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Miniaturized CSRR TAG Antennas for 60GHz Applications

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ABSTRACT

In this paper, a novel approach to design an antenna for a transponder in radio frequency identification (RFID) is proposed. This approach is based on using a slot-ring antenna with a coplanar waveguide excitation integrated antennas in silicon technology. The RFID frequency chosen is the worldwide available free 60-GHz band .The structure is simulated by using Computer Simulation Technology (CST). The antenna size is 1.5 × 1.3 mm^2. This proposed antenna presents a gain about 3.82 dB which means a possibility to increase the readable range.

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1. INTRODUCTION

Radio frequency identification (RFID) systems have already been transferred from research laboratories to industrial applications successfully and RFID has several types of applications which are widely used [1-2-3]. RFID systems currently operate primarily in the frequency bands between 125 kHz and 5.8 GHz.

Given the increasing number of such systems in these bands begin to saturate and it becomes difficult to incorporate new systems. We propose a new concept in this work, which uses millimeter wave frequencies instead of below 3 GHz frequencies typical for RFID [4-5].

Clearly, a tendency to move to ever higher frequencies is seen here. Herein, we propose using millimeter waves for identification applications. Here we call the millimeter RFID millimeter wave identification (MMID) [6].

Many studies are currently being spent, they focus on different aspects: systems, propagation, antennas, circuits and components. They intensify more and more as technology millimeter becomes more efficient and less costly.

Millimeter Wave Identification (MMID) has been introduced as an update/upgrade of conventional RFID from the high frequency (HF) and the ultra high frequency (UHF) bands to 60 GHz millimeter wave band in [6]. Pursula et all advocate in [6] that using higher carrier frequency results in the following advantages: smaller tag antennas which result in smaller tags, more compact reader modules [7] and more directive reader antenna arrays which have narrower beams and higher gain. A 60 GHz semi-active MMID tag was successfully designed and tested as a proof of concept MMID tag in [7]. There are several advantages of MMID over RFID. At millimeter waves, e.g., 60 GHz, high data-rate communications with even gigabit data rates can be implemented. Here, an interesting application would be battery less wireless mass memories that can be read in a few seconds with high data rates. Furthermore, at millimeter waves, directive antennas are small. A reader device with a small directive antenna would provide the possibility of selecting a transponder by pointing toward it. This is not possible in today's UHF RFID systems because directive antennas are too large. A directive reader antenna would help in locating transponders in high-density sensor networks or other places where transponders are densely located, e.g., in item level tagging. Finally, there are already applications where millimeter-wave radars are used, as in automotive radars. In [8], D. Hou et all present a novel antenna that resonates on 130GHz. The proposed antenna is realized by merging two three different techniques: the meander line, a slot technique for and the dielectric resonators. C. Liu et all develop an helical array, for 60 GHz. The designed array is composed by a 4×4 element and it's characterized by a circular polarization, [9]. As for [10], N.Ghassemi et all use the substrate integrated non radioactive dielectric to propose a wideband planar dielectric antenna for W-Band and up-millimeter wave application. Finally, in [11], M.Henry et all develop a new technique in antenna design. The proposed concept was tested in the millimeter band.

In this paper, a meta-material inspired loop antenna is proposed to simultaneously reduce size, enhance bandwidth and achieve frequency scanning [12]. The proposed antenna consists of CSRR structures and a modified rectangular loop element. The proposed antenna is then simulated by using Computer Simulation Technology (CST) Studio Suite 2009.

This paper is organized as follows. In the first section, we propose a CSRR antenna which resonates at 60 GHz. In the second section we use a parasitic element in order to reduce antenna size. In the third section, we try to introduce a via-hole between the two layers in order to study its effect. Finally, we conclude our work and we suggest some perspectives.

