IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

DESIGN OF CORONA SHAPE METAMATERIAL BASED ANTENNA FOR 5G APPLICATIONS

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Abstract: In this paper a Corona shape metamaterial antenna consisting of rectangular Split Ring Resonator(SRR) is proposed. The Left Handedness of the unit cell is verified and investigated.The antenna is designed using HFSS software and it is etched on Rogers RT/Duroid 5880 substrate having a thickness of 1.6 mm and the overall dimension of the antenna is 10 x 10 x 1.6 mm3.The antenna achieves frequency band of 25.97 to 27.27 GHz with a return loss of -10 dB and voltage standing wave ratio of less than 2 with a maximum gain and directivity of 5.8dBi and 2.56dB respectively. The efficiency of the proposed antenna is 93.3% at the frequency of 26 GHz which is considerable higher. The proposed metamaterial antenna is better miniaturized, and have frequencies which mainly find applications in 5G applications.

***Key Words* – metamaterial, split ring resonator, HFSS software**

I. INTRODUCTION

Negative – Index metamaterial or Negative – Index Material (NIM) is a metamaterial whose permittivity,permeability and refractive index for an electromagnetic wave has a negative value over a frequency range [1]. The metamaterial having a negative refractive index is called left handed material. In recent times, there have been studies on these material and theoretically discussed by Veselago. NIMs are constructed by basic part called unit cells which are significantly smaller than the applied electromagnetic radiation. Varieties of metamaterial have been envisioned and fabricated [2], [3]. In this paper, a corona shape left handed metamaterial antenna is proposed based on the working principle [4], [5], [6]. The constructions of unit cells are made by providing a Split Ring Resonator which can exhibit an effective negative permeability and permittivity [7], [8].

II. ANTENNA DESIGN AND CONFIGURATION

In this section, geometry of proposed antenna is shown in Figure 1 and Table 1 provides the details about the geometrical parameters of the proposed antenna. The antenna is printed on both the side of a Rogers RT/Duroid 5880 substrate with thickness 1.6 mm and the relative permittivity of 2.2. The antenna structure consist of a combination of corona shape patch on the top surface and rectangular two SRRs repeated three times with ground as shown in the Figure 1.

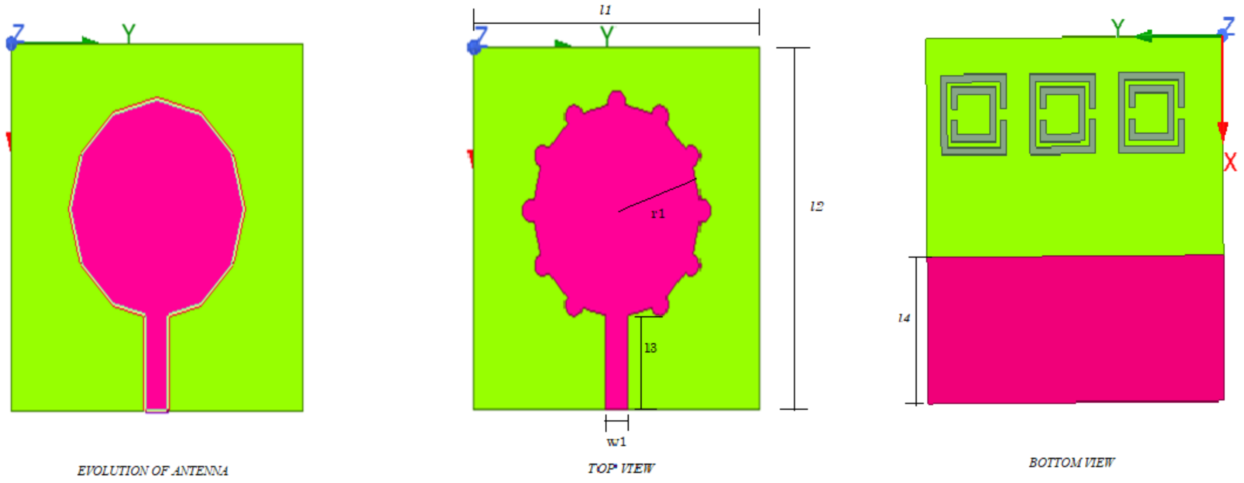


Figure 1 Evolution of the antenna

Table 1

Dimension of antenna parameters (with respect to Figure 1).

