Improvement for Radio Jove Telescope Antenna Using Directive Angle Yagi

Kamal M. Abood, Moretadha J. Kadhim, Mohammed I. Abd-Almajied, and Zinah F. Kadhim

Abstract—This paper presents a new technique to design the yagi antenna in order to receive radio signals from Jupiter at 20.1MHz from Baghdad city at (44.45, 33.35) latitude and longitude respectively in the period (2005 to 2020). EZNEC+ 5.0 package has been used in order to build a yagi with three and seven elements. The elevation angle was matched with the elevation angle of Jupiter for the same period. In order to increase the efficiency of the yagi and to cover all the elevation angles of Jupiter at Baghdad location because yagi didn't cover all the elevation angle at Baghdad. The yagi with directive angle has also been designed by raising the yagi with an angle above ground where it has assumed three and seven elements.

Index Terms— Ground effect on antenna, Liner wire antenna, Radio signal, Yagi antenna.

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1 INTRODUCTION

THE antenna is an essential component in any radio system. An antenna is a device that provides means for radiating or emitting radio waves. It is considered to provide transmission of guided waves on transmission line to free space [1] representing the transmission unit between free-space and guiding device. The guiding device or transmission line may take the form of coaxial line or hollow pipe (waveguide), and it is used to transport electromagnetic energy from the transmitting source to the antenna or from the antenna to the receiver [2]. The antenna is considered as a detector used for collecting the radiation [3].

2 FUNDEMENTAL ANTENNA PARAMETERS

2.1 Radiation Pattern

Radiation pattern (or antenna pattern) is a graphical representation of the radiation properties of an antenna [4]. It is define as a mathematical function or a graphical representation of the radiation properties as functions of space coordinates. In most cases the radiation pattern is determined in the far-field region (space coordinates) and is represented as a function of the directional coordinates [2]. Radiation pattern provides a description of the angular variation of radiation level around an antenna, which is provides a one of the most important characteristic of an antenna [4] as illustrate in fig.1 .

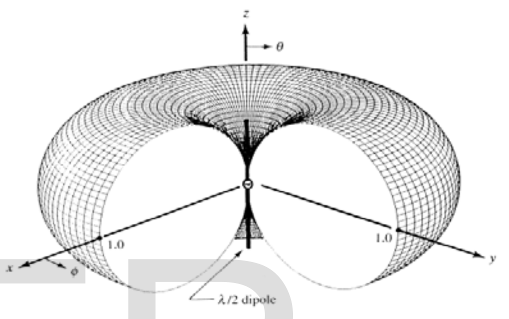

Fig. 1. Three-dimensional pattern of a λ/2 [2]

2.2 Directivity

The directivity of an antenna is defined as "the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions [5]. The average radiation intensity is equal to the total power radiated by the antenna divided by 4π, given by the equation:

$$D = \frac{U}{U_o} = \frac{4\pi U}{P_{rad}} \qquad (1)$$

Where U = radiation intensity (W/unit solid angle), P_{rad} the total radiated power.

2.3 Efficiency

The antenna efficiency takes into consideration the ohmic losses of the antenna through the dielectric material and the reflective losses at the input terminals [6].

2.4 Gain

The antenna gain measurement is linearly related to the directivity measurement through the antenna radiation efficiency. The antenna absolute gain is "the ratio of the intensity, in a given direction, to the radiation intensity that

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would be obtained if the power accepted by the antenna were radiated isotropically” [7, 8]. Antenna gain is:

$$G = e_{rad} D = 4\pi \frac{U(\theta, \varphi)}{P_{in}} \qquad (2)$$

where e_{rad} is the radiation efficiency, P_{in} power input.

3 ANTENNA ABOVE PERFECT GROUND PLANE

If the antenna has been treated for free space environment in practice, environment effects are small for elevated high gain antenna .However the radiation properties of antenna with broad beams are affected by their surrounding environment .both pattern and impedance are influenced by the presence of nearby object .The most commonly encountered object is aground plane .the real earth is aground plane .the ideal form of aground plane is planar ,Infinite in extent ,and perfectly conducting and is referred to assume a perfect ground plane [1].

