Microstrip Patch Antenna Design and Implementation for 5G/B5G Applications

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***Abstract*—As demand for video downloads, wearable devices, and the Internet of Things (IoT) skyrockets, the next generation of communication systems will concentrate on attaining fast data transfer speeds and low energy consumption. These gadgets will be used for several applications, such as healthcare, environment monitoring, tourism, smart grid, intelligent traffic management, and agriculture. New applications need a fast transmission rate and bandwidth for data. The antenna is a crucial component inside communication systems that determines its bandwidth, data rate, and capabilities. Therefore, the authors of this work designed and modeled a microstrip patch antenna (MPA) for 5G and Beyond 5G (B5G) applications at 26 GHz frequency using millimeter wave bands. In this proposed design, CST software was used to design and model the antenna.**

Keywords—Microstrip Patch Antenna, millimeter wave bands, 5G, B5G, CS software

I. Introduction

In recent years, the global need for safe, quick, and substantial data rates has skyrocketed in several modern and sophisticated applications, including video calls, emergency communication, broadcasting, smart energy, the Internet of Everything (IoET), and emergency communication[1]. The huge demand for faster data rates adds considerable pressure on existing cellular and WIFI communication networks to improve the performance and abilities[2], [3]. Every successive generation of wireless and mobile communication systems has been created to accommodate these requirements. Despite this, the applications' data-hungry technologies have expanded, necessitating huge data rates[4], [5].

Bandwidth is a probable method for increasing data rates and capacity in the present and upcoming generations of cellular and wireless[6]. Data rates and bandwidth are firmly connected, where increased bandwidth increases the data rate[7].

To increase the quality of mobile communication, a faster data rate and wider bandwidth are required than the current 4G wireless infrastructure. The current 4G data rate cannot sustain the revolution in mobile communication and ultra-high-resolution 4K-8K podcasts. A rectangular microstrip patch antenna (MPA) was designed to offer high gain, high bandwidth, excellent antenna radiation efficiency, and a good reflection coefficient for the 5G and beyond 5G (B5G) millimeter wave bands at a 26 GHz frequency [8].

The MPA is crucial for wireless communication devices because of its small size and excellent properties. A ground plane, a dielectric substrate, and a copper or gold metallic patch that is very thin are the main parts of the MPA. The ground plane and the patch are isolated from the dielectric substrate. MPA can be divided into several kinds, including rectangular, circular, dipole, triangular, elliptical, and square patch antennas[9]. Typically, circular and rectangular Microstrip antennas are employed. 5G and B5G applications represent the most demanding applications for these two patch antennas. The suggested work has a bandwidth of more than 2.667 GHz and a loss of -40.287dB at a 26 GHz frequency. The proposed design is an MPA developed utilizing the X-band corporate feed technique[10]. This study ensures that newly created communication apps have uninterrupted access to fast data rates and wider bandwidth.

The rest of the paper is arranged as follows: section 2 investigates the frequency spectrum for 5G and B5G. Section 3 goes through the design for the rectangular MPA. The findings of the invention, including analysis and simulation results, are presented in Section 4. Finally, section 5 provides the conclusion and a synopsis of the whole study.

II. Frequency Spectrums for 5G and B5G

Current frequency ranges, such as 1,7 GHz for the GSM band, 2.0 GHz and 1.8 GHz for the 4G/LTE band, and 2.6 GHz and 2.1 GHz for the LTE band, all provide insufficient bandwidth in comparison to the bandwidth needs of future applications. Recently, the high-frequency bands 39 GHz, 37 GHz, 28 GHz, and 24 GHz were proposed for 5G applications[2]. High-frequency bands, often known as mm-wave bands, may provide an extensive bandwidth > 500 MHz. However, present 5G telecommunication runs in the sub-6 GHz spectrum, i.e., 4.4 GHz to 5 GHz and 3.3 GHz to 4.2 GHz. Although there have been advancements to the wireless communication system, such as the use of more contemporary and many multiple-input multiple-output (MIMO) antennas[11], [12], the bandwidth at sub-6 GHz continues to limit the data rates.

