

# Dual Band David Fractal Microstrip Patch Antenna for GSM and WiMAX Applications

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Received 15 May 2015; accepted 6 June 2015; published 9 June 2015

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## Abstract

The design and development of a proximity fed dualband microstrip patch antenna based on David fractal geometry are presented. David fractal microstrip antenna offers good performance in the 1.754 - 1.816 GHz and 3.37 - 3.415 GHz bands and is suitable for GSM 1800, WiMAX applications. The use of David fractal geometry offers miniaturization of the antenna structure. The proposed first iteration fractal configuration is fabricated and measured results along with simulation results are presented. Good radiation patterns and moderate gain are also obtained.

## Keywords

Microstrip, David Fractal, Proximity Feed, Dualband

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## 1. Introduction

Nowadays antennas with multi-band and smaller dimensions than conventional ones are preferred. Multiple resonances with good gain in a single patch are not directly attainable in simple microstrip antenna. Various techniques have been utilized in the antenna research to reduce size and to achieve multi-band characteristics in a single patch. A review of various techniques to minimize the antenna size is given in Ref. [1]. In [2] miniaturization of the patch antenna is obtained by combining two techniques, inserting slots as inductive loading and making some short point in the middle of the patch. In [3] a technique is proposed for reducing the size of a shorted microstrip patch antenna where notches are placed near the shorting pin and feed. And another technique is employed to achieve antenna size reduction by increasing the electrical length of the antenna [4]. Numerous research papers have reported for achieving dual band operation of microstrip antennas. A novel design of a dual band planar monopole antenna, consisting of a rectangular strip ring with double meander-lines and a top loaded vertical strip, is presented in [5]. In [6] slot antennas were used to achieve multiband characteristics. The conventional monopole CPW fed antenna with a U shaped strip and a pair of L slits in the ground plane to develop

multi-band antenna is presented in [7]. In [8] multi-band probe fed stacked patch antenna for global navigation satellite systems is reported which is intensively used both in civilian and military application.

Recently fractal techniques have been widely applied to antenna design to reduce the antenna size and to achieve multi-band behavior. Fractal antennas can be physically small but have electrically long lengths in small packages. Fractal geometry composed of multiple iterations of a single elementary shape, can be continued infinitely thus forming a shape within a finite boundary but of infinite length or area. This compactness in property is highly desirable in mobile wireless applications. The advantages of fractal antenna compared with a standard microstrip antenna are centered on miniaturization and bandwidth. Various geometries have been utilized to develop fractal antennas in order to have multi-band characteristics and miniaturization. Much intensive researches have been done in recent years to develop fractal antennas: long periodic fractal Koch antenna [9] and bow shaped fractal helix antenna [10]. A modified Minkowski fractal geometry for multiband operation is presented in [11]. Koch-like curve and Sierpinski Gasket are synchronized in a way, comprising so called Sierpinskized Koch-like sided bow-tie (SKLB) multi-fractal to achieve size reduction and multi-frequency use [12]. A plus shaped slotted fractal antenna with first and second iteration is reported in [13] that gives a good size reduction and enhanced band width.

Compared with the conventional square and circular patch antennas nowadays a lot of fractal antennas are developed with pentagon and hexagon shaped patches. A slotted grounded hexagonal microstrip antenna with a parasitic element is presented in [14]. Pentagonal shape for basic fractalization combined with inner sides etched with Koch fractal is reported [15] with achievement of good size reduction. A circular-hexagonal fractal antenna where iterations of a hexagonal slot inside a circular metallic patch is done to achieve multi-band behavior [16]. Another hexagonal fractal microstrip antenna where iterations of hexagonal slot inside a hexagonal patch with multi-band and broad band characteristics has been demonstrated in [17]. In [18] a CPW feed dual band fractal antenna structure is formed by inscribing a hexagonal slot within a circle.

