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Meander Line Antenna for LTE Communications

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Abstract : Long Term Evolution (LTE) is a fourth generation standard for wireless communications of high data speed at the user terminal. This evolved technology needs a cutting edge system component to be designed for the node B (Base station) and the user mobile device. In any wireless device, the performance of radio communications depends on the design of an efficient antenna. Achieving Long Term Evolution (LTE) frequency bands (the second generation (2G), third generation (3G), and the proposed fourth generation (4G) frequency bands) using a small-size antenna in a compact device remains a major technical challenge. Antenna is an inseparable part of these systems. Meander line antenna is the most usage of antenna that use in design of these applications. The Objective of Paper is to design a meander line antenna for WLAN application that is 2.4 GHz has been achieved. The meander line microstrip antenna has been designed, constructed, and measured. The microstrip element is quarter wavelength at the design frequency. The properties of antenna like return loss, bandwidth and radiation pattern have been measured. The design starts with calculation of dimension like the width, effective dielectric constant of microstrip line and length of antenna. Thus by using HFSS Version 11 the antenna has been designed and simulated. As the result, the antenna can radiate the signal at WLAN frequency and provide good return loss bandwidth and sufficient gain. The antenna can operate less than -10db that is 2.4GHz with at s11 measured at -35.5db.After finish with the simulation, the design has been fabricated on FR4 substrate using the etching technique. Finally the design has been tested with network analyzer.

Keywords: *MLA, LTE, WLAN, RFID, FR4, CPW*

I. Introduction

The development of small integrated printed antennas plays a significant role in the progress of rapidly expanding wireless communication applications. They are increasingly used in wireless communication systems due to advantages of being lightweight, compact and conformal. In mobile communications, meander line antennas are recently favoured over other printed antennas due to its simplicity and ease in integration. A more compact design of a meander line antenna was designed to operate at 2.4-GHz for WLAN application [7]. The researchers described two different designs of meander line antenna with and without conductor line. The designed antennas were fabricated on a double-sided FR-4 printed circuit board using standard PCB technique and tested with a Network Analyzer. The effect on the antenna radiation and reflection properties with varying the MLA length, Width, number of turns and conductor dimensions are also discussed in this paper. Meander Line Antenna is a type of printed antenna that achieves miniaturization in size by embedding the wire structure on a dielectric substrate. MLA technology was originally developed by BAE SYSTEMS (a former Lockheed Martin Company) , for the Information and Electronic Warfare Systems (IEWS), which require high performance antennas for both satellite and terrestrial communications. Recently, this class of antennas are found to be suitable for application mobile handsets; wireless data networking for laptops,[3] PC cards and access points. In basic form meander line antenna is a combination of conventional wire and planer strip line. Benefits include configuration simplicity, easy integration to a wireless device, inexpensive and potential for low Specific Absorption Rate (SAR) features. **SAR** is a measure of the rate at which energy is absorbed by the body when exposed to a radio frequency (RF) electromagnetic field. It is defined as the power absorbed per mass of tissue and has units of watts per kilogram.

II. Designing of Meander Line Antenna

In a meander line antenna (also called rampart line antenna), the radiating element consists of a meandering micro strip line formed by a series of sets of right angled compensated bends, as shown in Figure 2.1 The fundamental element in this case is formed by four right angled bends and the radiation mainly occurs from the discontinuities (bend) of the structure.[1] The right angle bends are chamfered or compensated to reduce the right angled discontinuity susceptance for impedance matching. The current directions are changing in every half wavelength and there are more than four half wavelength changes in this design. The radiations from the bend add up to produce the desired polarization depending on the dimensions of the meander line antenna.