Parameter	Dimensions (mm)
l_1	10
l_2	10
l_3	3
l_4	4
$r1$	4
W_1	1

First corona shape patch antenna is designed and the simulated return loss is obtained. The S11 parameter of less than -10dB is obtained between 24.69 GHz to 27.27 GHz with a minimum of -16.54dB at 25.92 GHz with VSWR less than 2 and maximum gain of 5.45dBi. Next two rectangular SRR metamaterial is incorporated at the bottom of the antenna and the simulated results of the antenna with and without metamaterial is compared in this paper.

III. METAMATERIAL UNIT CELL CONFIGURATION

In this paper the combination of rectangular two SRRs which are repeated three times in the bottom of the antenna is designed and studied.In this design, both negative μ and negative ε are achieved. The proposed LHM structures are shown in Figure 2, with geometrical parameters given in the Table 2.

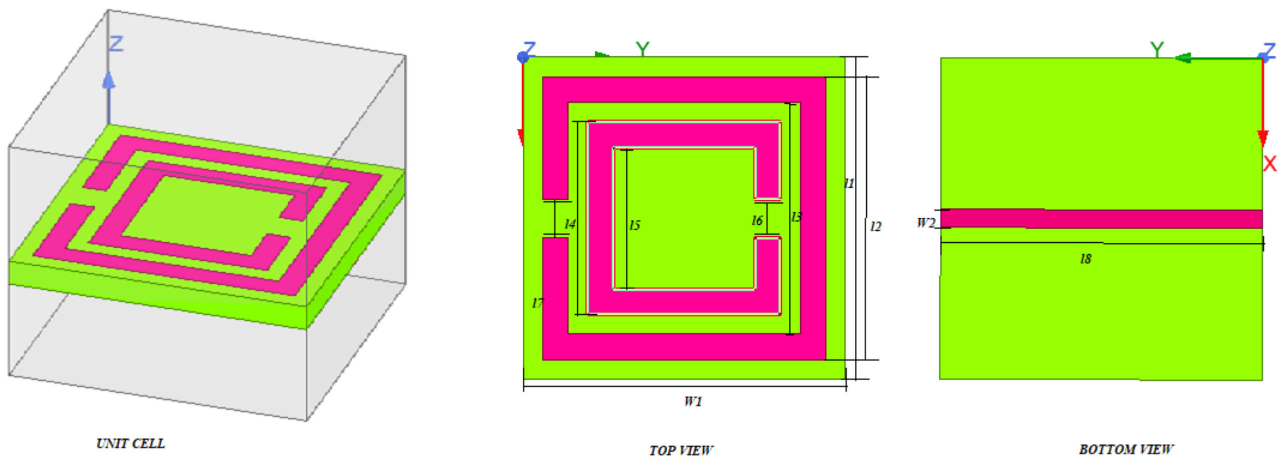


Figure 2 Metamaterial unit cell configuration

Table 2

LHM Unit cells design parameters

Parameter	Dimensions (mm)
Unit cell size	3
Substrate thickness h	1.6
l_1	3
l2	2.8
l3	2.6
l4	2.2
l5	2.0
l6	0.3
w1	3
w2	0.15
l8	3

3.1 Retrieved effective parameters

The electromagnetic properties of the LHM design is verified from retrieval algorithm described in [9], [10], and [11]. It was used to obtain the constitutive effective parameters based on the reflection and transmission coefficient characteristics, Impedance z, the relative effective permittivity ε, the permeability μ, and the refractive index n. These are obtained by the following equations.

$$z = \pm\sqrt{\frac{(1+S11)^2 - S21^2}{(1-S11)^2 - S21^2}} \quad (1)$$

$$e^{(jnk_0 d)} = \frac{S21}{1 - S11\frac{z-1'}{z+1}} \quad (2)$$

$$n = \frac{1}{k_0 d}\left[\{[\ln(e^{(jnk_0 d)})]'' + 2m\pi\ \} - j\,[\ln(e^{(jnk_0 d)})]'\right] \quad (3)$$

Where, k0 is the wave number, d is the maximum length of the unit element, m is the branch due to the periodicity of the sinusoidal function, (.)” represents the complex component and (.)’ represents the real component of the complex number, E and H are the electric and magnetic field component, respectively. The relationship between permittivity (ε), permeability (μ), refractive index (n) and the impedance (z) are given by the expression (4) and (5):

$$\varepsilon = n / z \quad (4)$$

$$\mu = n \times z \quad (5)$$

The retrieved effective parameters of proposed LHM structures are shown in the Figure 3.