The recent growth and rapid development of mobile communication systems and devices operating at multiple frequency bands have led to the requirement of antennas which support multi-band or wideband operation. Various wireless communication services have been available which may use frequency spectrum allocation like WiMAX/Wi-Fi etc. along with GSM communication system. This leads to development of multi-band antennas, where GSM mobile communication as well as WiMAX/Wi-Fi can be used simultaneously. Various research papers have reported about dual band antennas that are suitable for above mentioned application [19] [20]. The WiMAX standard has the advantage of allowing wireless connection between a base transceiver station and thousands of subscribers without requiring the subscriber to be in a direct line of sight with the station, called non line of sight communication [NLOS]. This gives users the mobility to move around within a broad coverage area and still be connected to the network, to provide high speed internet access. The advantage of multi-band antenna is the ability to integrate several frequency bands on one single antenna, making it useful for several frequency ranges.

In this paper, a novel hexagonal fractal microstrip antenna is proposed for multi-band applications. David fractal [21] concept is introduced into a hexagon shaped microstrip patch antenna to obtain multi-band behavior and miniaturization. This hexagon shaped dual band David fractal microstrip patch antenna resonates at 1.8 GHz and 3.4 GHz. The first frequency is used for GSM cellular communication and the second frequency is used for WiMAX applications. In order to obtain antenna, with optimized parameters, simulation studies were carried out using CST microwave studio. In the proposed antenna, at upper resonance frequency the maximum power received will be at  $43^\circ$  away from the bore sight, and these characteristics may find applications in non-line of sight communication including WiMAX [22].

## 2. David Fractal Geometry

The fractal design of antennas results from the blend of two discipline, electromagnetic theory and fractal geometry. The term fractal and fractal dimensions were coined by B. Mandelbrot [23]. Mandelbrot defined a fractal as a rough or fragmented geometric shape that can be subdivided in parts each of which is a reduced copy of the whole. The David fractal is a class of fractal geometries whose recursive procedure is demonstrated in **Figure 1**. The David fractal pattern is formed from the basic hexagon shaped patch or the initiator as in **Figure 1(a)** by dividing it in to six smaller hexagons, six equilateral triangles and a David star at the center; the triangles and the star are removed. It results in first iteration level as shown in **Figure 1(b)**. The second iteration as shown in

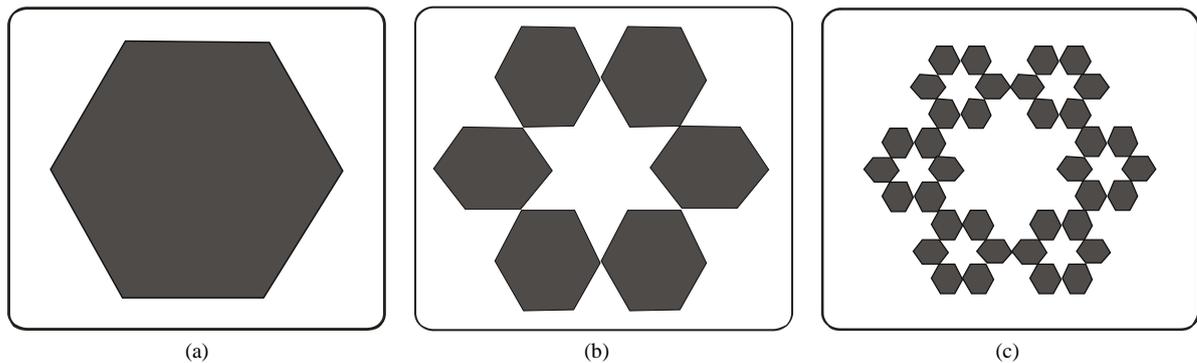
**Figure 1(c)** is a reduced copy of the design of the first iteration repeated in each smaller hexagon. From the iteration stages it is observed that at the end of the first iteration stage six smaller hexagons with equal dimensions are produced and at the end of the second iteration stage thirty six further smaller hexagons are produced. The six hexagons of the first iteration stage are fractalized in to thirty six hexagons.