4 ANTENNA ABOVE AN IMPERFECT GROUND PLANE

The operation of low –frequency (roughly VHF and below) antenna is affected significantly by the presence of typical environmental surroundings, Such as the earth buildings, and so forth [2].

5 GROUND CONDUCTION EFFECT

To explain the effect of the ground supposes the source of radio signal will induce current in receiving antenna. This is deliberate transfer of signal, but the radiation from the source also induces currents re-radiates waves. This sound like every object in the universe is making waves, but, while this is true in principle, as the objects become more distant from the receiving antenna both the incident wave amplitude and the induced currents and re-radiation become vanishingly small. Large nearby object have two major effects: they change the total radiation pattern, and they change the impedance of the transmit source by inducing current back into the source itself. The effect on the total radiation pattern can be thought of as a far-fieled effect, while the impedance change is near field effect [2].

In addition, the earth is not a plane surface. To simplify the analysis, however, the earth will initially be assumed to be flat. For pattern analysis, this is a very good engineering approximation provided the radius of the earth is large compared to the wavelength and the observation angles are greater than about 57.3*/(ka)*1*/*3 degrees from grazing (*a* is the earth radius) [8]. Usually these angles are greater than about 3◦.In general, the characteristics of an antenna at low (LF) and medium (MF) frequencies are profoundly influenced by the lossy earth. This is particularly evident in the input resistance. When the antenna is located at a height that is small compared to the skin depth of the conducting earth, the input resistance may even be greater than its free-space values [9]. This leads to antennas with very low efficiencies. Improvements in the efficiency can be obtained by placing radial wires or metallic disks on the ground.

5 YAGI–UDA ARRAY ANTENNA

The practical radiator in the HF (3-30MHz), VHF(30-300MHZ),and UHF(300-3,000 Mhz) ranges is the yagi-uda antenna. This antenna consists of a number of linear dipole elements, as shown in fig.2.

In other word yagi antenna is aparasitic linear array of paralled dipoles .ayagi –uda array or simply “yagi” is popular because of their simplicity and relatively high gain [1]. Where the yagi –uda antenna has been shown to perform well due to its advantages such as high gain, Simple configuration and easy maintenance [10].

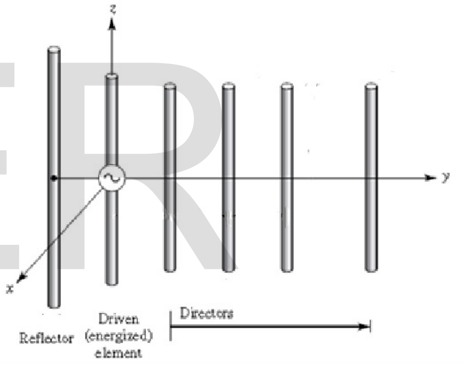


Fig. 2. Yagi-Uda antenna configuration [2].

Yagi performance can be considered in three parts [2]:

1-the reflector –feeder arrangement

2-the feeder

3-the rows directors

One of the element is energized directly by a feed transmission line while the other act as parasitic radiators currents induced by mutual coupling. A common feed element for a yagi –uda antenna is a folded dipole. This radiator is exclusively designed to operate as an end-fire array, Accomplished by having the parasitic element in the forward beam act as director while those in the rear act as reflectors. So to achieve the end-fire beam formation, the parasitic element in the direction of the beam is somewhat shorter than the feed element [11, 12].

6 YAGI ANTENNA DESIGN CONSIDERATION

In this work, there are two types of yagi that have been designed where each type of yagi was consisted to compose of three main parts. The reflector, the arrangement feeder, and the rows of directors.

These yagi types where designed using EZNEC+ 5.0 package. Usually yagi with three elements has a total length of reflector is (0.5 λ) the total length of feeder equal is (0.47 λ) and also total length of director equal (0.406 λ). The spacing between reflector and feeder is equal to (0.25 λ). Yagi with seven elements was also design using EZNEC+ 5.0 package and its design was similar to the yagi with three elements but differs by adding other directors adjacent to the last director, where the spacing between adjacent directors equals (0.34 λ).

Through the analyzing results, the elevation angle of Jupiter can be covered in all year to the same period where the value of elevation angle can be found with more than one type of yagi. The gain value changed by increasing with increasing the number of element of each yagi.

Fig.3 reveals the height versus maximum gain of the three and seven elements, and Fig. 4 shows height versus elevation angle.