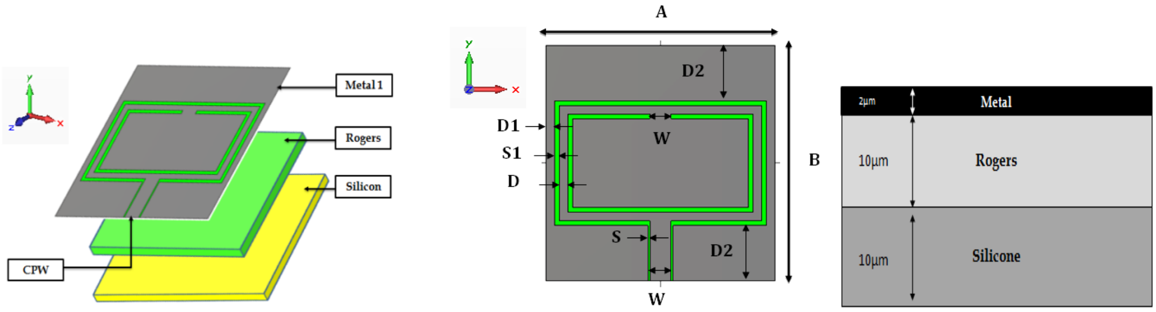
2. A SPLIT-RING RESONNATOR (SRR) MULTILAYER ANTENNA

In this section the designs and the simulation results of different antennas, integrated with silicon technology, will be described.

2.1. Proposed Design

Configuration of the proposed split-ring resonator-based RFID loop antenna is shown in figure 1.a. The proposed antenna consists of a modulated loop element printed on the Rogers substrate.

Presented in Figure 1.a is a detailed of the on-chip antenna. The width of the rings is denoted as S1, the gap between the rings is denoted as S and the gap on either end of the rings is denoted as W. It consists of a silicon based on-chip feeding structure. The feeding structure is created by a coplanar waveguide (CPW) and a slot ring [13].The slot ring is implemented on the 2 µm thick top metal. It is shielded by the bottom metal and connected to a 50-Ω CPW with a signal line width of W= 150 µm and slot width of S= 14 µm.



(a) (b) (c)

Figure 1. Geometry of the proposed antenna (All dimensions in µm)
a. General view
b. Front view
c. Button view

The CPW (Coplanar waveguide) topology is a good candidate to design the antenna for the 60-GHz µRFID tag. The work in [14] has also demonstrated that in HR substrates the losses are drastically reduced if compared with the bulk silicon technology in which the CPW transmission lines are made only on the top metal layer in order to reduce substrate losses.

Table 1. OPTIMIZED design parameters

Parameters	Value, mm
A	1.63
B	1.7
D1	0.06
D2	0.4
W	0.15
S	0.014
S1	0.03

One of the main advantages of using meta-material based elements in the design of antennas is that the resulting antenna is much smaller than traditional printed antennas. Particularly, meta-material based elements [15-16] have been incorporated into the design of printed antennas on two ungrounded dielectric.

The proposed loop antenna has novel properties mainly because of the inclusion of component split-ring resonator (CSRR). The suggested CSRR unit cell has two enclosed ring with a split gap at the end at ring.

The front view of the loop antenna is shown in figure 1.b. The rectangular loop element is placed at the central part of a metal with a height of 2µm. The coplanar line is composed of three conductors deposited on the upper level of the second layer which is the Rogers.

To analyze the CPW transmission lines, a line of characteristic impedance of 50 Ohms for feeding the antenna was studied [17]. The characteristic impedance of the line can be calculated by the method of conformal transformation, and using the formula (1), where K is the elliptic integral coefficients k and k' connected the dimensions of the line, εeff is the effective permittivity of the Rogers substrate.

$$Z_e = \frac{30\pi}{\sqrt{\varepsilon_{eff}}} \frac{K(k)}{K(k^{'})} \qquad (1)$$

W is the width of the ribbon core, S is the spacing between the central ribbon and two ground planes.

2.2. Simulation Results

This antenna is optimized to have a resonance frequency around 60 GHz. Simulations under CST helped find the results of simulations of the antenna. An antenna at 60 GHz integrated with a coplanar feed is formed on a substrate Rogers and Silicon. Figure 2 shows the simulated values of reflection coefficient of the antenna (| S11 | dB).

