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Bandwidth Enhancement Using Annular Ring Microstrip Antenna With Slits.

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ABSTRACT

Microstrip Antenna (MSAs) consist of a metallic radiating patch on one side of thin dielectric substrate and other side is ground plane. Most important advantageous of MSAs are low profile, light weight and can be made conformal with host surface. So microstrip antennas are widely used as efficient radiators in many communication systems. One of the most interesting applications is their use in linear polarization. Linear Polarized radiation is obtained with single feed.

The size of the regularly shaped microstrip antenna operating in the ultra high frequency band is quite large. To design a smaller antenna at these frequencies with large bandwidth, the conventional microstrip antenna configurations, such as Annular Ring and circular configurations, need to be modified.

Here, An Annular Ring Microstrip Antenna with slits has been successfully fabricated and tested. This Annular Ring Microstrip Antenna with slits operates in 2.60 - 2.72 GHz frequency band for VSWR ≤ 2. This band is used for Indian Satellite (INSAT) Communication System. The impedance bandwidth is 116.5 MHz or about 4.38% is achieved. Gain of Antenna becomes 9.15 dBi. The Antenna and Radiation Efficiency are 90.68% and 97.46% respectively.

INTRODUCTION

1.1 Microstrip Antenna (MSA) Configuration

A microstrip antenna in its simplest form consists of a radiating patch on one side of the dielectric substrate ($\varepsilon_r \leq 10$), which has a ground plane on the other side.

Radiation from the microstip antenna can occur from the fringing fields between the periphery of the patch and the ground plane. The length L of the rectangular patch for the fundamental TM_{10} mode excitation is slightly smaller than $\lambda/2$, where λ is the wavelength in the dielectric medium, which in terms of free-space wavelength λ_0 is given as $\lambda_0/\sqrt{\varepsilon_l}$, where ε_l is the effective dielectric constant of a microstrip line of the width *W*. The value of ε_l is slightly less than the dielectric constant of ε_r the substrate because of the fringing fields from the patch to the ground plane are not confined in the dielectric only, but are also spread in the air. To enhance the fringing fields from the patch, which account for the radiation, the width *W* of the patch is increased. The fringing fields are also enhanced by decreasing the ε_r or by increasing the substrate thickness *h*. Therefore, unlike the microwave integrated circuit (MIC) applications, MSA uses microstrip patches with lower dielectric constant ($\varepsilon_r \leq 2.5$) and thicker *h*.

ANNULAR RING MICROSTRIP ANTENNA

Annular Ring

An annular ring MSA (ARMSA) is shown in Figure 1.1.

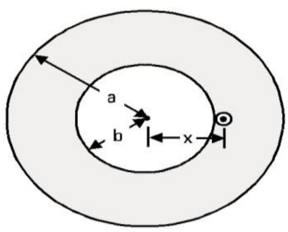

Figure 1.1 an Annular Ring MSA

The outer and inner radii are *a* and *b* respectively. The ARMSA can be considered as a removal of a smaller inner concentric circle from the outer circle. The resonance frequency of the ARMSA is always smaller than that of the CMSA because of its larger resonant length. The resonance frequency of the ARMSA is given by:

$$f_{nm} = \frac{X_{nm}\ c}{2\pi b\sqrt{\varepsilon_e}}$$

Where *c* is the velocity of light and X_{nm} represents the roots of the equation

$J_n'(CX_{nm})\, Y_n'(X_{nm}) - J_n'(X_{nm})\, Y_n'(CX_{nm}) = 0$

$J_n(x)$ and $Y_n(x)$ are the Bessel functions of the first and second kind, and $C = a/b$.

1.1-Comparison of Various Configurations for Broad B

Table 1.2 gives a comparison of various regularly shaped probe-fed MSA configurations, such as rectangular, circular, semicircular, equilateral triangular, 30-60-90 triangular and annular ring.