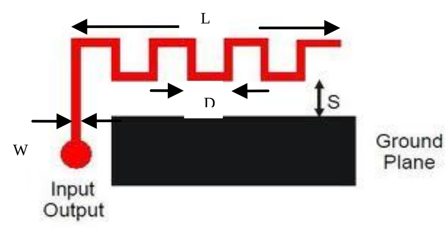


Figure 2.1 Meander Line Antenna

Three types of feed structure can be implemented in proposed antenna:

1. CPW feed (Coplanar Waveguide)
2. Inset Feed
3. Microstrip Feed

Coplanar waveguide is a type of electrical transmission line which can be fabricated using printed circuit board technology, and is used to convey microwave-frequency signals. On a smaller scale, coplanar waveguide transmission lines are also built into monolithic microwave integrated circuits. [2]
Microstrip line feed is one of the easier methods to fabricate as it is a just conducting strip connecting to the patch and therefore can be consider as extension of patch. It is simple to model and easy to match by controlling the inset position. However the disadvantage of this method is that as substrate thickness increases, surface wave and spurious feed radiation increases which limit the bandwidth.
Advantages of CPW over Microstrip Feed:

a. Low Dispersion
b. Low Radiation Leakage
c. Ground plane not interdependent
d. Radiation from feed structure is negligible because of coplanar waveguide is excited in odd mode of coupled slot. This feature is useful in design of antenna arrays since mutual coupling between adjacent lines is minimized.

Inset fed is technique where the path of feed is pushed at a particular distance to match impedance This typically yields high input impedance. Since the current is low at the ends of a half wave patch and increases in magnitude toward the center, the input impedance could be reduced if the patch was fed closer to the center.

Basic dimensions and board type is FR4 board for the material substrates. The dielectric constant is $\epsilon = 4.4$, loss tangent $\tan \delta = 0.02$ and the thickness d=1.6mm. [4]

III. Principle

The meander-line antenna can be in a dipole or ground plane format. The idea is to fold the conductors back and forth to make the overall antenna shorter, which is shown in Figure 3.1. It is a smaller area, but the radiation resistance, efficiency and bandwidth decrease [9]. The parameters of meander shape, for example H, La, Lb and Lc shown as in the figure will affect the antenna performance parameter [8]. In order to find the best antenna solution, different values of meander width are simulated and studied. (actual report MLA)

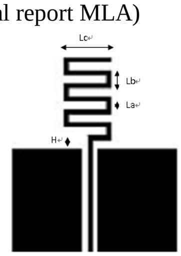


Figure 3.1 Shape of Meander Line Antenna (MLA)

A meander-line antenna can be realized by bending the conventional linear monopole antenna to decrease the size of antenna [5]. The influence of the meander part of the antenna is similar to a load and the meander line sections are considered as shorted-terminated transmission lines as shown in Figure 3.2. The meander line section can be modeled as an equivalent inductor. In the far-field pattern, in the result of the cancellation of magnetical fields, the transmission lines of a meander line antenna do not radiate fields. The radiation fields will be radiated from the vertical pars of MLA. The currents' intension of vertical parts can be clearly seen in Figure 3.3.

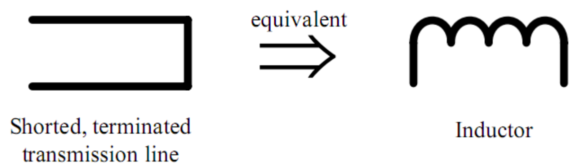


Figure 3.2 Equivalent Model of meander line sections

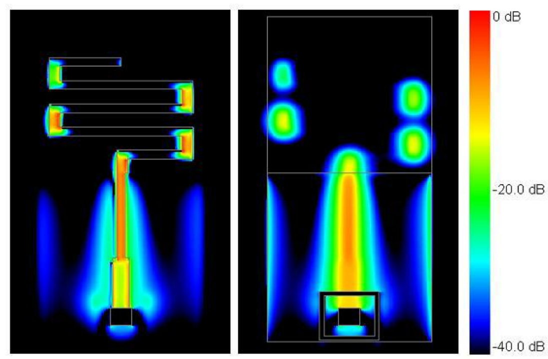


Figure 3.3 Electric Current Magnitude Plot for the MLA. Drawing on the left is the current on the upper traces. Drawing on the right is of the current on the ground plane. One can see that the large magnitude of the currents on the vertical sections of the meanderline. These are essentially the only sources of radiation when the ground plane is enlarged.

IV. Parametric Analysis for 2.4GHz MLA

1. By changing Width (gap) of MLA
2. By changing Height of MLA
3. S11 parameters calculations
4. $\lambda/4$ matching done in order to match impedance.

