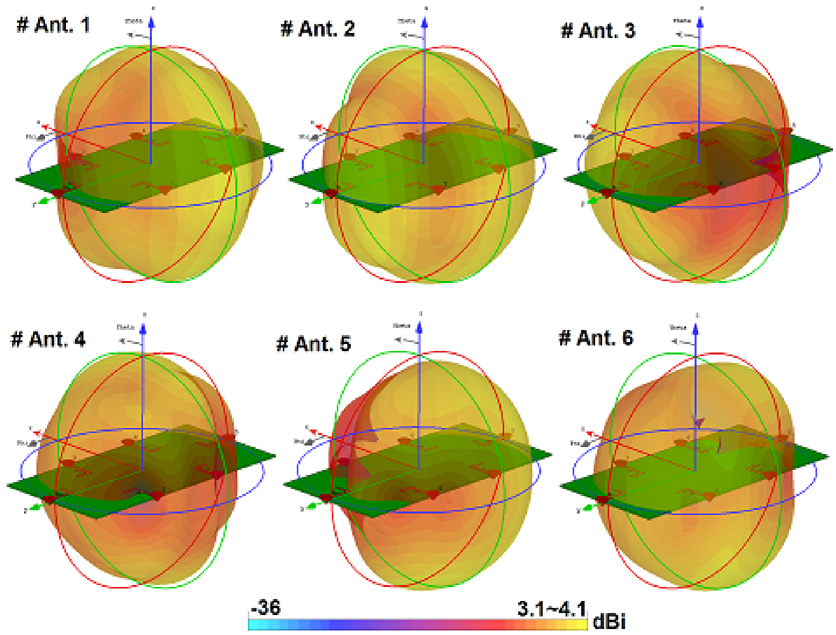

Fig. 5. 3D radiation patterns at 3.6 GHz.

The 3D radiation patterns for the six elements of the main design at both operation frequencies including 3.6 GHz and 5.45 GHz are displayed in Figs. 5 and 6, respectively. It can be observed that the 6-element MIMO antenna can offer sufficient radiation coverage for each radiator [34-37]. As illustrated, 3.6 GHz, the IEEE gain level of the design varies from 3.1 to more than 4.1 dB. However, at the second operation band (5.45 GHz), the elements exhibit constant gains of 5.8 dB.

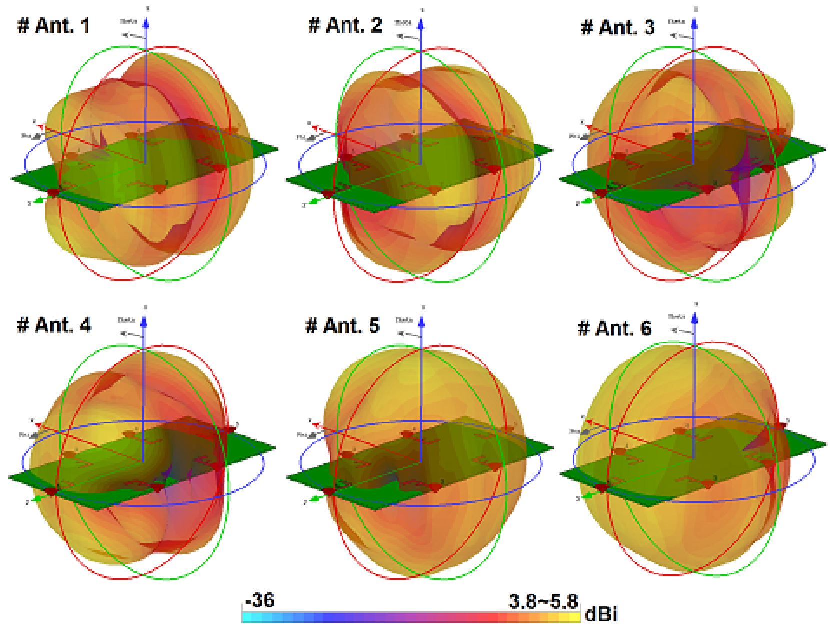

Fig. 6. 3D radiation patterns at 5.45 GHz.

The efficiencies (radiation and total) of the antenna resonators are also given in Figs .7 and 8. It is evident that high efficiencies with slight variations are achieved within the operation bands [38-40]. More than 95% and 90% radiation efficiencies were observed for the elements of the proposed MIMO design at the first and second operation bands. Moreover, as shown in Fig. 8, the antenna elements provide more than 75% and 80% total efficiencies.

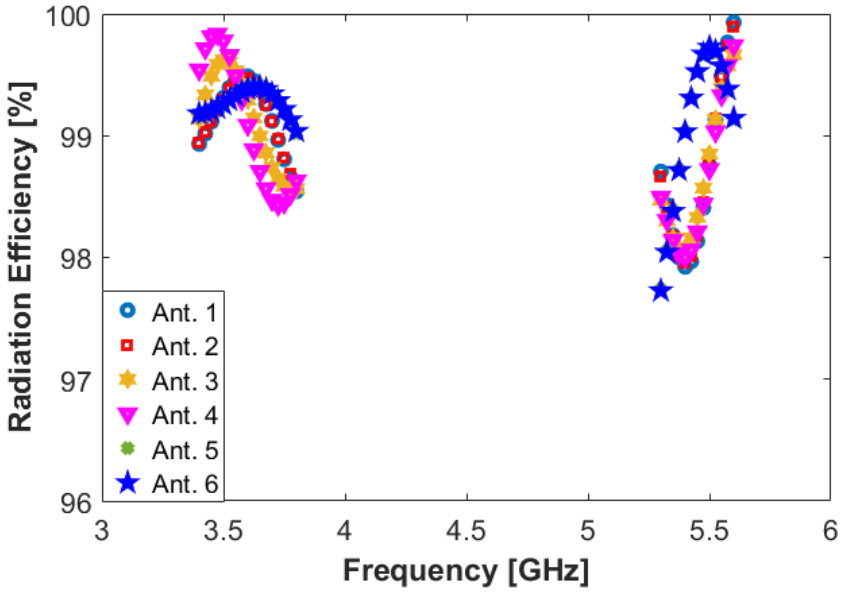

Fig. 7. Radiation efficiencies of the MIMO antenna over its operation band.