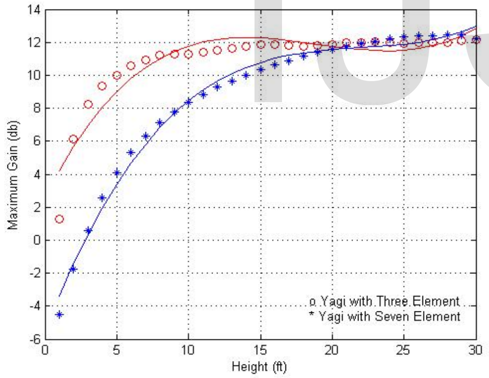


Fig. 3. Height versus maximum gain of designed yagi types of three, and seven elements.

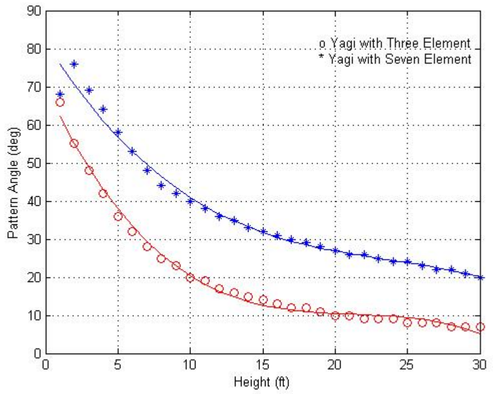


Fig. 4. Height versus elevation angle of the yagi types with three and seven elements.

In the yagi types with three element it was found that the value of gain was increasing with increment height where it's started with (1.27db) at 1ft and its continued to increase to reach its maximum value at (12.3db) at height (30ft). As compared with the value of pattern angle, it is seen to be decreasing from 66.0at 1ft to reach its minimum value (7deg) at 30ft.

With the seven elements the quality of gain increased gain value took negative values at height (5, 6)ft at (-4.49 to -4.48) because there was attenuation occurring when we increase the elements of yagi. After that height, the gain value will an increase as height increased to reach values (11.58 to 13.48). While the pattern angles for these yagies start between values (85 to 86) and end with value between (18 to 22).

7 ELEVATION ANGLE MATCHING

The matching between the elevation angle of Jupiter and elevation angle of yagi with 3- element and 7-elements, and comparison the value with the elevation angle of Jupiter at the period from 2005 to 2020 are illustrated table 1-2:

TABLE 1. YAGI ANTENNA WITH 3-ELEMENT

Elevation angle of Jupiter at Max. [deg]	Height of Antenna [ft]	Year
66	**1**	**2011, 2014, 2015**
55	**2**	**2010, 2011, 2016**
48	**3**	**2005, 2016**
42	**4**	**2006, 2009, 2010, 2017**
36	**5**	**2006, 2018**
32	**6**	**2018**
28	**7**	**2019, 2020**

8 YAGI ANTENNA WITH DIRCTIVE ANGLE

For more accuracy to find any antenna angle suitable to Jupiter position above the horizon, two types of yagi has

TABLE 2. YAGI ANTENNA WITH 7-ELEMENT

Elevation angle for Jupiter at Max.[deg]	Height of antenna [ft]	Year
68	**1**	**2011, 2014, 2015**
76	**2**	**2012**
69	**3**	**2011, 2012, 2014, 2015**
64	**4**	**2011**
58	**5**	**2011, 2015, 2016**
53	**6**	**2010, 2016**
48	**7**	**2005, 2016**
44	**8**	**2017**
42	**9**	**2006, 2009, 2010, 2017**
40	**10**	**2006, 2009**
38	**11**	**2006**
36	**12**	**2006, 2018**
35	**13**	**2007, 2008, 2009, 2018**
33	**14**	**2007, 2008**
32	**15**	**2018**
31	**16**	**2018**
30	**17**	**2020**
29	**18**	**2019, 2020**

been designed. Yagi with three elements with different height and different value of the angle that raising the yagi with the horizon called directive angle (ψ). Yagi with seven elements has been design with different height and different value of ψ as seen in fig. 5.