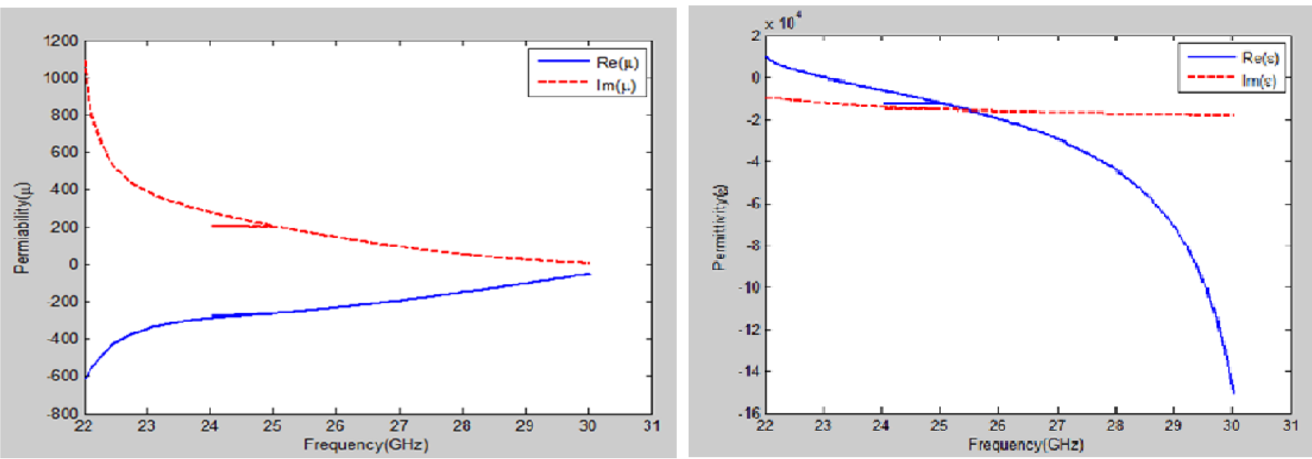


Figure 3 Negative permeability and permittivity

IV. RESULTS AND DISCUSSION

In Figure 4 the obtained simulated return loss of the antenna without metamaterial is -16.54dB and it resonates at the frequency range of 24.69 to 27.27 GHz. When the metamaterial is incorporated it achieves a return loss of -34.29dB in Figure 5.The VSWR of the proposed antenna is less than 2 in Figure 6.The gain of the antenna is 5.45dBi without metamaterial and it is improved to 5.83dBi when the metamaterial is incorporated in Figure 7. The surface current distribution is plotted in the Figure 8.