Table 1.1- Comparison of Various Regularly Shaped Broadband MSAs ($e_r = 1$, $h = 0.5$ cm, and $d = 0.12$ cm)

Configuration	Dimension (cm)	*x* or *y* (cm)	f_0 (GHz)	BW (MHz)	Gain (dB)	Area (cm^2)
RMSA	$L = 5.2$ $W = 6.0$	1.8	2.602	171	9.8	31.20
CMSA	$a = 3.0$	1.5	2.663	185	9.7	28.27
SCMSA	$a = 3.0$	1.0	2.634	120	9.1	14.14
ETMSA	$S = 6.5$	2.9	2.676	132	9.2	17.42
HETMSA	$S = 6.5$	2.6	2.595	81	8.9	8.71
ARMSA	$a = 2.8$ $b = 1.0$	1.1	2.655	132	9.6	21.48

The substrate with $e_r = 1$ and $h = 0.5$ cm is taken to realize broad BW for all theses configurations. The patch dimensions are chosen in such a way that the resonance frequency of all these antennas operating in their fundamental mode is around 2.6 GHz. The RMSA and CMSA have the largest BW, but RMSA has larger gain and area. The ARMSA has a smaller area and BW than the CMSA, but the gain is comparable. An SCMSA has half the area of the CMSA and has a smaller BW, but its gain is only slightly less. An ETMSA has a smaller BW and gain but its area is also smaller. The most compact antenna among all these configurations is the HETMSA, but it has the least BW. However, gain is only slightly less than the other configurations. As a result, if BW and gain are the main requirements, RMSA or CMSA should be used. However, if compact size is required, then SCMSA or HETMSA should be used.

1.2 Modified Annular Ring:-

Several variations of CMSAs are possible to realize a compact CP antenna. Two variations are shown in Figure 1.2. A CMSA with tuning stub along its periphery and cross-slots of equal lengths at its center is shown in Figure 1.2(a). With an increase in the slot length, the resonance frequency decreases and the tuning stub controls the excitation of the orthogonal modes. A quarter-wave transformer is used to obtain impedance matching with a 50-V microstrip line feed. Instead of rectangular cross-slots, four curved slots are cut along the periphery of the circular patch as shown in Figure 1.2(b). The orthogonal modes are excited by cutting another slot perpendicular to one of the curved slots. However, these compact CP configurations yield lesser AR BW and gain due to the smaller aperture area.

Several variations of circular ring MSAs are possible for generating CP, including an annular ring with an offset polarizer and a pair of narrow slits in the outer or inner circle of the annular ring, as shown in Figure 1.2(c–e). In general, either the outer circle or the inner circle should produce two orthogonal modes, which are excited equally, and in-phase quadrature by properly locating the feed.

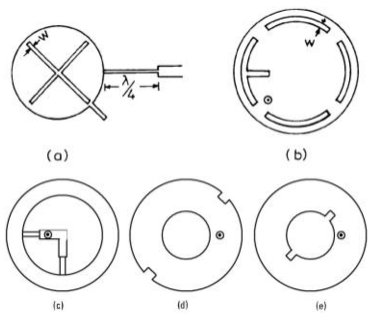

Figure 1.2 Compact CMSA with (a) cross slot with tuning

stub and (b) curved slot with tuning stub. Annular ring MSA with (c) an internal offset polarizer and slits in the (d) outer and (e) inner circle.

2. RESULTS AND DISCUSSION

Fig.2.1 shows the geometry of Annular Ring MSA with Slits (width=3.5mm, depth=5mm). The Annular Ring MSA has a outer ring radius of a= 28mm and inner ring radius of b = 10mm .The dielectric used for the patch is (ϵ_r) = 1 and the thickness of substrate h =5mm. The co-axial probe is fed of the patch at (x= 11, Y= 0). The radius of the feed conductor of co-axial probe is 0.6mm. The center frequency of this Annular Ring MSA is 2.655GHz

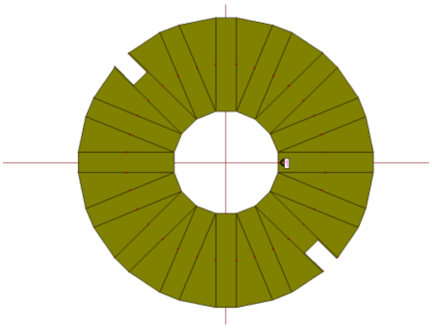

Fig. 2.1 Geometry Annular Ring MSA with Two Slits

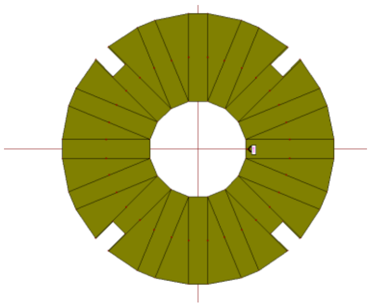

Fig. 2.2 Geometry Annular Ring MSA with Four Slits

2.2.1Parametric study of Annular Ring MSA with Two Slits

1) *Effect of Dielectic constant* :