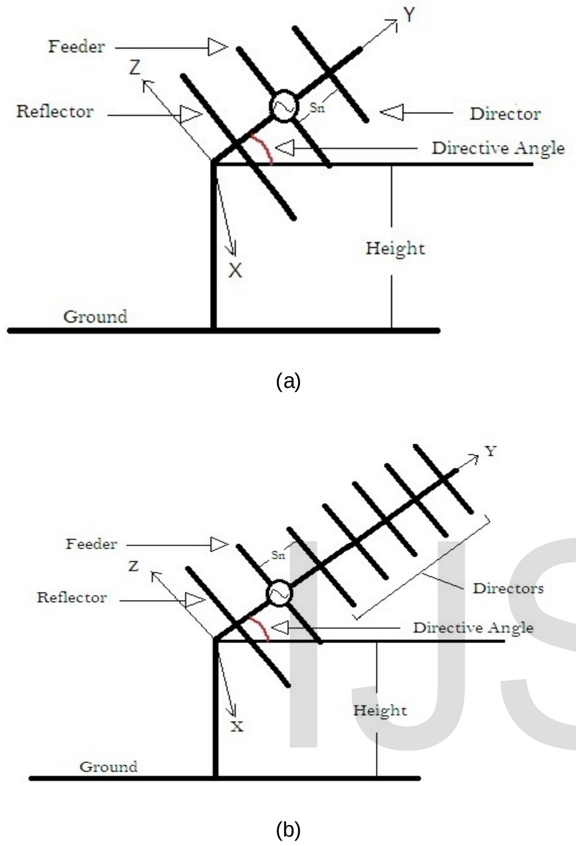


Fig. 5. Yagi types designed in this work with directive angle of (a) three elements (b) seven elements.

The first type of yagi antenna that has been designed was 3-elements, where the elements were shifted above the ground by an angle called directive angle which is the angle required to raise the level of yagi in especial height to be able to captures the elevation angle of Jupiter at any value .

For a yagi with 3-elements (shifted by any angle should be rise) as fellow when the spacing between reflector and feeder equal (3.75 ft).

The distance between adjacent director was equal (5.1 ft), and to rise each element of yagi above ground, the spacing between each element will be added to one other one such as the first wire will be at (8.85 ft) above ground and the next wire, height will be found by adding the distance between adjacent director to the earlier wire the end the height rise of the yagi antenna will be added to each result, until the suitable directive angle is reached.

A yagi with 3- elements has been taken for many angles from 10^o to 80^o with 10^o spacing and for different heights.

In this case yagi with 7-elements the design will be in the same way that the yagi with 3- elements by adding number of director to the last director. The yagi has been rised by an angle (directive angle) in the same way used with dipole of 3- elements used here but with 7- elements.

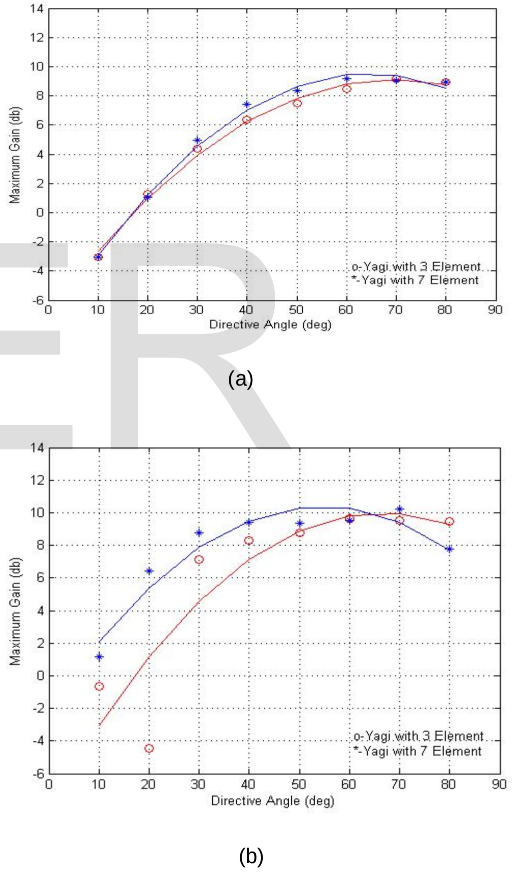
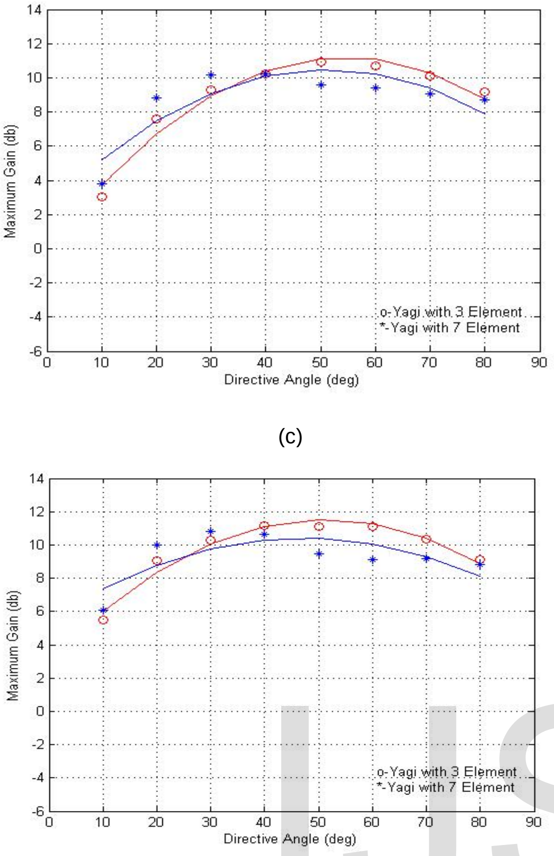