The consideration of massive MIMO and mm-wave spectrum for 5G has garnered significant work in recent years[13]. Multiple antennas in wireless communication systems, particularly those operating at mmWave and THz frequencies, have the potential to enhance service quality significantly. Due to the fact that getting precise instantaneous channel state information (CSI) might cost a significant amount of bandwidth, statistical CSI-dependent approaches are favored.

Nevertheless, the fundamental barrier is the restricted presented space, particularly in a compact, smart wearable and mobile devices. Current smart wearable devices and mobile terminals that work on many bands, such as GPS, WIFI, 3G, and 4G, are crowded, advancing in sophistication, and reducing in size. Therefore, multiband antennas that are more compact are desired[14].

Moreover, 3G/4G/Wi-Fi and sub-6 GHz 5G will continue to exist throughout the transition to mm-wave 5G connection. Also needed are integrated antenna modules adopting antenna topologies with standard aperture.

Additionally, the coverage area is vital to the current and future communication system. The 5G systems cannot provide entire coverage with the same data speeds for external communications, such as those in the air, on the water, or in isolated or rural locations.

Due to the progress of transition technologies, it is projected that B5G will be implemented by 2030 or earlier, based on previous mobile transitions in which each generation took about a decade to be implemented (4G 2010s, 5G 2020s).

Throughout the shift to the 5G and B5G communication systems, Wi-Fi/3G/4G communications technology will continue to exist. Consequently, sub-6 GHz communication will remain to function and be included in B5G communication[15], [16]. Recent 5G communication, particularly mobile communication, has indeed begun and runs on frequency ranges lower than 6 GHz. The sub-6 GHz bands for 5G are shown in Table I:

TABLE I. THE SUB-6 GHZ BANDS FOR 5G

Country	Frequency Band
China	3300–3600 MHz
	4800–5000 MHz
Europe	3400–3800 MHz
United States	3700–4200 MHz
	3100–3550 MHz
South Korea	3500 MHz

Fig. 1. Comparison between 5G and 6G Spectrum

At a higher frequency, a larger bandwidth is projected, which will ultimately increase data rates. Therefore, it is envisaged that B5G communications would use mm-wave frequency bands between 30 and 100 GHz and THz frequency bands between 100 and 300 GHz [6]. Therefore, the B5G communication system will consist of mm-wave, sub-6 GHz (BW 0.1 GHz), and THz (BW > 10 GHz) bands [3]. The spectrum components and applications of 5G and B5G are shown in Figure 1. This research focuses on creating an MPA for 5G/B5G applications in the so-called mid-band spectrum at 26GHz [17].

III. Rectangular Microstrip Patch Antenna Design

Rectangular MPAs have the best configuration of all known patch geometries and are thus widely used[9]. Significantly, the dielectric material is Flame Retardant fiberglass epoxy FR-4(loosely) with a constant □r equal to 4.4 and a height of 1.6 mm. The substrate material is copper annealed, which has a high degree of flexibility and was chosen as the best electric substrate with a reduced dielectric constant for the design of this 5G application. The next crucial step is to compute the patch's length and width using equations (2) and (1) and to choose the appropriate resonance frequency from the millimeter-wave spectrum; the authors have selected 26 GHz [8]. The MPA design parameters are shown in TABLE II below.

TABLE II. THE SUB-6 GHZ BANDS FOR 5G

Parameters	Parameters Symbols	Value(mm)
Length of Substrate	L_S	11.367
Width of Patch	W	4.5
Width of Substrate	W_S	13.144
Length of Patch	L	11.73
Width of Microstrip line feed	W_F	1
Height of Substrate	h	1.6
Length of Microstrip line feed	L_F	4.8

The width and length of the patch are determined by the following design equations [6]

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

where ε_r is the dielectric constant for the substrate, fr is the resonant frequency, and c is the light velocity.

$$L = L_{eff} - \Delta L \quad (2)$$

standard Where L_{eff} is effective patch length stated as follows:

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} \quad (3)$$

where ε_{eff} is the dielectric constant calculated as follows:

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{W} + \frac{\varepsilon_r-1}{W}\left(1+\frac{12h}{W}\right)^{-\frac{1}{2}} \quad (4)$$

And ΔL is the expanded total length as described below:

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (5)$$

The suggested MPA architecture with dimensions (WS LS) is shown in Figure 2. The used dimensions are shown in Table I.