Table No.2.1: Effect of Dielectric constant on BW, Gain, Efficiency and resonance frequency. Inner ring radius b = 10mm and outer ring radius a =28mm, thickness of the substrate h = 5mm, slits width =3.5mm, slits depth=5mm, Probe position= (X=11, Y=0), radius=0.6 mm.

Table 2.1: Effect of Dielectric constant

(Dielectric Constant) ϵ_r	Lower Freq. GHz	Upper Freq GHZ	center Freq foGHz	Bandwidth MHz	Gain dBi	Antenna Efficiency at f_o	Radiation Efficiency at f_o
1.0	2.6063	2.7228	2.6566	116.5	9.1577	90.6877	97.4666
1.1	2.5181	2.6063	2.5559	88.2	8.5172	82.2937	94.7328
1.2	2.4425	2.4960	2.4740	53.5	7.8112	74.0715	92.0098

- Comment :

With increase in dielectric constant (ϵ_r)

(a) Gain, Bandwidth, Antenna and Radiation efficiency decreases.

(b) Center, Upper and Lower frequency shift to lower side

2) *Effect of Thickness:*

Table No.2.2: Effect of Thickness on BW, Gain, Efficiency and resonance frequency, inner ring radius b = 10mm and outer ring radius a =28mm., ϵ_r =1slits width =3.5mm, slits depth=5mm, Probe position=(X=11, Y=0), Probe Radius=0.6mm.

Table 2.2: Effect of Thickness

Height (h)	Lower Freq. GHz	Upper Freq GHZ	Center Freq foGHz	Bandwidth MHz	Gain dBi	Antenna Efficiency at f_o	Radiation Efficiency at f_o
4.8	2.6252	2.7070	2.6598	81.8	8.9879	87.1572	97.3745
4.9	2.6157	2.7165	2.6598	100.8	9.0250	88.1316	97.4118
5.0	2.6063	2.7228	2.6566	116.5	9.1577	90.6877	97.4666
5.1	2.6000	2.7259	2.6566	125.9	9.1888	91.5904	97.4978
5.2	2.5937	2.7291	2.6598	135.4	9.1867	92.0334	97.5153

Comment : -With increase in Thickness

(a) Bandwidth, Antenna efficiency and Radiation efficiency increases

(b) Lower frequency shift to lower side.

(c) Higher frequency shift to upper side.

3) *Effect of Probe Radius :*

Table No.2.3: Effect of Probe Radius on BW, Gain, Efficiency and resonance frequency, inner ring radius b = 10mm and outer ring radius a =28mm. thickness of the substrate h

= 5mm ϵ_r =1 slits width =3.5mm, slits depth=5mm, Probe position=(X=11, Y=0), ϵ_r = 1

Table 2.3: Effect of Probe Radius

Probe Radius	Lower Freq. GHz	Upper Freq GHZ	center Freq GHz	Band width MHz	Gain dBi	Antenna Efficiency at f_o	Radiation Efficiency at f_o
0.4	2.5779	2.7228	2.6566	144.9	9.3391	95.1224	97.5068
0.5	2.5842	2.7291	2.6535	144.9	9.2683	93.5300	97.5248
0.6	2.6063	2.7228	2.6566	116.5	9.1577	90.6877	97.4666
0.7	2.6189	2.7165	2.6566	97.6	9.0785	89.0259	97.4704
0.8	2.6440	2.7007	2.6724	56.7	8.8835	85.9957	97.4230

- Comment :

With increase in Probe Radius
(a) Gain, Bandwidth and antenna efficiency decreases.
(b) Lower frequency shift to upper side.