For points 1 and 2 simulation results as done in HFSS version 11 are shown in below tables Different simulation results obtained for varying height and spacing are shown in below table 3.4 and 3.5

Height	F-start	F-stop	Impedance	B/W
0.2	3.034	3.066	56.60	32MHz
0.4	3.444	3.492	68.43	48MHz
0.8	3.923	3.961	101	38MHz
1.6	4.517	4.603	99.89	86MHz
3.2	4.709	4.767	52.55	58Mhz

Table 3.4 Simulation for different height

Spacing	F-start	F-stop	Impedace	B/W
0.9	3.090	3.108	22.24	18 MHz
1.4	3.250	3.284	68.64	34MHz
1.7	3.032	3.066	42.03	34Mhz
2.5	3.186	3.220	38.93	34Mhz
3.2	3.086	3.118	38.81	32Mhz

Table 3.5 Simulation for different spacing

3. S11 Parameter Calculation

$$S_{11} = \frac{Z_{IN} - Z_O}{Z_{IN} + Z_O}$$ ....Equation 1

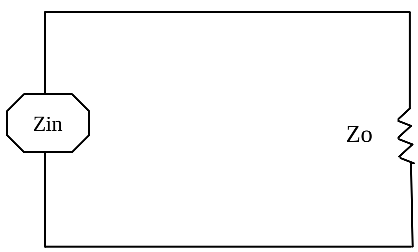
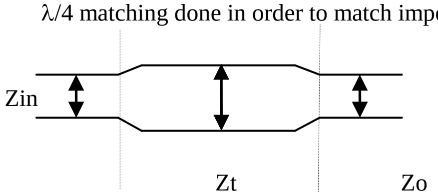


Figure 4.1 Load calculation

Now Z (Load) = 50
Assuming we get result for
Now 20 Log r = S11 ………………..Equation 2
Example: h = 0.4 and Zo = 59.8659..... from Tx Line software
From equation 1 we get r = 0.08
And further S11 from equation 2 we get = -21

4. Impedance Matching

λ/4 matching done in order to match impedance.



λ/4 Transformer

Figure 4.2 Impedance matching

$$Zt = \sqrt{Zin * Zo}$$

Tx Line Software Used for Impedance calculation with respect to Height and gap variation of Meander Line Antenna (MLA).

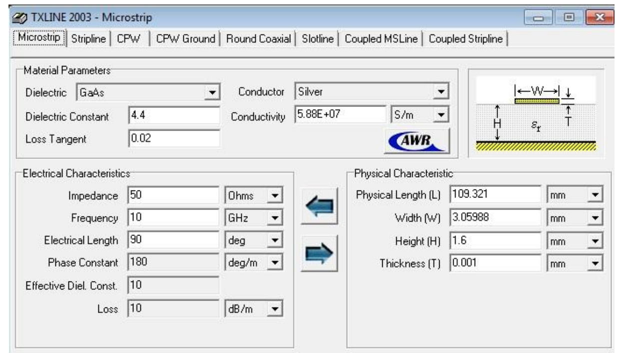


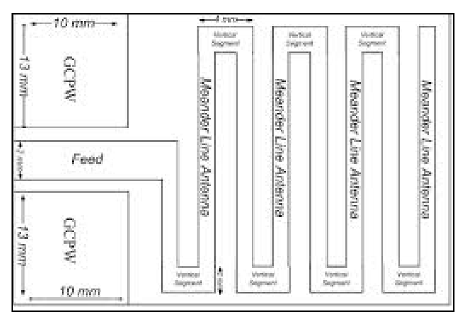
Figure 4.3 Tx line software

V. Design of different Types of MLA

5.1 MLA with Different Thickness of Vertical Segment

An important application of meander line antenna is in wireless Communication systems such as WLAN. In these applications, bandwidth is an important factor. As it mentioned before meander line antenna has low efficiency [5]. So if this kind of antenna want to use in WLAN systems, it must to improve it bandwidth.

If we analysis current distribution of classic meander line antennas it could be observed that vertical segment of meander line antenna has more role in constructing electrical field of this antenna. Therefore, with applying some changes in this segment, such as different thickness, it might get better results. Figure.5.1 shows MLA with different thickness of vertical segment. In this structure, thickness of vertical segment and feed line are 2mm and thickness of horizontal segment is 1 mm.



Zout

Figure. 5.1 Illustration of MLA with different length of vertical segment.