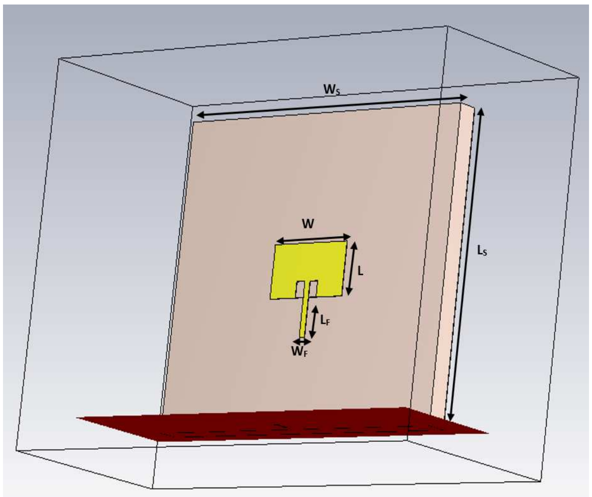

Fig. 2. Geometry of the proposed rectangular microstrip patch antenna

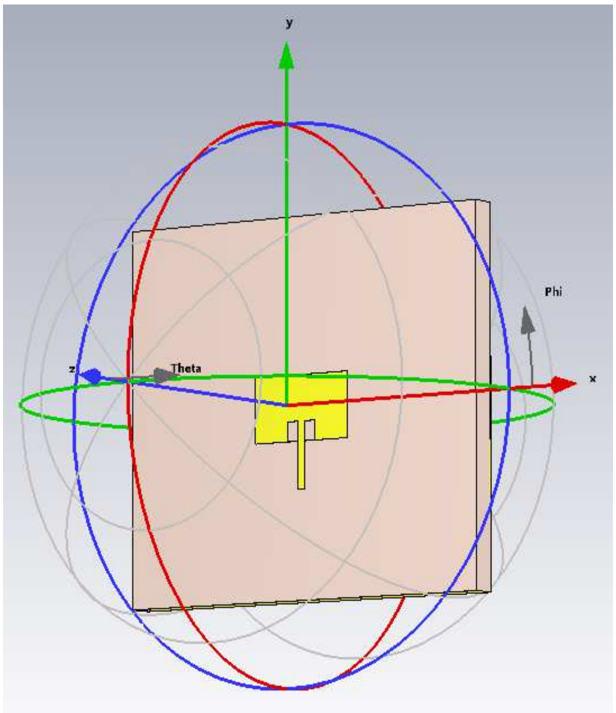

Fig. 3. 3D Geometry of the proposed rectangular microstrip patch antenna

III. Analysis And Simulation Results

After the authors calculate the design parameters for MPAs, the next step will be to simulate and analyze the proposed design. The simulation was done by using CST Studio Suite. CST is a collection of simulation tools used in the electromagnetic field. CST gives the ability to design and monitor the proposed patch.

A. *Reflection coefficient*

The symbol denotes the reflection coefficient, known as the return loss (S11). Because the return loss of an antenna indicates a ratio of the incoming power to the reflected power, an antenna's performance is often based on a reflection coefficient" S11" or return loss of at least -10 dB or, in some cases, less than -15 dB. Suppose the reflection coefficient is 0 dB; in this situation, no energy has been emitted since all the energy has been reflected off the antenna [8], [9]. As seen in Figure 4, the S11 return loss equals -40.287 dB, and the bandwidth is more than 2 GHz. With such a significant bandwidth and excellent return loss, which indicate the amount of collected power of more than 99% in the band centered around the operating frequency 26GHz, it is feasible to transmit ultra-high quality video streaming such as 4K-8K films without hindering in the streaming of the signal, which is tremendously convenient for several applications such as online health care, online education, tourism, and agriculture.