Fig. 6. ψ and maximum gain for yagi with 3 and 7 element for height of (a) 5 ft, (b) 10 ft, (c) 20 ft, (d) 30 ft

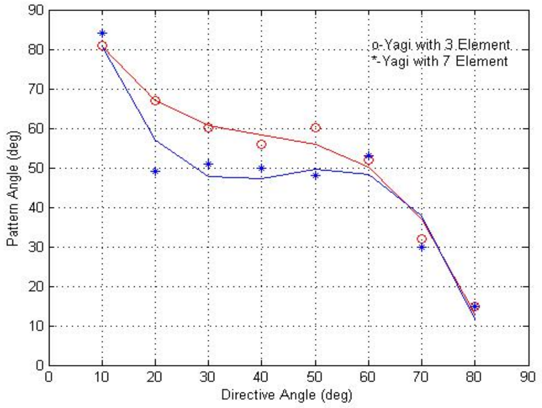
The maximum gain results of yagi with 3 and 7 elements with ψ are show in fig. 6, and pattern angle with ψ shown in fig. 7.



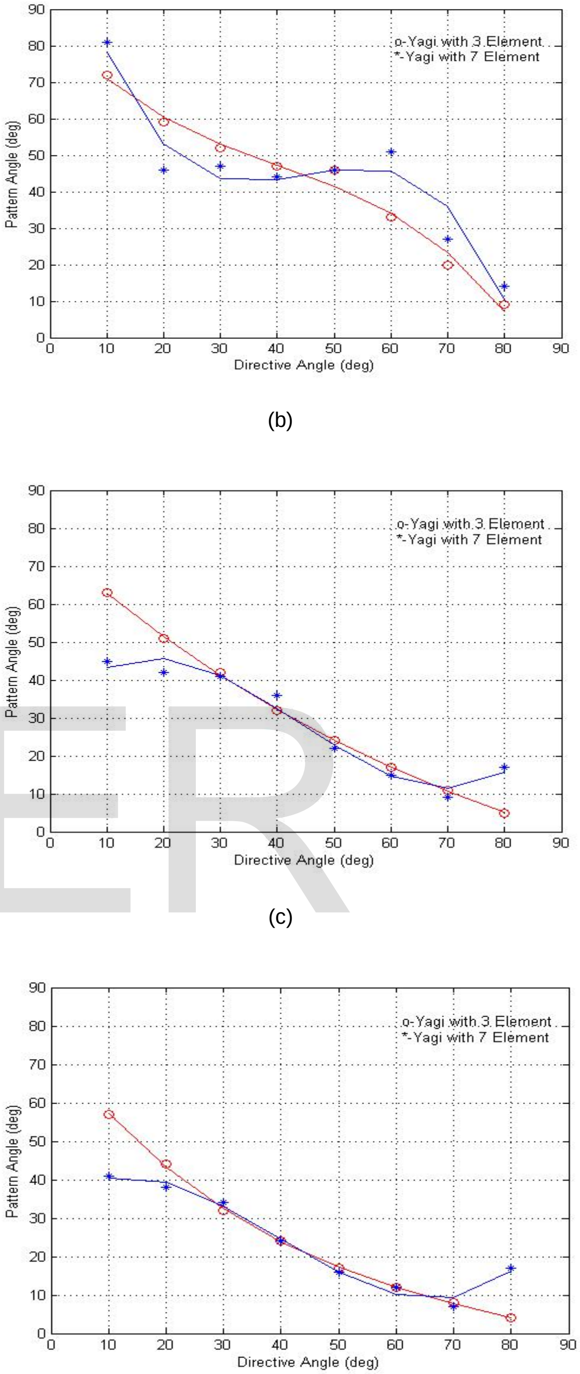
(c)