5.2 Log Periodic Meander Line Antenna

The increasing use of wireless communication systems, demands the antennas for different systems and standards with properties like compact, broadband and multiple resonant frequencies. Classic meander line antenna is able to perform in single band. Log periodic antenna is a kind of frequency independent antenna and is able to achieve multi-band performance [6]. Therefore, log periodic technique has been combined with classic meander line antenna to get dual band antenna. Figure.5.2 shows illustration of this antenna.

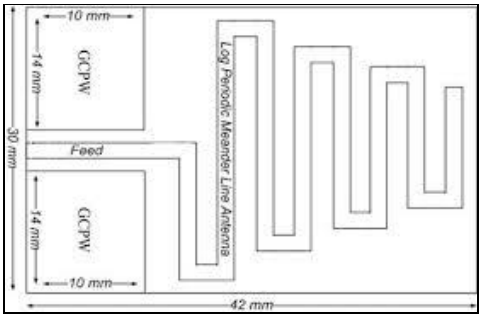


Figure. 5.2 Illustration of Log periodic Meander line antenna.

5.3 Symmetrical Meander Line Antenna

Nowadays, communication devices which have more properties are more usable than other devices. One of its properties is devices that able to operate in dual band frequencies [6]. As it mentioned before, log periodic MLA approach is one of them. Another technique to get dual-band resonance is two segment MLA. In this mode main antenna, composes in two sub MLA. Each one can be designed to operate in one resonance frequency. These segments can be symmetrical or asymmetrical [6].
In this paper symmetrical meander line antenna has been presented. Figure 5.3 shows the illustration of this antenna. In this structure taper plane has been designed to get better matching network.

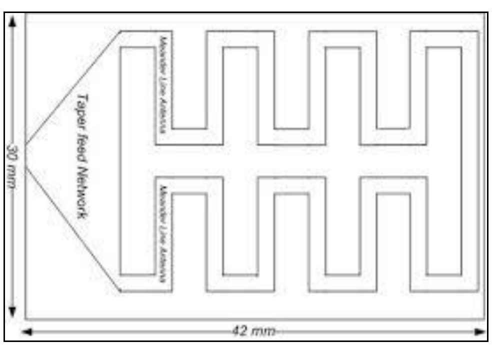
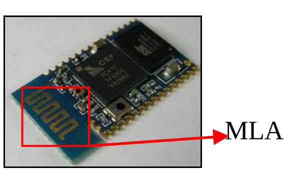


Figure. 5.3 Illustration of symmetrical MLA.

VI. Final HFSS design of MLA and simulation results

6.1 HFSS design:



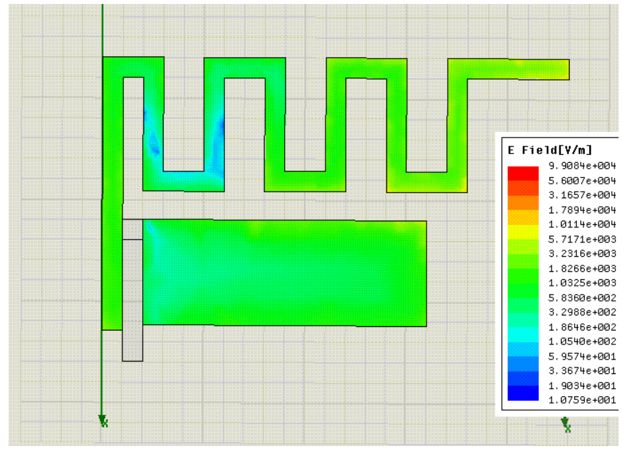


Figure 6.1 HFSS design of MLA

The final design in HFSS is as shown in figure 6.1 above. It shows the electric field distribution throughout the antenna.

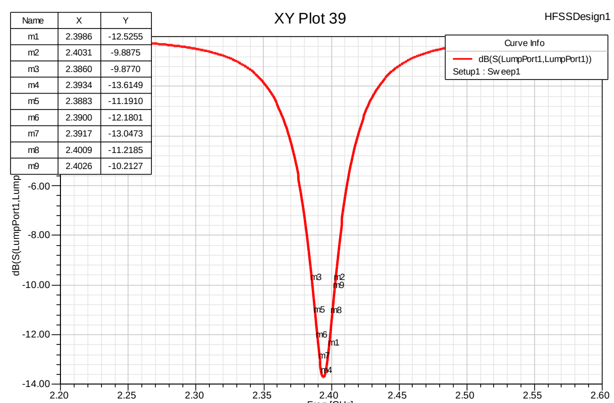


Figure 6.2 Return Loss Plot

The Return Loss (S11 Parameters) is as shown in above figure 6.2 where antenna can operate less than -10db.