### 3. Antenna Configuration

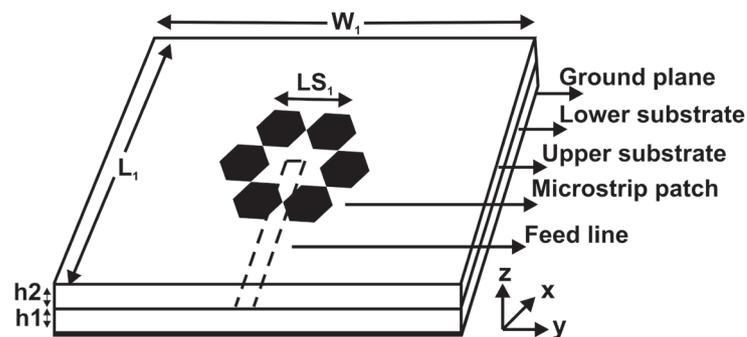
The antenna is fabricated on an FR-4 substrate of thickness 1.6 mm with relative permittivity of 4.4 and loss tangent of 0.002. The zeroth iterated level antenna consists of a hexagonal patch, with each side of the patch having a length of 24.6 mm, resonating at 1.8 GHz called the initiator as shown in the **Figure 1(a)**. In this antenna proximity feeding technique is employed. The antenna is fed by 50 ohm microstrip feed line with a width of 3.03 mm and length of 31 mm. In order to achieve multiband characteristics David fractal geometry is introduced in to the hexagon shaped patch. **Figure 2** illustrates the structure of the proposed dual band miniaturized David fractal first iteration level antenna. The fabricated prototype of the David fractal antenna is shown in **Figure 3**. The return loss variations with frequency of the first iterated level David fractal antenna shows dual band characteristics. It has two resonant frequencies at 1.55 GHz and 2.64 GHz. The dual band antenna is optimized so that the simulated David fractal antenna produces two resonances at 1.8 GHz and 3.4 GHz. The lower resonant frequency is suitable for GSM mobile communication and the upper resonant can be used for WiMAX applications in 4 G phones, which is used to provide high speed internet access for non-line of sight environments. In this case resonant frequency optimization is done where optimization parameter is the side length of the hexagonal patch antenna. The detailed dimensions of the antenna are shown in **Table 1**. The design of the antenna was optimized using CST Microwave Studio Suit 2010.

### 4. Measurement Set-Up

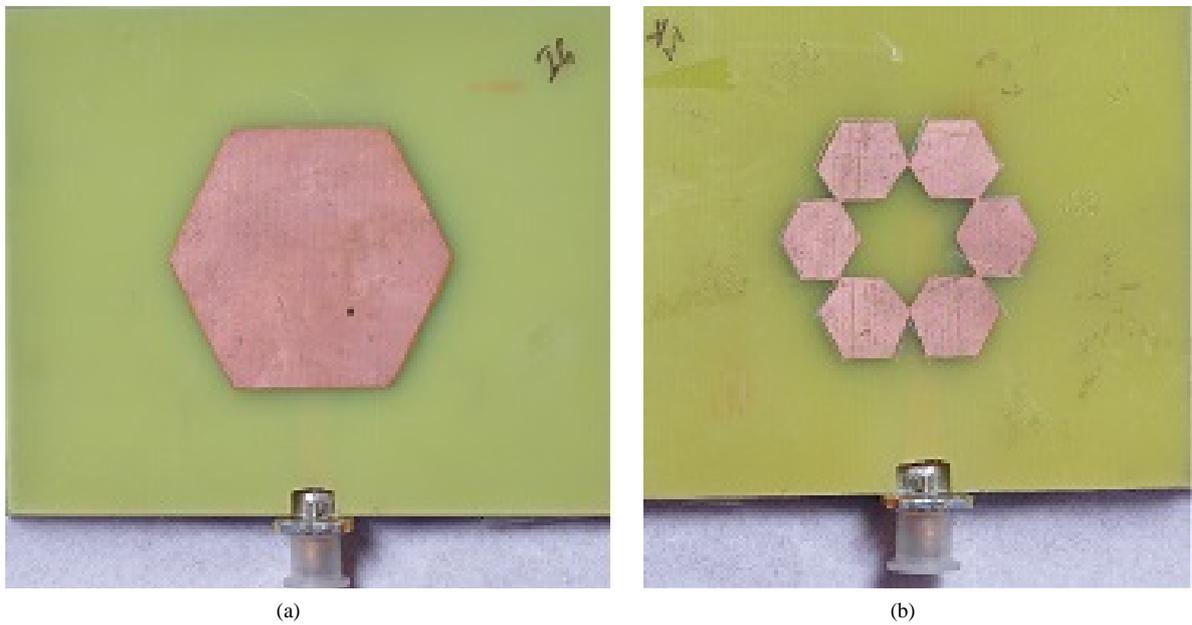
The measurements were carried out in an anechoic chamber using HP 8510C Network Analyzer. The chamber was arranged such that the source remains stationary as the antenna under test (AUT) rotates. A standard horn antenna is used as the reference antenna for the measurements. The antenna under test is placed in an antenna



**Figure 1.** Different iteration stages of David fractal.



**Figure 2.** Structure of the proposed dual band fractal antenna.



**Figure 3.** Photograph of the fabricated antenna: (a) Zeroth iteration level David fractal antenna; (b) First iteration level David fractal antenna.