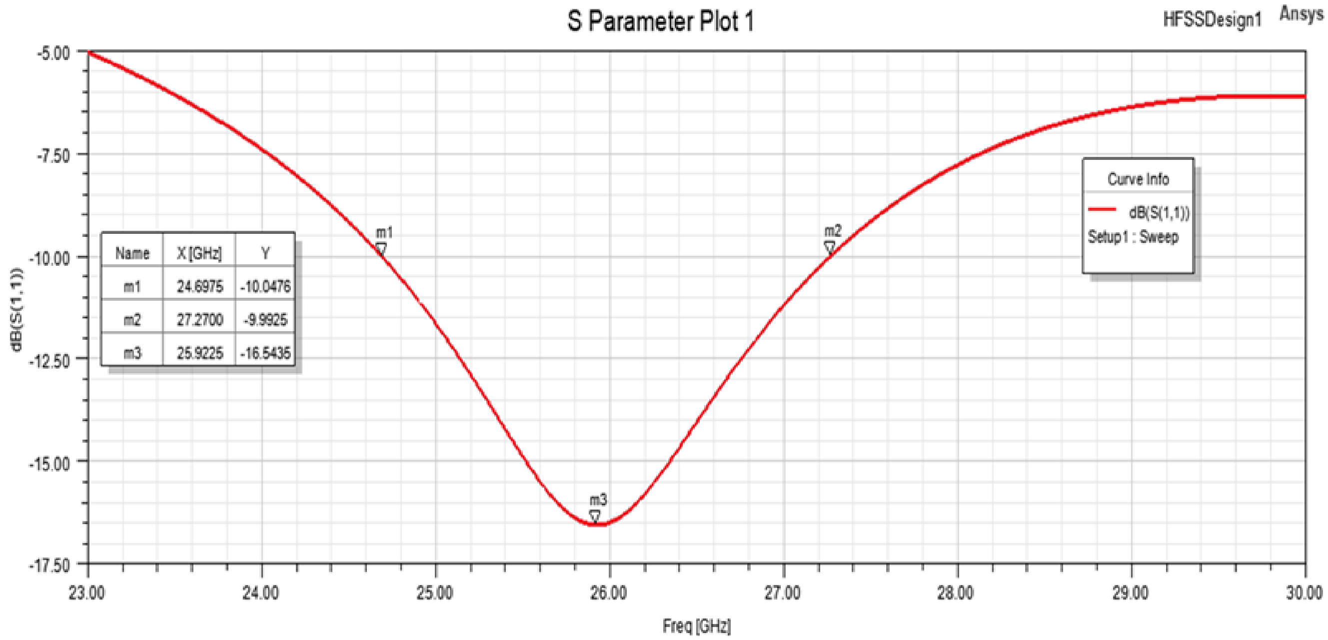


Figure 4 S11 parameter without metamaterial

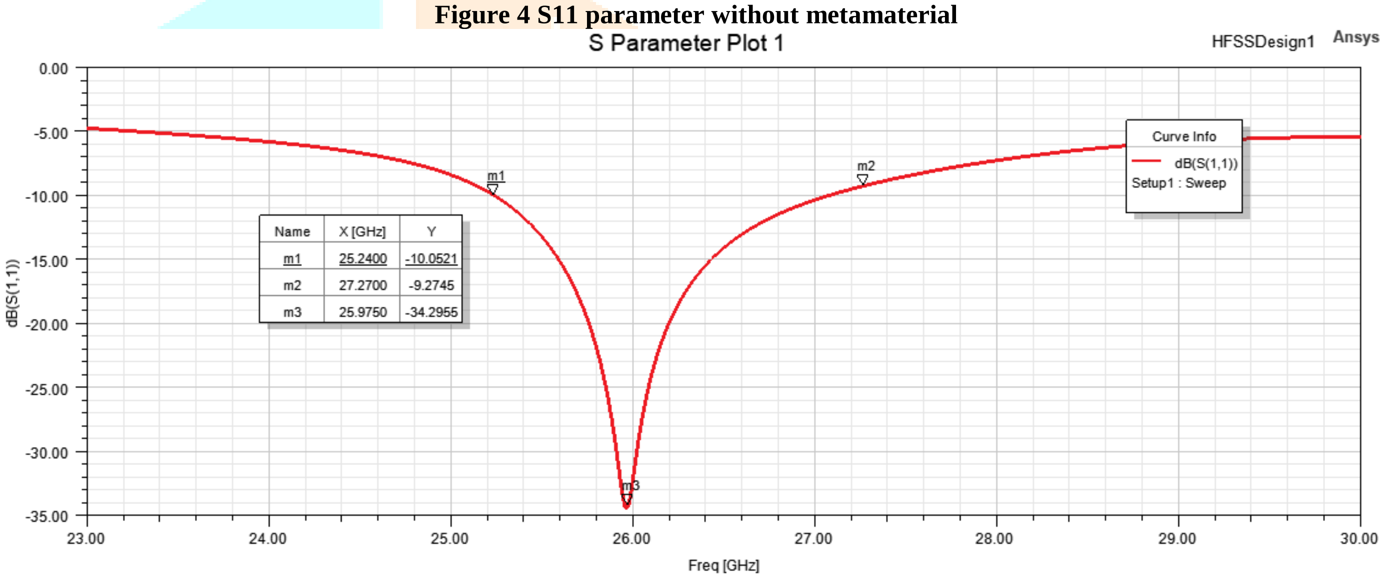