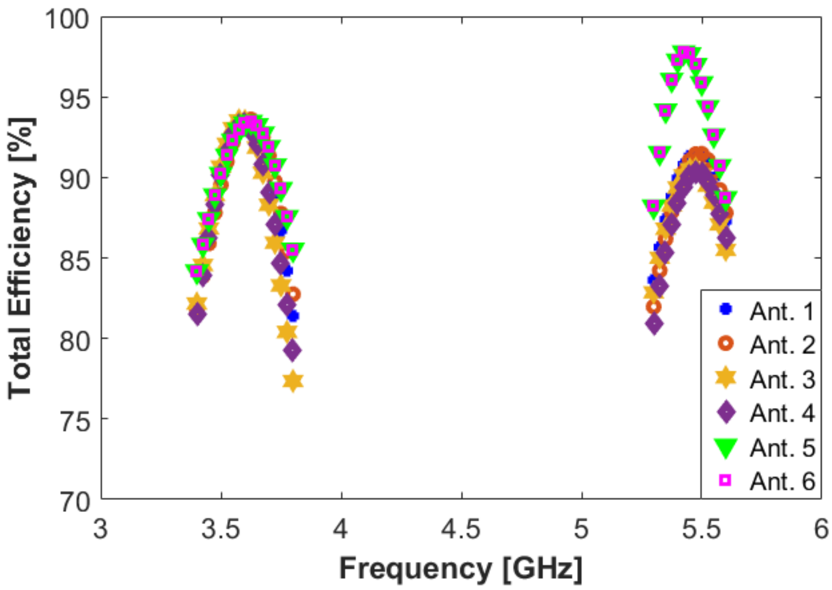

Fig. 8. Total efficiencies of the MIMO antenna over its operation band.

The maximum gain results of the antenna elements are shown in Fig. 9. It is seen that all antenna elements exhibit more than 3 dBi up to 6.5 dBi maximum gains at different frequencies. As shown, unlike the first operation band with a centre frequency of 3.6 GHz, the maximum gains of the antenna at the second resonance are almost constant with the value of 6 dBi.

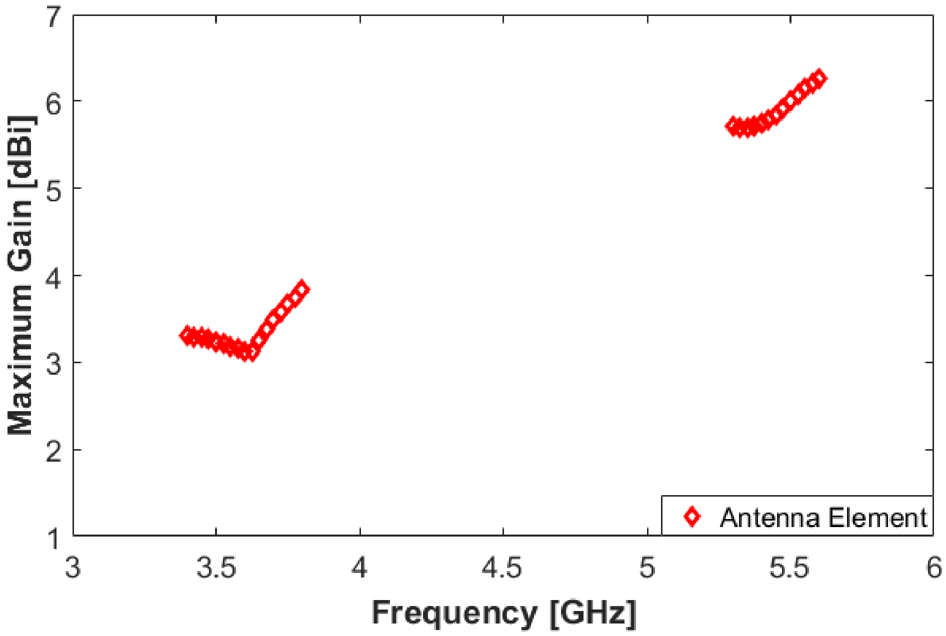

Fig. 9. Maximum gains of the MIMO antenna over its operation band.

4. Conclusion

In this proposed article, an F-shape dual-band 6-port MIMO antenna array for 5G applications has been presented. Utilizing a part of the copper edge as a radiation branch, the antenna array can work appropriately in a metal-frame smartphone. The consequences demonstrate that the working frequency band of the presented mobile antenna array can cover 3.42 – 3.77 GHz and 5.30 – 5.63 GHz. The antenna radiation and total efficiencies within the operating bandwidth are higher than 80% and 90% respectively. All results specify that the suggested MIMO antenna array is a worthy candidate for the future 5G massive MIMO mobile communication systems.

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