(d)

Fig. 6. (Continued)



(a)



(b)

(c)

(d)

Fig. 7. ψ and pattern angle for yagi 3 and 7 elements for height of (a) 5 ft, (b) 10 ft, (c) 20ft, (d) 30 ft

9 ELEVATION ANGLE MATCHING

The matching between the elevation angle of Jupiter and elevation angle of yagi with 3- elements by directive angle and comparison of the values with the elevation angle of Jupiter for the period from 2005 to 2020 are illustrated table 3-6:

TABLE 9. YAGI WITH 7-ELEMENTS WITH Ψ AT HEIGHT 20 FT

Elevation angle of Jupiter at Max.[deg]	Height of antenna with ψ[ft]	Year
45	10	2005, 2010
42	20	2006, 2009, 2010, 2017
41	30	2006, 2009

TABLE 4. YAGI WITH 3-ELEMENTS WITH Ψ AT HEIGHT 10 FT

Elevation angle of Jupiter at Max.[deg]	Height of antenna with ψ[ft]	Year
72	10	2013
59	20	2016
52	30	2005, 2010
47	40	2010, 2017
46	50	2016, 2017
33	60	2007, 2008

TABLE 5. YAGI WITH 3-ELEMENTS WITH Ψ AT HEIGHT 20 FT

Elevation angle of Jupiter at Max.[deg]	Height of antenna with ψ[ft]	Year
51	20	2005
42	30	2006, 2009, 2010, 2017
32	40	2018

TABLE 6. YAGI WITH 3-ELEMENTS WITH Ψ AT HEIGHT 30 FT

Elevation angle of Jupiter at Max.[deg]	Height of antenna with ψ[ft]	Year
57	10	2016
44	20	2017
32	30	2018

The matching between the elevation angle of Jupiter and elevation angle of yagi with 7-element by directive angle and comparison the value with the elevation angle of Jupiter at the period from 2005 to 2020 are illustrated in table 7-10:

TABLE 7. YAGI WITH 7-ELEMENTS WITH Ψ AT HEIGHT 5 FT

Elevation angle of Jupiter at Max.[deg]	Height of antenna with ψ[ft]	Year
51	30	2005
50	40	2005, 2016
48	50	2005, 2016
53	60	2010, 2016

TABLE 8. YAGI WITH 7-ELEMENTS WITH Ψ AT HEIGHT 10 FT

Elevation angle of Jupiter at Max.[deg]	Height of antenna with ψ[ft]	Year
46	20,50	2016, 2017
47	30	2010
44	40	2017
51	60	2005

10 CONCLUSIONS

In yagi antenna types the value of the gain is seen to be increasing with increasing the number of elements in yagi. By increasing the height, the value of gain was also increasing in each type of linear wire antenna that were used. The elevation angle of radiation pattern for type of antenna became less when the height of antenna was increasing.

TABLE 10. YAGI WITH 7-ELEMENTS WITH Ψ AT HEIGHT 30 FT

Elevation angle of Jupiter at Max.[deg]	**Height of antenna with ψ[ft]**	**Year**
41	10	2006, 2009
38	20	2006
34	30	2007, 2008, 2018

In directive angle for yagi with three elements and yagi with seven elements each elevation angle (for Jupiter) has been found as showed in the previous tabled.

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