4) Effect of Inner Ring Radius :

Table No.2.4: Effect of Inner Ring radius on BW, Gain, Efficiency and resonance frequency, outer ring radius a =28mm. Thickness of the substrate h = 5mm ϵ_r =1 slits width =3mm, slits depth=5mm, Probe position=(X=11, Y=0), Probe Radius=0.6mm

Table 2.4: Effect of Inner Ring Radius

Inner Ring Radius (b)	Lower Freq. GHz	Upper Freq GHZ	Center Freq GHz	Band width MHz	Gain dBi	Antenna Efficiency at f_o	Radiation Efficiency at f_o
9.0	2.6189	2.7669	2.6944	48.0	9.0177	88.7815	97.5621
9.5	2.6126	2.7448	2.6755	132.2	9.0788	89.6865	97.5192
10.0	2.6063	2.7228	2.6566	116.5	9.1577	90.6877	97.4666
10.5	2.6031	2.6913	2.6378	88.2	8.9694	87.2560	97.3823
11.0	2.6012	2.6615	2.6158	87.4	8.7213	87.6425	97.2516

- Comment :

With increase in Inner Ring Radius (b)
(a)Radiation efficiency decreases.
(b) Center, Lower and Upper Frequency shifts lower side

5) Effect of Outer Ring Radius

Table No.2.5: Effect of Outer Ring radius on BW, Gain, Efficiency and resonance frequency, inner ring radius a =10mm. Thickness of the substrate h = 5mm ϵ_r =1 slits width =3.5mm, slits depth=5mm, Probe position=(X=11, Y=0), Probe Radius=0.6mm.

Table 2.5: Effect of Outer Ring Radius

Outer Ring Radius (b)	Lower Freq. GHz	Upper Freq GHZ	Center Freq GHz	Bandwidth MHz	Gain dBi	Antenna Efficiency at f_o	Radiation Efficiency at f_o
26	2.8047	2.9086	2.8582	103.9	8.8868	86.8609	97.3710
27	2.7039	2.8110	2.7574	107.1	8.7194	83.5586	97.3920
28	2.6063	2.7228	2.6566	116.5	9.1577	90.6877	97.4666
29	2.5212	2.6378	2.5748	116.6	9.0814	89.1696	97.4527
30	2.4425	2.5622	2.4960	119.7	9.0642	88.6031	97.4596

- Comment :

With increase in Outer Ring Radius (a)
(a)Bandwidth increases
(b)Center Frequency shift to Lower side

5.1.4 Results of Annular Ring with Two Slits

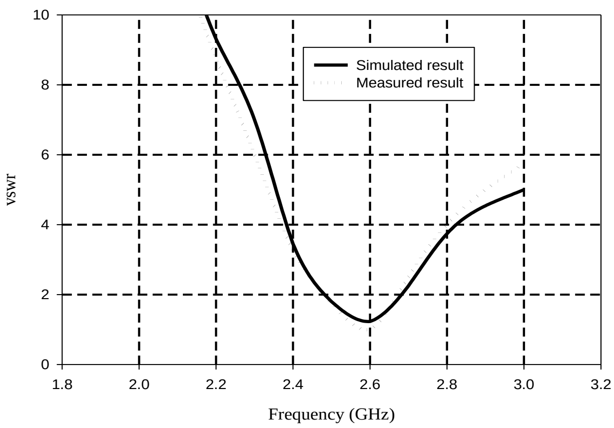

Fig. 2.3 Simulated & Measured results of Annular Ring MSA with Two Slits shown in fig. 2.1 VSWR

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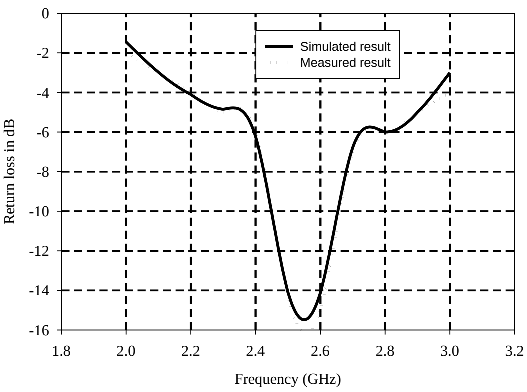

Fig. 2.4 Simulated & Measured results of Annular Ring MSA with Two Slits shown in fig. 5.1 Return loss