Figure 5 S11 parameter of the metamaterial antenna

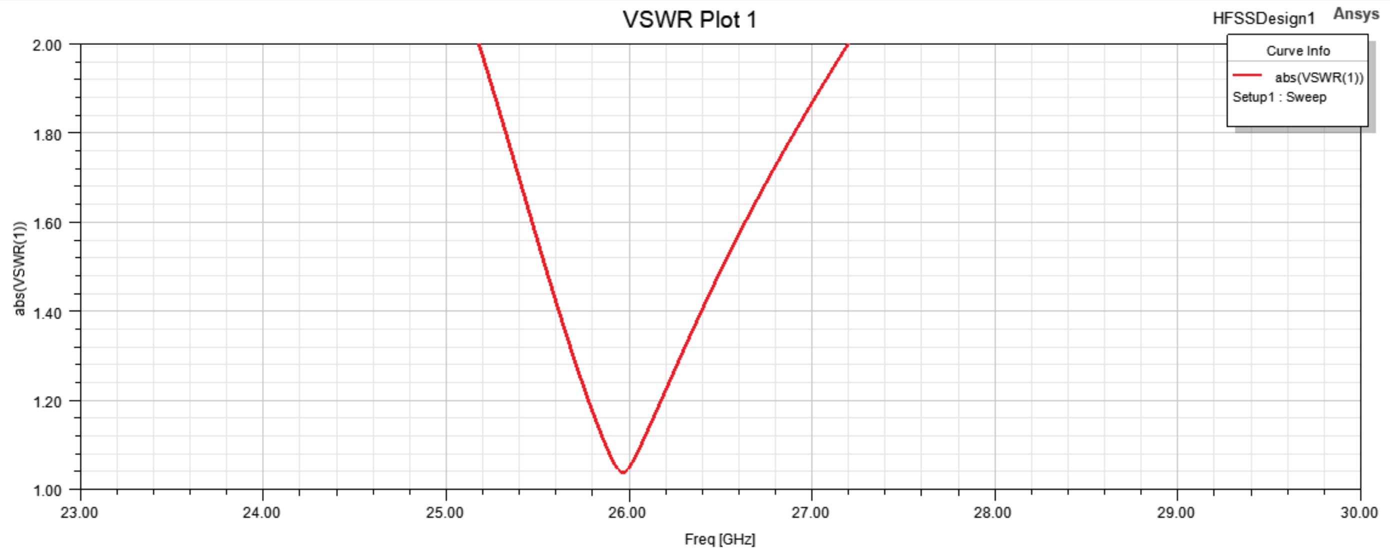
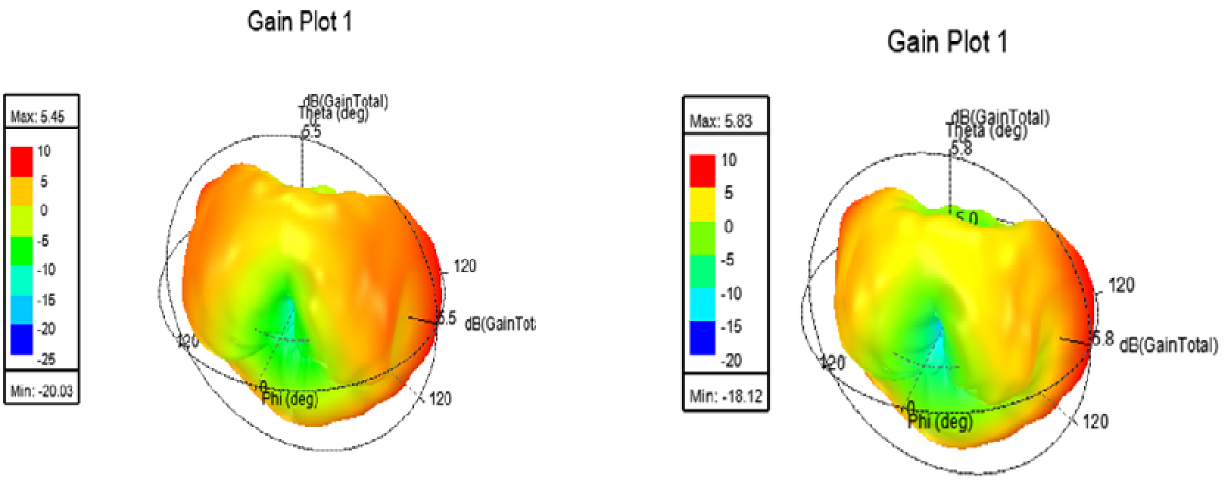