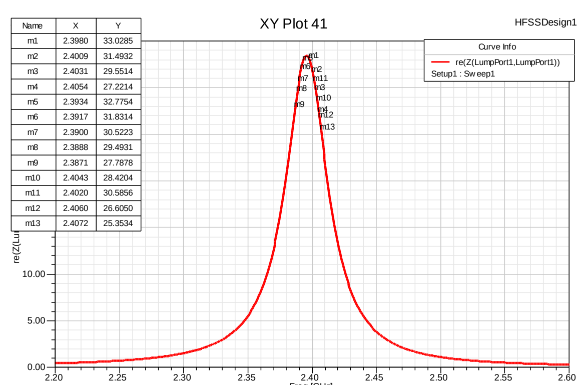


Figure 6.3 Impedance Real

The Real Impedance as simulated is shown in figure 6.3 where at frequency 2.39GHz real impedance is 33.028

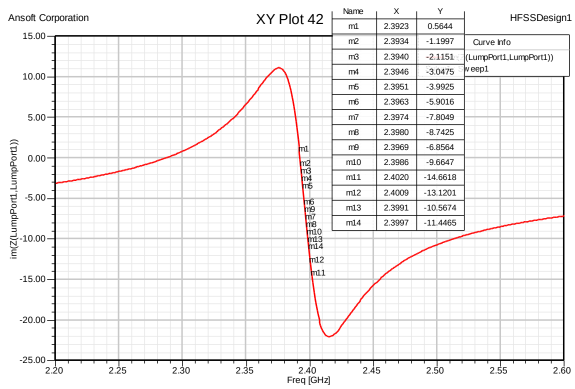


Figure 6.4 Impedance Imaginary

The Imaginary Impedance as simulated is shown in figure 6.4 where at frequency 2.39GHz real impedance is 0.5644.

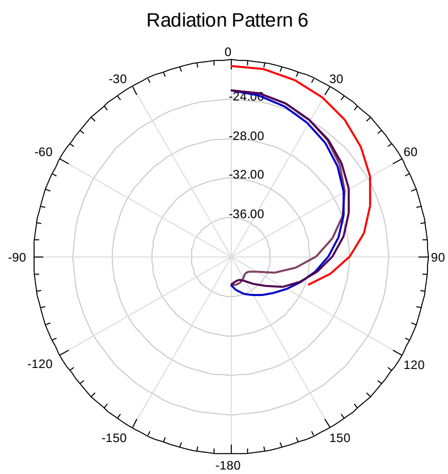


Figure 6.4 Radiation pattern

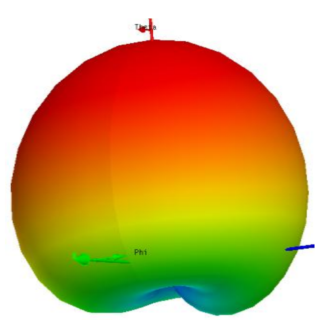


Figure 6.5 Radiation pattern

The above figure 6.5 shows the simulation result for radiation 3D polar plot.

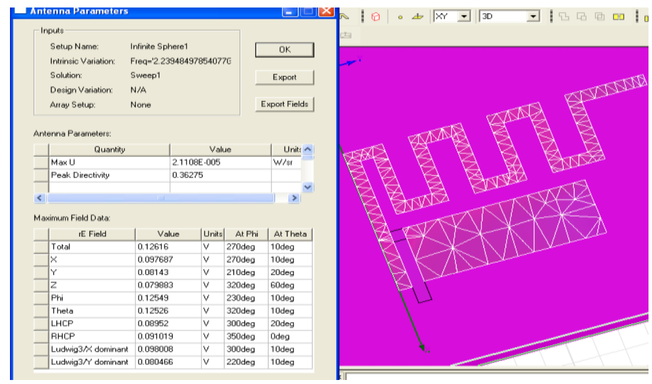


Figure 6.6 Antenna Parameter

Computed Antenna parameters are as shown in above figure 6.6 where peak directivity is 0.3625 as antenna is omnidirectional and Max U is 2.110E.005