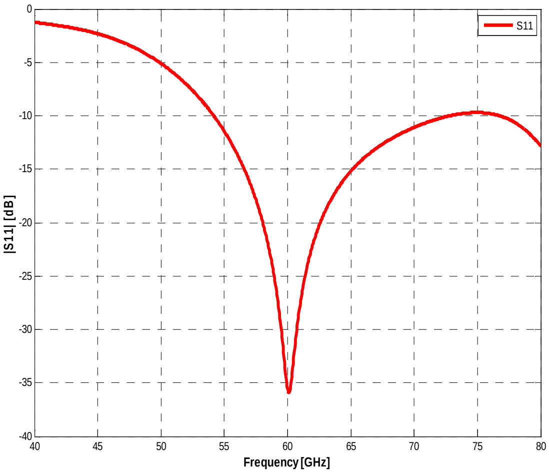
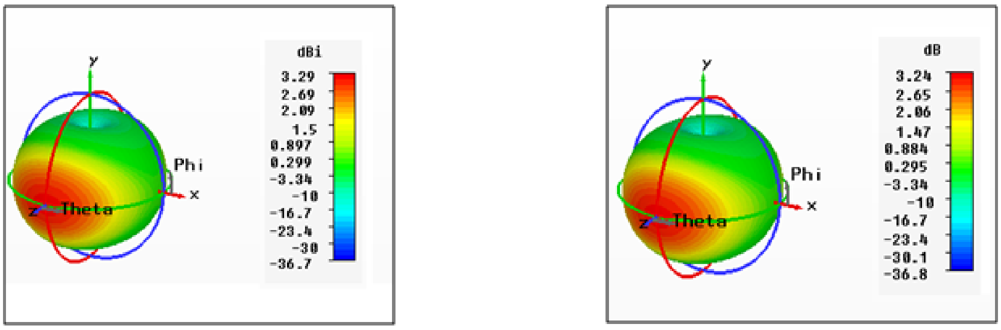


Figure 2. Simulated reflection coefficient for the proposed antenna .



(a) (b)

Figure 3. Far Field parameters of the proposed antenna
(b) Directivity (a) Gain

The 3D plot of the antenna gain obtained by means of 3D-EM simulations are shown in Figure 3. In detail, a maximum gain of 3.24 dB, a return loss (S11) equal to - 36 dB with bandwidth of 20 GHz at -10 dB and an efficiency of 98 % at 60 GHz have been obtained.

3. A MINIATURIZED CSRR ANTENNAS

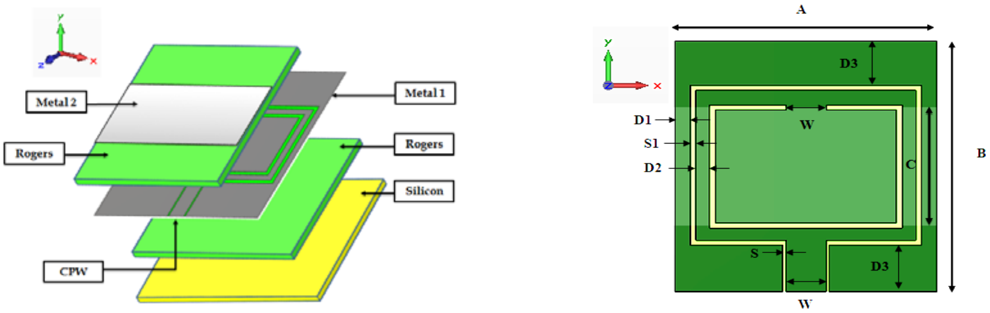
3.1. First Technique: A Parasitic Antenna

3.1.1. Proposed Design

Figure 4.b shows the structure and dimensions of the element, whose conductor is fabricated on an inexpensive substrate with the effective dielectric constant of 3.38 and the substrate thickness of 0.01mm.

Table 2. OPTIMIZED design parameters

Parameters	Value,mm
A	1.3
B	1.4
C	0.66
D1	0.076
D2	0.068
D3	0.26
S	0.014
S1	0.028
W	0.2



(a) (b)

Figure 4. Geometry of the proposed antenna (All dimensions in µm)

a. General view
b. Front view

The proposed near-field antenna is implemented on a Rogers 4003 substrate (thickness of 0.01 mm, relative dielectric constant ε_r = 3.38, and loss tangent tan = 0.0027) with an overall size of 1.3 x 1.4 mm^2. The scheme of the proposed near-field antenna is shown in Figure 4.b. The dimension of the parasitic element is c = 0.66 mm. When a parasitic element is added in the antenna structure, as shown in Figure 4.a the pattern shows some improvement in term of steering angle compared to antenna without parasitic elements.