**Table 1.** Dimensions of the dual band fractal antenna (units: mm).

Parameter	Value	Parameter	Value	Parameter	Value
$L_1$	72	$W_1$	84	$LS_1$	21.4

holder, which is set to rotate the antenna in small steps of  $1^\circ$  to obtain a  $360^\circ$  radiation pattern. The microwave materials that covers the wall, top and bottom surfaces absorbs electromagnetic energy so that the anechoic chamber to replicates a space equivalent.

## 5. Results and Discussions

**Figure 4** shows the simulated and measured return loss variation with frequency for the 1<sup>st</sup> level iterated David fractal hexagon patch antenna. It can be seen that the  $-10$  dB bandwidth for the measured return loss is 62 MHz (1.754 - 1.816 GHz) and 45 MHz (3.37 - 3.415 GHz) respectively, which can cover GSM mobile communication system and WiMAX applications in the 4 G mobile phones. **Table 2** shows comparison between simulated and measured antenna parameters for the first iterated level David fractal microstrip patch antenna. The discrepancy between the measured and simulated results is due to fabrication tolerance and small air gap between dielectric layers.

**Figure 5** illustrates the simulated surface current distribution on the antenna at the two operating frequencies. At lower resonant frequency current density is concentrated along the inner region of the radiating patch and for the upper resonant frequency; the current density is concentrated along the outer regions of the radiating patch while small amount of current is flowing at the inner areas of the patch.

The co-polar and cross polar radiation patterns have been measured at two different frequencies of 1.79 GHz and 3.385 GHz for both E and H plane. The radiation pattern data are normalized in order to plot the co-polar and cross polar patterns in one graph. The measured far field radiation patterns of the dual band David fractal first level iterated antenna in the E plane (y-z plane) and H plane (x-z plane) are plotted at the frequency of 1.79 GHz and 3.385 GHz is shown in **Figure 6** and **Figure 7** respectively. At the lower resonance frequency (1.79 GHz) the maximum power was received by the antenna at the bore sight direction while at the upper resonance frequency (3.385 GHz) the maximum power was received at angle  $43^\circ$  with respect to bore sight. The upper band characteristics are suitable in non-line of sight applications.

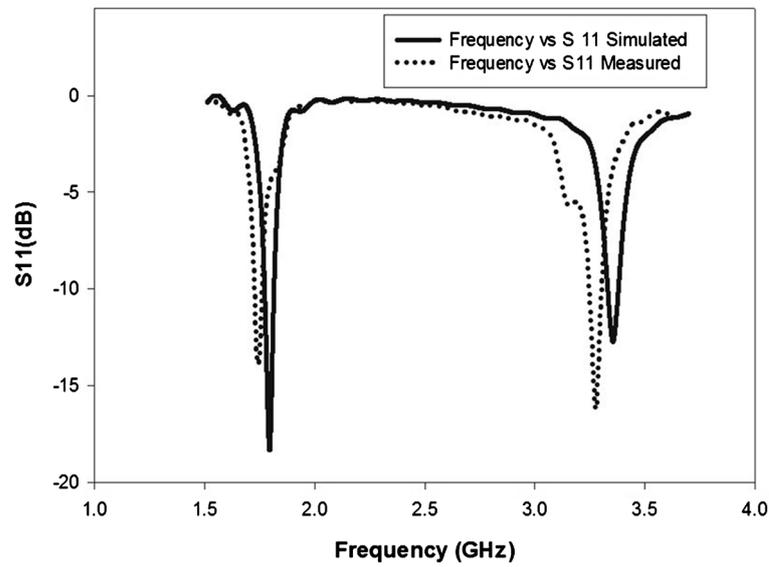


Figure 4. Measured and simulated return loss for the proposed antenna.