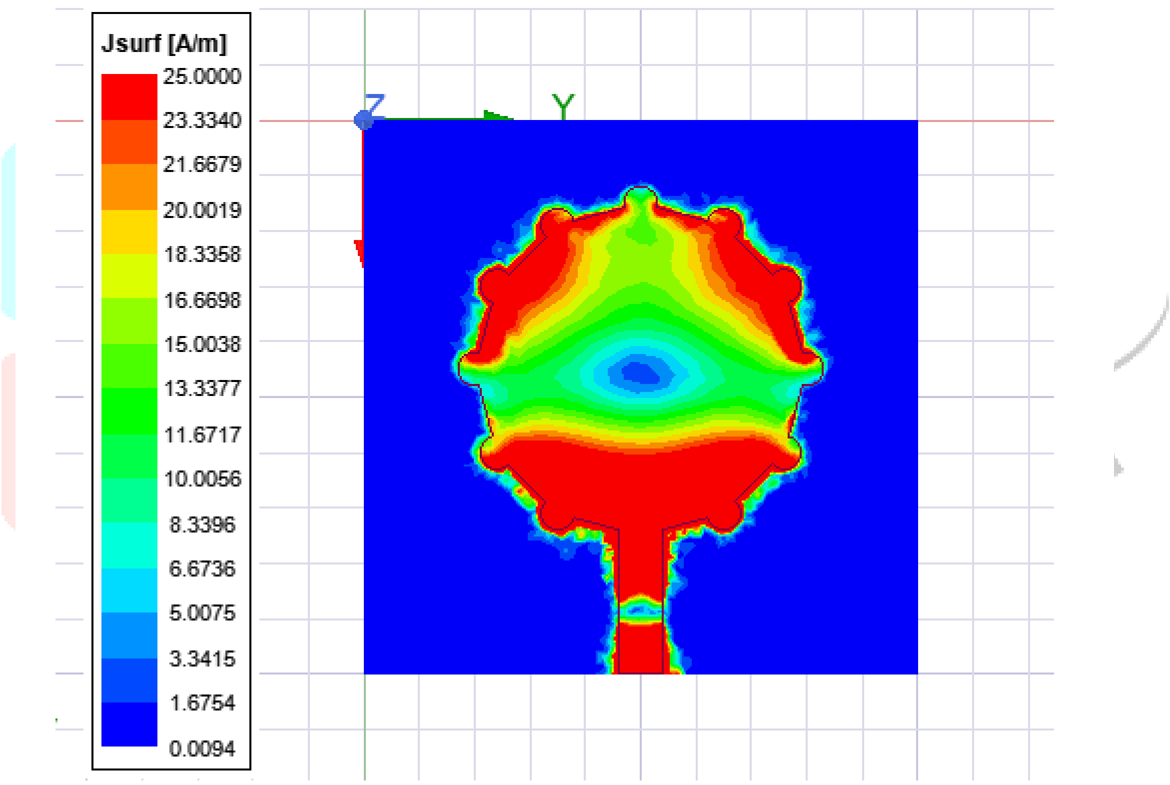
Figure 6 VSWR of the metamaterial antenna



a)Gain of the antenna without metamaterial=5.45dBi

b)Gain of the antenna with metamaterial= 5.83dBi

Figure 7 Gain of the antenna with and without metamaterial



Simulated Current Distribution of the metamaterial antenna

Figure 8

V Conclusion

The proposed antenna resonates in the 5G frequency range of 25.24 to 27.27 GHz with a return loss of -34dB.The gain of the antenna without metamaterial is 5.45dBi and the gain is improved by using the metamaterial.The gain of the metamaterial antenna is 5.83dBi.The VSWR is less than two. The radiation efficiency of the metamaterial antenna is 93.3%.The directivity of the antenna is 2.56dB.Thus the gain of the antenna is improved using metamaterial.This antenna is used in the 5G applications.

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