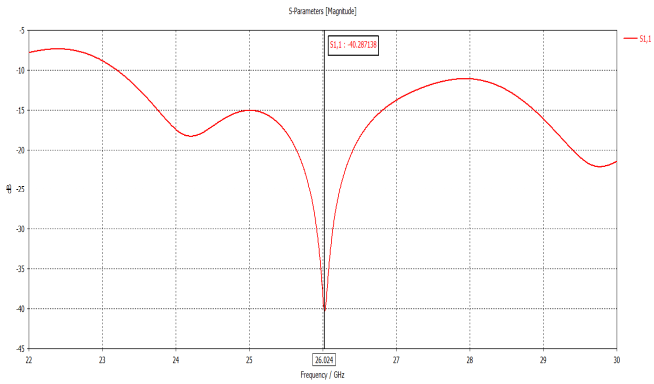

Fig. 4. Plot of S parameters

B. *Voltage Standing Wave Ratio (VSWR)*

The value of the standing wave ratio refers to the proportion of voltage standing waves. This ratio should fall between the area 1<VSWR<2 for Health care and e-learning/teaching applications to adopt MPA design. This value often appears as a positive and real number according to the models in the calculation process. The mismatch is higher the more significant the VSWR value. In Figure 5, the proposed microstrip rectangular patch antenna produces a value for VSWR equal to 1.03 at 26 GHz. The value of VSWR for the proposed patch indicated that the matching between the fed line and the antenna is perfect, and most or almost all the power will be transferred.

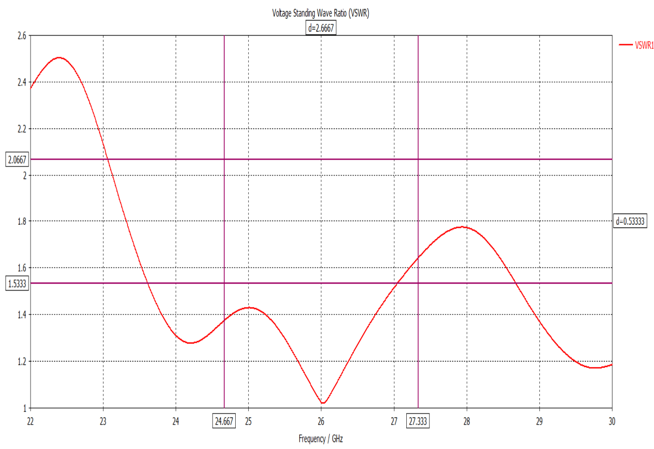

Fig. 5. Plot of Voltage standing wave ratio

C. *Radiation Pattern*

Figures 6 and 7 exhibit 10 dB gain 3D and 2D radiation patterns, respectively. This radiation pattern shows the amount of power produced by the antenna; hence, 5G and B5G wireless systems must have extremely high gain.