3.1.2. Simulation results

In the figure above, we see that we have a good adaptation S11 = -40 dB to frequency 60GHz with a bandwidth of 2GHz, figure 5.

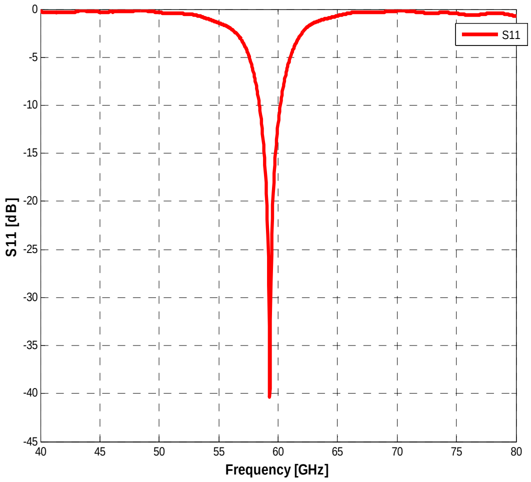


Figure 5. Simulated reflection coefficient for the proposed antenna with parasitic antenna

The simulated antenna presents an acceptable gain and directivity for the needy application, figure 6.

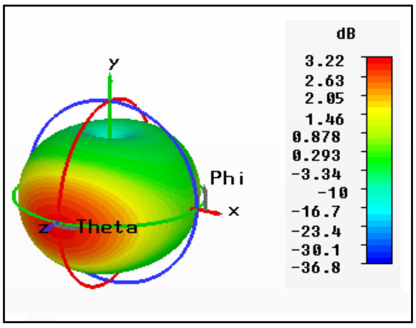


Figure 6. Simulated gain of proposed antenna

3.2. The Second Technique: Via-hole

3.2.1. First Antenna with 1Via

The first structure is composed by the original patch in a multi layers structure with a parasitic element. Besides the structure, we use a Via-hole between the two elements.

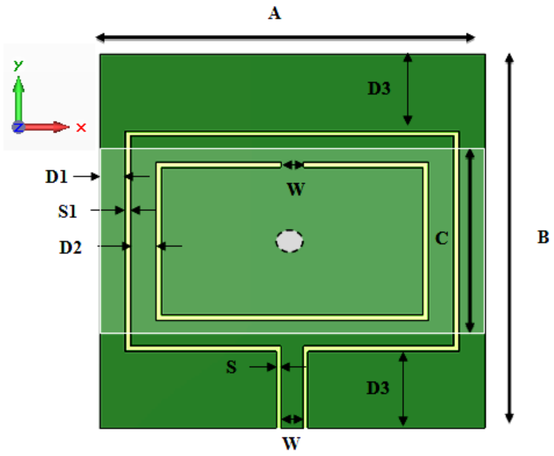


Figure 7. Dimensions of the proposed antenna with parasitic element with 1 Via-hole

With this configuration of the antenna, it has a center frequency of 60 GHz with bandwidth of 200 MHz, a reflection coefficient S11 = -26 dB and a gain of 2.38 dB using the substrate Rogers 0.01 mm thick.

Acting on the length of the patch above, you can adjust the frequency Central.

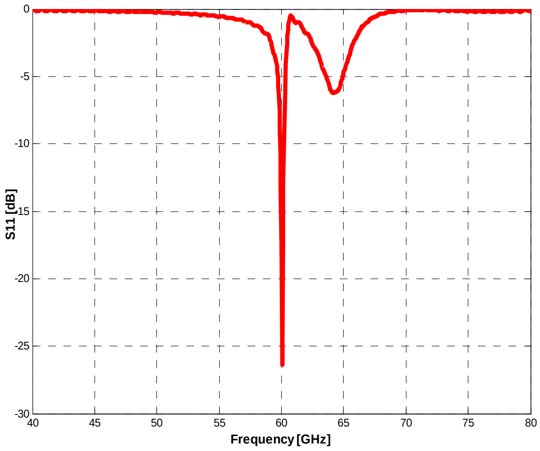


Figure 8. Simulated reflection coefficient for the proposed antenna with parasitic antenna with 1 Via-hole

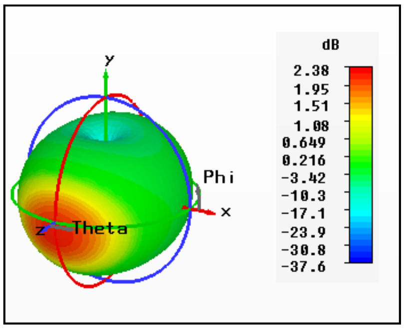


Figure 9. Simulated gain of proposed antenna

The introduced via-hole decrease the antenna gain, besides the bandwidth antenna becomes narrow but it still accepted for the proposed application.