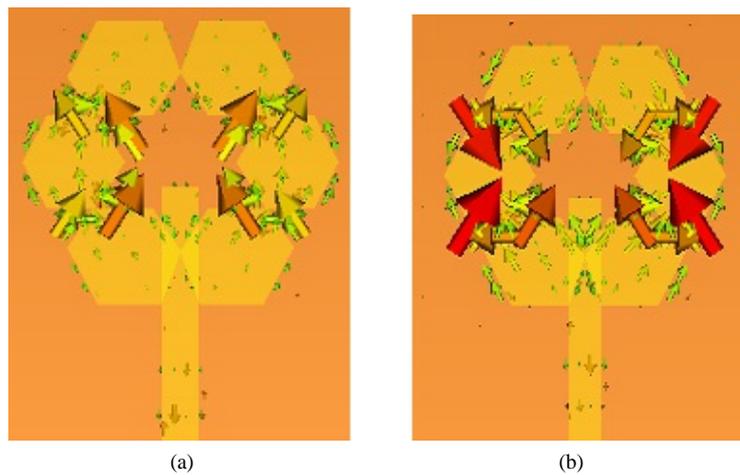
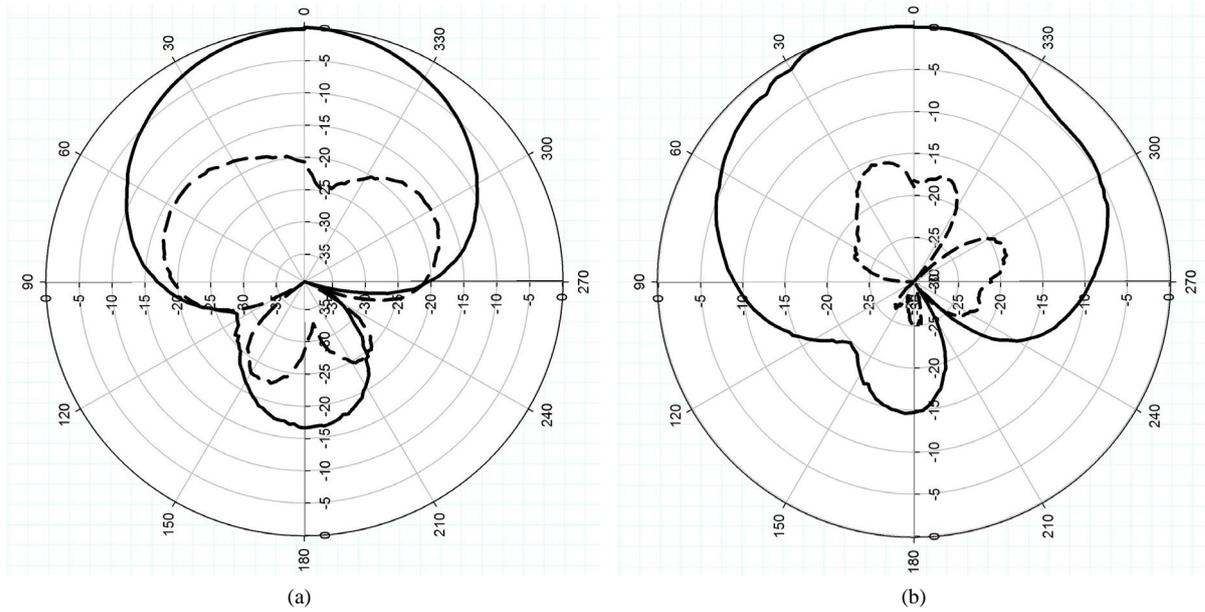