Parameter	Value
Max U	2.110E.005
Peak Directivity	0.36
Impedance	33.34
Bandwidth	17Mhz
VSWR	1.5177
Frequency	2.39GHz

Table 6.1 Parameters

VII. Results Obtained On VNA

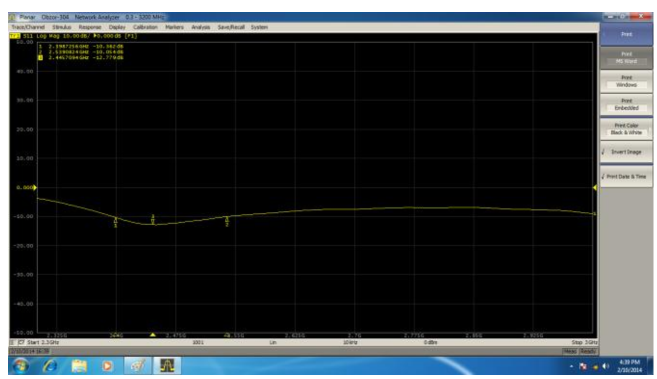


Figure 8.1 S11 Parameters (Return Loss obtained)

The actual S11 parameters measured on VNA plot is as shown in above plot figure 8.1 where the resonant frequency is 2.44 GHz at -12.779db.The S11 parameters are obtained by impedance matching done with a capacitor of 10pf mounted at feed to match impedance.

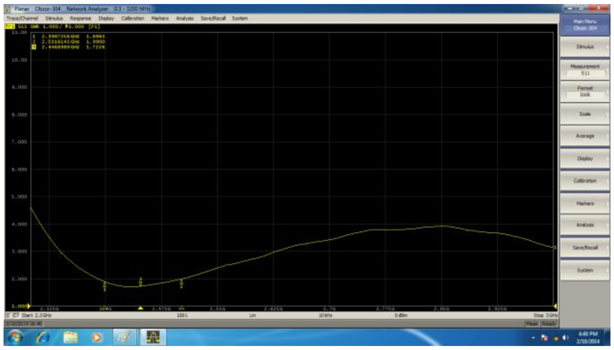


Figure 8.2 VSWR

The actual VSWR measured on VNA plot is as shown in above plot figure 8.2 where the VSWR at frequency 2.44 GHz at 1.7226.

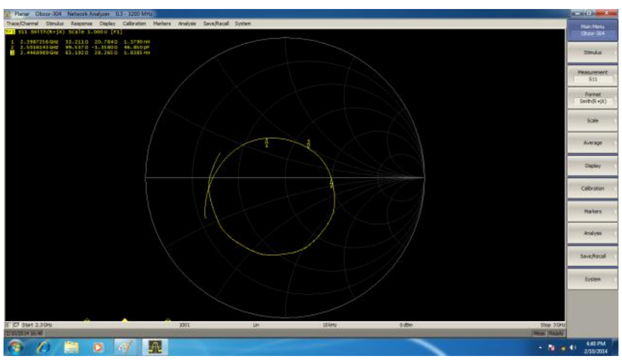


Figure 8.3 Smith Chart

The actual Smith Chart on VNA plot is as shown in above plot figure 8.3 at 2.4468 GHz.

Parameter	Result
Frequency	2.44 GHz
B/W	93.3 MHz
VSWR	1.72

VIII. Conclusion

Meander line antenna has good properties such as, small, low profile, simple and cheap. These nice features make meander line antenna very popular and usable in many aspect of communication systems such as RFID and WLAN. In this project, planar MLA with inset feed has been designed. A Meander Line Antenna (MLA) for 2.4 GHz is proposed and implemented. This research focuses on the optimum value of gain and reflection coefficient. Therefore, the MLA's parametric studies are discussed which involved the Height of substrate and Gap between turns and number of turns. The MLA also resembles the monopole antenna behavior of Omni-directional radiation pattern. Measured and simulated results are presented. The proposed antenna has big potential to be implemented for Wireless devices such as mobile phones, tabs etc.

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