3.2.2. Second Antenna with 2 Via-holes

In order to study the effect of introducing via-hole, we modify the via-hole number. In this section, we use two via. The problem is the position exact of introduced via. The proposed geometry is described in the figure bellow.

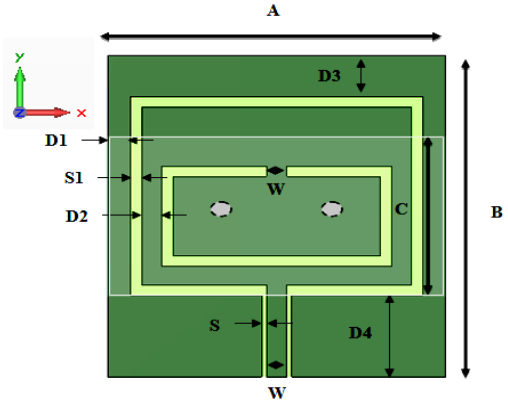


Figure 10. Dimensions of the proposed antenna with parasitic element with 2 Via-holes

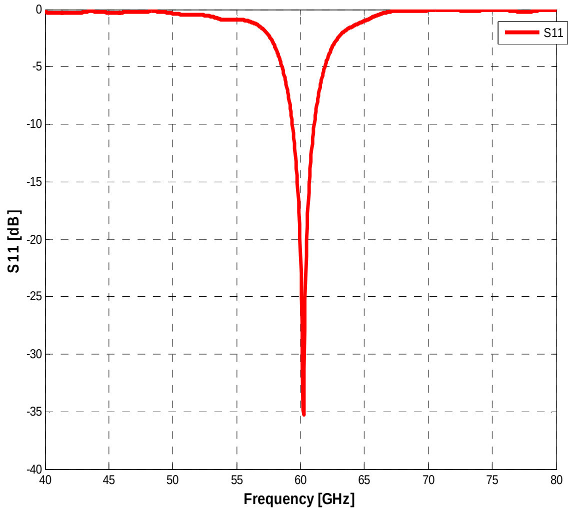


Figure 11. Simulated reflection coefficient for the proposed antenna with parasitic antenna with 2 Via-holes

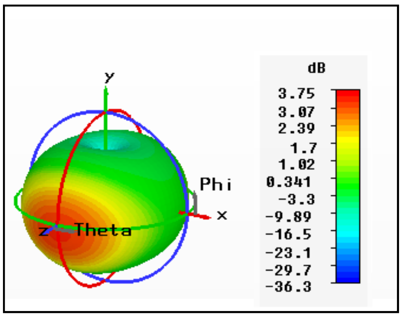


Figure 12. Simulated gain of proposed antenna

As can be seen in figure 11, the structure resonates at 60 GHz. The bandwidth was increased to 1.4 GHz, besides the antenna gain is better that the previous structure.

3.2.3. Third Antenna with 4 Via-holes

In the last structure, we introduce 4 via holes. The via-holes were placed as is clear in the figure below.