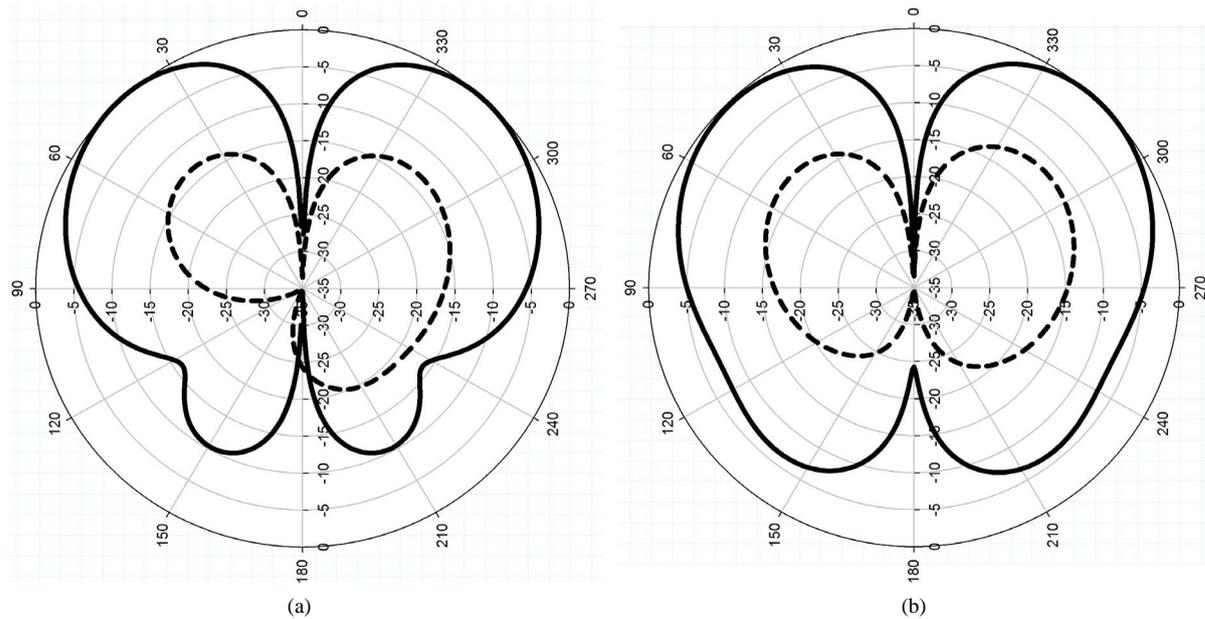
Figure 5. Simulated surface current distributions on the radiating path for the proposed antenna at (a) first resonance frequency 1.8 GHz and (b) second resonance frequency 3.4 GHz.

Table 2. Simulated and measured results.

Parameter	Simulated	Measured
Resonance frequency $f_1$ (GHz)	1.8	1.79
Bandwidth <sub>1</sub> (MHz)	55	62
$S_{11}$ (dB)	-18.7	-13.54
Gain (dBi)	6.93	6.5
Resonance frequency $f_2$ (GHz)	3.4	3.385
Bandwidth <sub>2</sub> (MHz)	31	45
$S_{11}$ (dB)	-14.3	-16.48
Gain (dBi)	5.3	4.9



**Figure 6.** Measured normalized radiation patterns of the antenna at resonant frequency 1.79 GHz. (a) E plane; (b) H plane (co-polarized, \_\_\_\_\_solid line and cross polarized, .....dashed line. (a) y-z plane; (b) x-z plane.



**Figure 7.** Measured normalized radiation patterns of the antenna at resonant frequency 3.385 GHz. (a) E plane; (b) H plane (co-polarized, \_\_\_\_\_solid line and cross polarized, .....dashed line. (a) y-z plane; (b) x-z plane.

The measured gain of the antenna is 6.5 dBi at the lower resonant frequency and 4.9 dBi at the upper resonant frequency. The upper band characteristics will find useful in the non-line of sight applications including Wi-MAX. It is also observed that size reduction up to 18.3% in terms of overall size and 23.4 % in terms of the copper cladding is obtained in comparison with a hexagon patch microstrip antenna resonating in the first resonant frequency band.

## 6. Conclusion

The proposed hexagon shaped David fractal microstrip patch antenna has demonstrated its potential for mul-

ti-band operation. The antenna generates two resonating modes centered at the measured frequencies of 1.79 and 3.385 GHz; the first band finds application in GSM mobile phone communication and the second band finds application in WiMAX. The proposed multi-band antenna provides moderate gain and good radiation characteristics.

## Acknowledgements

Authors would sincerely express the gratitude to Mr. Kuruvilla George, Verdant Telemetry and Antenna Systems (P) Ltd. for providing the measurement facilities.

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