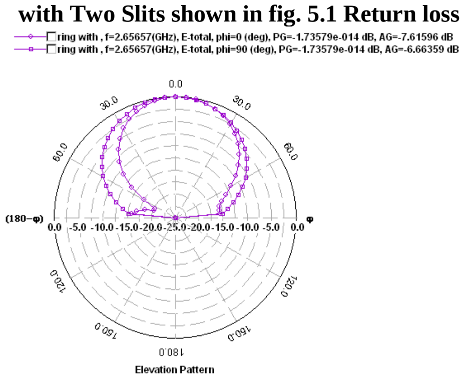

Fig. 2.5 Simulated results of Annular Ring MSA with Two Slits shown in fig. 2.1 Elevation Pattern Gain Display (dBi).

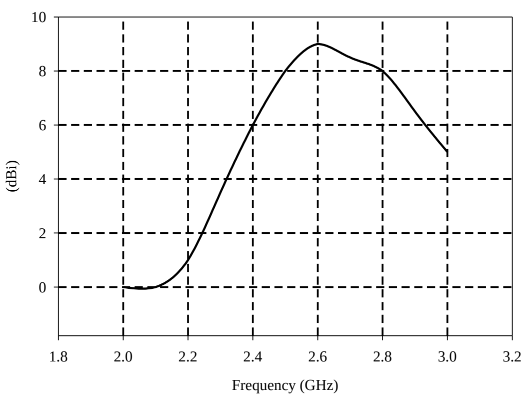

Fig. 2.6 Simulated results of Annular Ring MSA with Two Slits shown in fig. 2.1 Gain

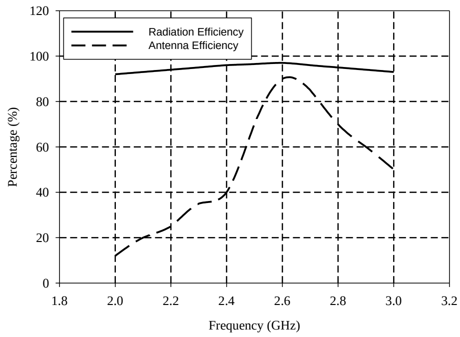

Fig. 2.7 Simulated results of Annular Ring MSA with Two Slits shown in fig. 2.1 Efficiency

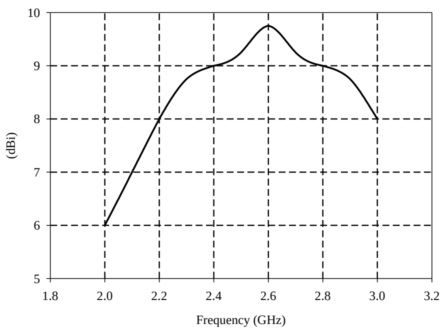

Fig. 2.8 Simulated results of Annular Ring MSA with Two Slits shown in fig. 2.1 Directivity

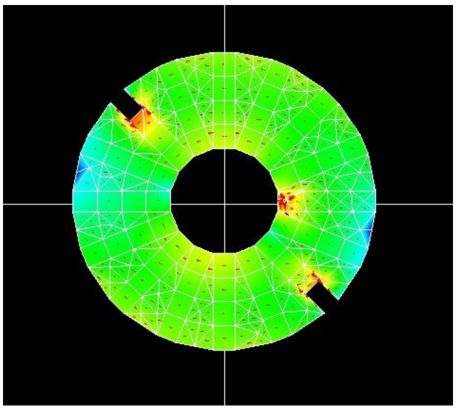

Fig. 2.9 Simulated results of Annular Ring MSA with Two Slits shown in fig. 5.1 Average Current Distribution.

2.1.5 Results of Annular Ring with Four Slits

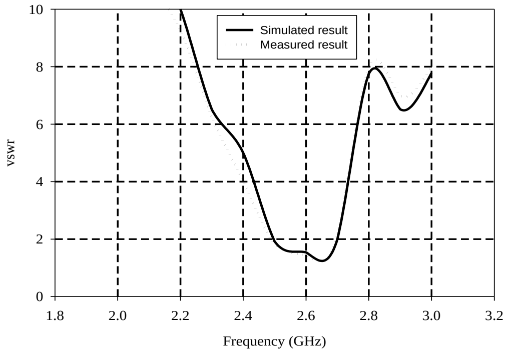

Fig. 2.10 Simulated & Measured results of Annular Ring MSA with Four Slits shown in fig. 2.2 VSWR