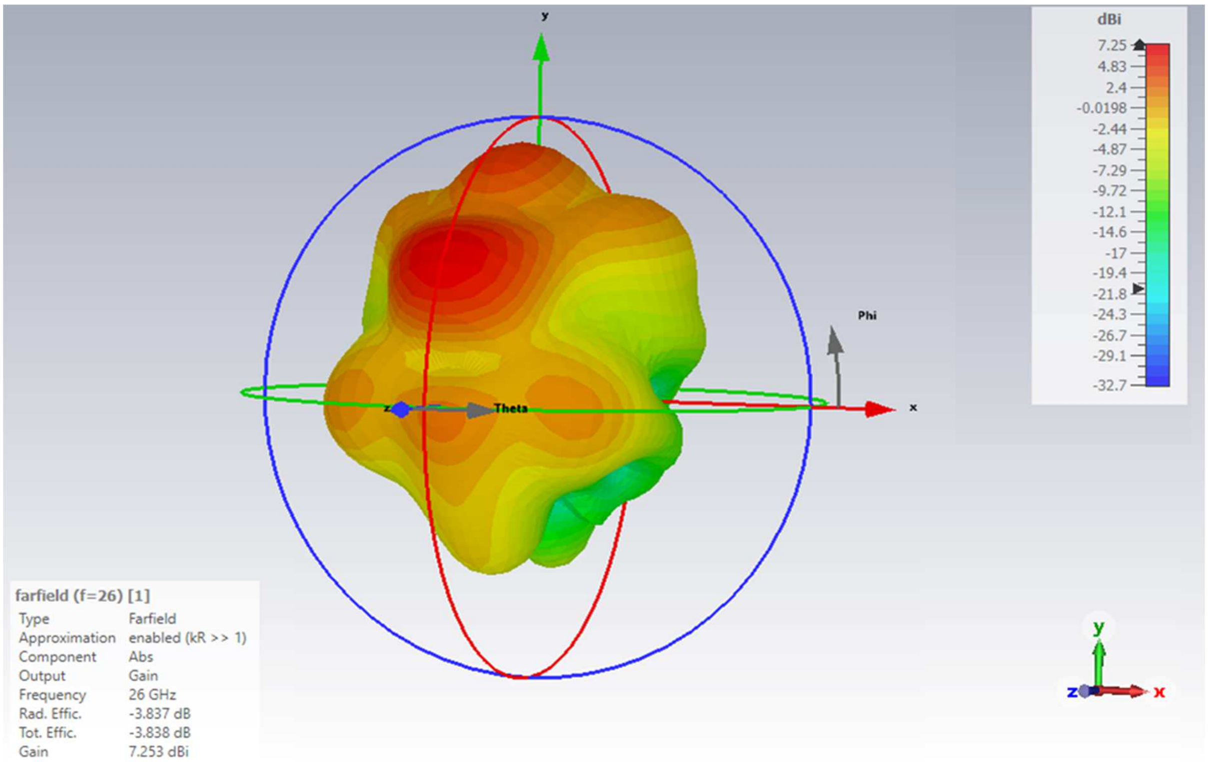

Fig. 6. Plot Of 3D Radiation Pattern

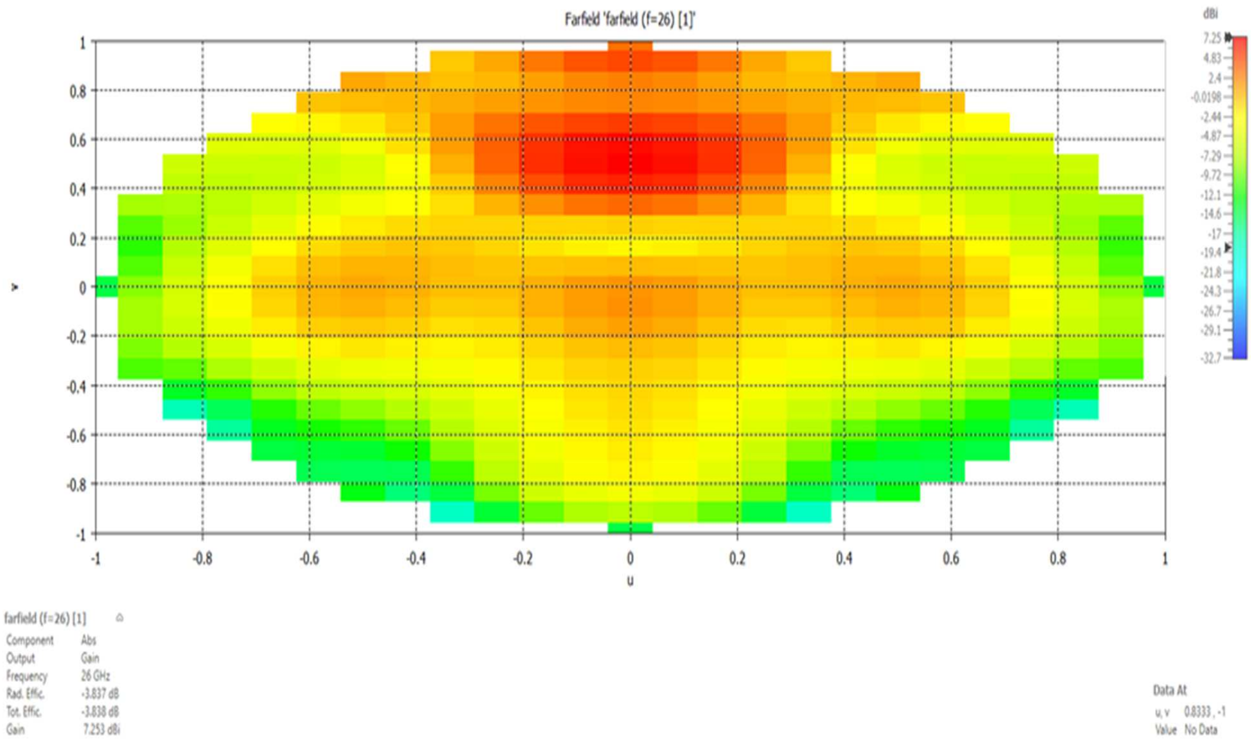

Fig. 7. 2D Radiation Pattern Plot

D. Antenna Radiation Efficiency

Fig. 8 shows the power values in the suggested antenna parts, implying that the input power has been effectively radiated.