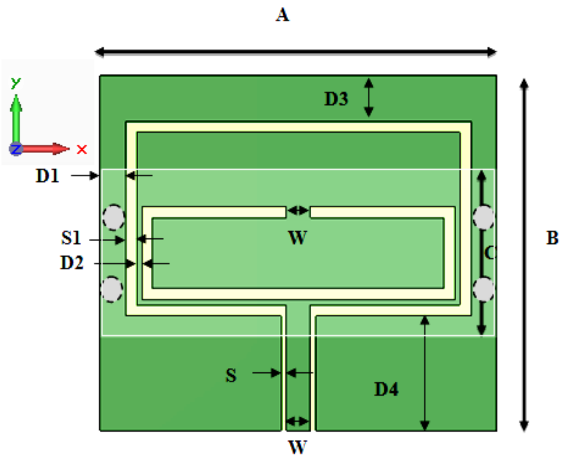


Figure 13. Dimensions of the proposed antenna with parasitic element with 4 Via-holes

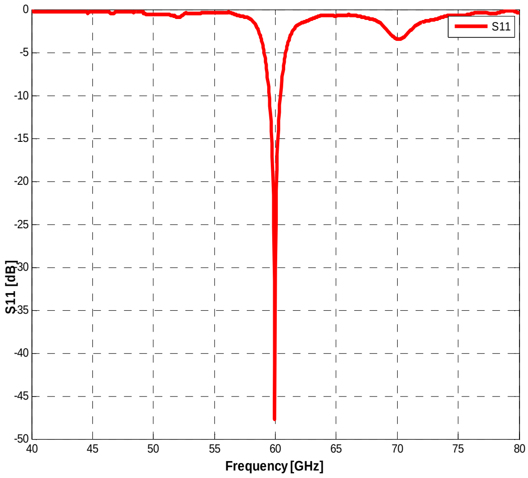


Figure 14. Simulated reflection coefficient for the proposed antenna with parasitic antenna with 4 Via-holes

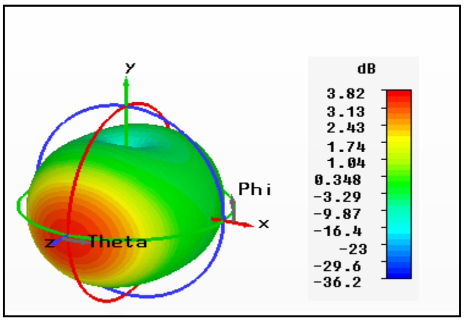


Figure 15. Simulated gain of proposed antenna

As clear in simulation result, this last antenna presents a resonant frequency equal to 60GHz and an acceptable Bandwidth. Besides, the gain of the proposed antenna in betters then the two previous antennas.

3.2.4. A comparison between the proposed antennas to other published on-chip antennas

The characteristics of the three antennas can be summarized as follows: compared with the antenna without via, the gain improvement of the antenna with 4 via-holes to the significant radiation efficiency improvement.

Table 3. Performance of proposed antennas as compared to other published on-chip antennas

	This Work	This Work	This Work	This Work	This Work	JSSC 2006 [20]	TED 2005 [18]	EDL 2008 [19]
Technology	The base antenna	Ant 1: Parasitic element	Ant 2 : 1 Via-hole	Ant 3 : 2 Via-holes	Ant 4 : 4 via-holes	Silicon lens	Inverted-F Quazi-Yagi	Yagi antenna
Freq.[GHz]	60	60	60	60	60	77	60	60
Bandwidth	40 %	4 %	0.04 %	8 %	2 %	--	20 %	17 %
Gain (dB)	3.24	3.22	2.38	3.75	3.82	2	-19/-12.5	-10.6
Area (mm2)	1.63×1.7	1.3×1.4	1.5×1.455	1.5×1.57	1.5×1.3	10×10	1.3×0.8	0.95×1.1

Summarized in Table 3 is a performance comparison of the proposed with the various published on-chip antennas. Compared with the conventional metallic antennas in [18] and [19], the performance of the proposed antenna structure shows considerable improvement. Also, compared with other techniques such as the silicon lens [20], our proposed low-cost and simple structured multiple via-holes antenna not only attains comparable gain and efficiency but is of a notably smaller size.

4. CONCLUSION

In this paper a miniaturized antenna for 60 GHz is developed. The obtained antenna is based on merging two techniques: parasitic element and via-hole Insertion. The antenna has also an acceptable gain and good impedance. The novel antenna can be considered as a best solution for an eventual MMID application. This work is one of the first steps in MMID and we desire in the future to use our antenna in MMID TAG Chip-Less.

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His a professor at the Grenoble Institute of Technology, France. His main research interest concerns design and miniaturized devices of wireless and sensor, such as Antenna, RFID, and Smart Paper. He is author or co-author about 100 papers published in international journals or conferences.

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