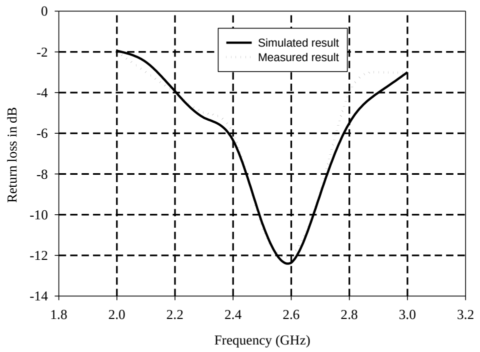

Fig. 2.11 Simulated & Measured results of Annular Ring MSA with Four Slits shown in fig. 2.2

Return Loss

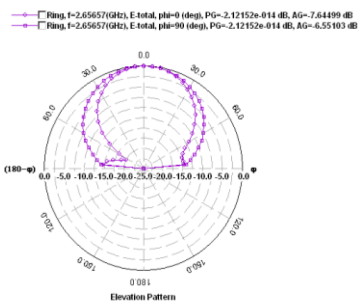

Fig. 2.12 Simulated results of Annular Ring MSA with Four Slits shown in fig. 2.2 Elevation Pattern Gain Display

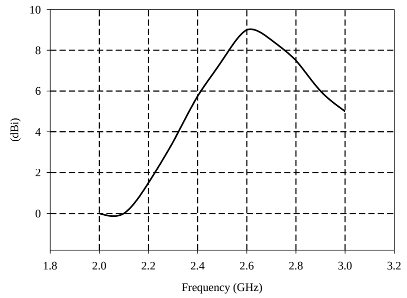

Fig. 2.13 Simulated results of Annular Ring MSA with Four Slits shown in fig. 2.2 Field Gain

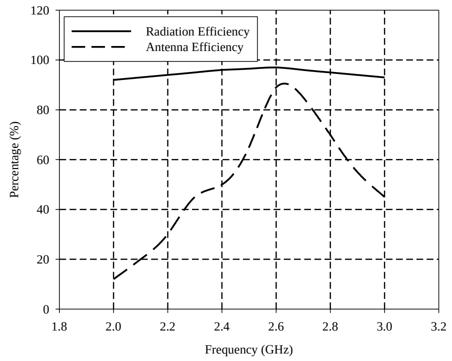

Fig. 2.14 Simulated results of Annular Ring MSA with Four Slits shown in fig.2.2 Antenna and Radiation Efficiency

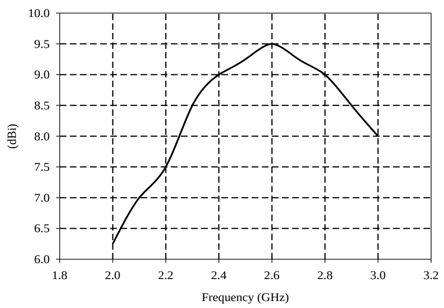

Fig. 2.15 Simulated results of Annular Ring MSA with Four Slits shown in fig. 2.2 Directivity

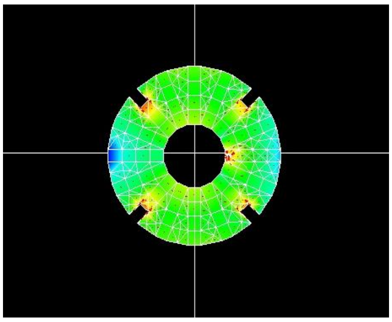

Fig. 2.16 Simulated results of Annular Ring MSA with Four Slits shown in fig. 2.2 Average Current Distribution

CONCLUSION

An Annular Ring Microstrip Antenna with slits has been successfully fabricated and tested. This Annular Ring Microstrip Antenna with slits operates in 2.60 - 2.72 GHz frequency band for VSWR ≤ 2. This band is used for Indian Satellite (INSAT) Communication System. The impedance bandwidth is 116.5 MHz or about 4.38 % is achieved. Gain of Antenna becomes 9.15 dBi. The Antenna and Radiation Efficiency are 90.68% and 97.46% respectively.

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