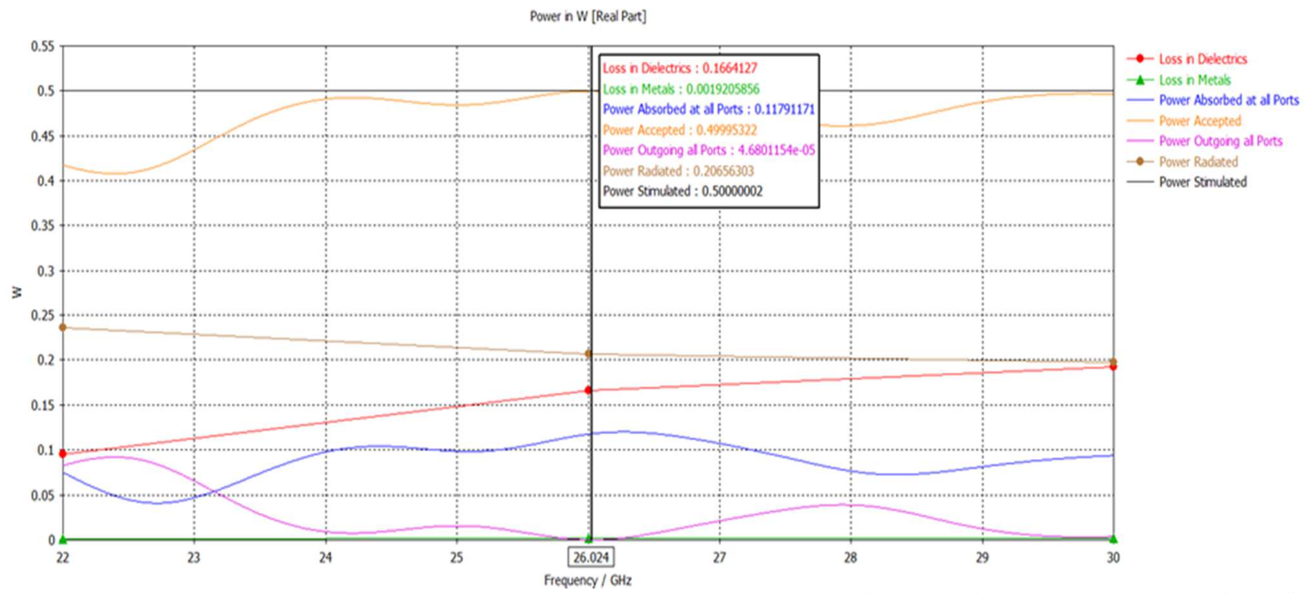

Fig. 8. Plot of Antenna Power

IV. CONCLUSION

Using CST software, the suggested microstrip rectangular patch antenna was modeled, developed, and simulated at the center frequency of 26 GHz. CST software is more authoritative than other antenna software for designing and visualizing reliable results; it also produces the radiation pattern in the form of 3D, which improves the image of the actual situation of the signal emission. The simulation results indicate that the suggested MPA has a maximum gain of 7.25 dBi. That gain in the wider bandwidth of more than 5 GHz made the patch a trustworthy choice in many applications like high-quality healthcare, Tourism, live far distance teaching, and agriculture applications, as well as the ability to transmit and receive other 4K-8K visual content and other 5G and B5G applications, a better and better return loss of -40.287 dB, a However, the return loss S11, and VSWR in the desired bandwidth of our proposed antenna are very, will which lead to Getting the most out of the signal exchange process. In the future, it will be feasible to attain a broader bandwidth, a minor return loss, and a more significant gain by designing antennas with array components.

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