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Multi-Band Rectangular Hybrid Antennas Loaded with Inter-Digital Structure Slot

T. Meghana[1], B. Rajesh[2], Dr. B.R. Sanjeev Reddy[3]
[1, 2] Students, [3]Ph. D Professor, Department of Electronics and Communication Engineering
B. V. Raju Institute of Technology, Medak, Telangana, India

Abstract: In this paper, two rectangular multi-band hybrid antennas are proposed. Modified Inter-digital structure slot is loaded on top of DRA to achieve multi-functional capability for sub 6 GHz wireless applications. The tri-band hybrid antenna with modified inter-digital structure resonates at 3.52 GHz, 3.57 GHz & 4.19 GHz and consequent Return Loss (RL) bandwidths are 40 MHz (3.5-3.54 GHz), 60 MHz (3.54-3.6 GHz) and 120 MHz (4.13-4.25 GHz) respectively. The proposed tri-band hybrid antenna without horizontal slot in H-slot resonates at 2.86 GHz, 3.27 GHz and 3.97 GHz and resultant RL bandwidths are 40 MHz, 60 MHz and 220 MHz respectively. The field analysis and parametric study of the proposed hybrid antennas are presented using Mentor Graphics IE3D full-wave Electro-magnetic simulator, formerly Zeland Software. The gains obtained for the proposed antennas are more than 3dBi at all the resonances that have been occurred.
Keywords—Inter-digital structure, Dielectric Resonator Antenna, Rectangular DRA, Hybrid DRA, Tri-band, CP Radiation.

I. INTRODUCTION

Modern wireless gadgets needed integration of multiband antennas to incorporate multiple applications in to a single antenna structure. The combined features of micro-strip and DR antennas known as Hybrid antennas facilitates these multi-functional properties. Various shapes and feeding techniques are employed to investigate practically different properties of micro-strip patch antennas and their advances [1]. Various antenna radiation parameters are experimentally investigated considering circuit properties of dielectric cylindrical cavity antenna is presented [2] and the resonant frequencies are validated.

A hybrid structure is formed by combining Dielectric-Resonator Antenna (DRA) and a slot radiating structure to achieve dual-band radiation is reported [3]. A circular and eccentric ring slot on ground plane is used to form two resonant cascaded structures to produce two different resonances. A hybrid DRA with experimental results of Return Loss impedance bandwidth (5.14–6.51 GHz) 23.5% is presented [4]. Antar presented the advancements and challenges in designing Hybrid and composite DRA structures and also discussed the comparison between micro-strip antennas and DRAs [5].

A Hybrid DRA of triple bands associated with rectangular patch, slot and dielectric-resonator respectively, are presented [6] and appropriate for W-LAN and Wi-MAX applications. A tri-band hybrid rectangular DRA resonator antenna (RDRA) is proposed with an integrated approach of higher order mode techniques and a radiating slot is proposed [7] to achieve three resonant bands (1.8, 2.6 and 3.4 GHz) for 4G-LTE applications.

A hybrid antenna loaded with magnetic LC resonator on the top of the DRA is reported [8] for miniaturization and dual-frequency applications. Both the bands are produced more than 6dBi gain and operates at 3.6 and 5.25 GHz applications. A novel feeding structure which is a combination of conformal vertical-strip and inverted H-shaped monopole is used to feed rectangular DRA by forming hybrid structure for triple frequency applications. This paper proposes [9] triple bands suitable for GPS (1.45–1.63 GHz), peer to peer microwave (3.62–4.1 GHz), and WLAN/Wi-Max (4.55–5.86 GHz) applications. CP radiation is achieved by combination of four slots etched geometrically on the ground plane and with a feed network comprising strip-lines arranged in 90 degrees phase difference to couple the radiation to dielectric resonator over a wide bandwidth [10]. In this article, a tri-band hybrid DRA loaded with inter-digital structure slot is proposed for sub 6 GHz wireless applications.

II. PROPOSED HYBRID ANTENNAS

The proposed hybrid DRAs are having DR permittivity of 10.2 with a height of 6.4 (H_D) and a length (D) of 25 mm is fed by conformal strip line (W_f = 2.4mm and H_f = 3.5 mm), which is being laid on the substrate permittivity of 2.2 with a thickness of 0.787 mm (H_s) is shown in Fig. 1. On the top of DR material copper metal was placed with inter-digital structure slot to achieve multi-functional capability. The overall dimensions of the proposed antenna are (50 X 50 X 7.2) mm^3 and micro-strip feed length is of (L_f) 17.25 mm.

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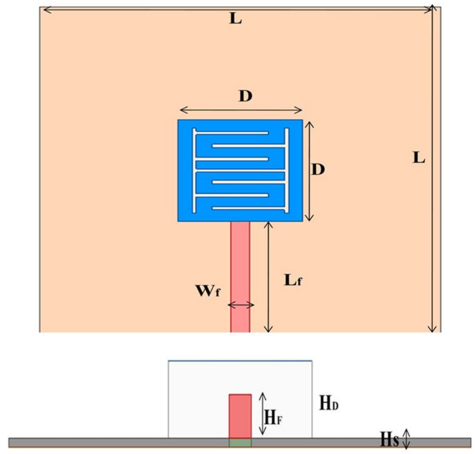
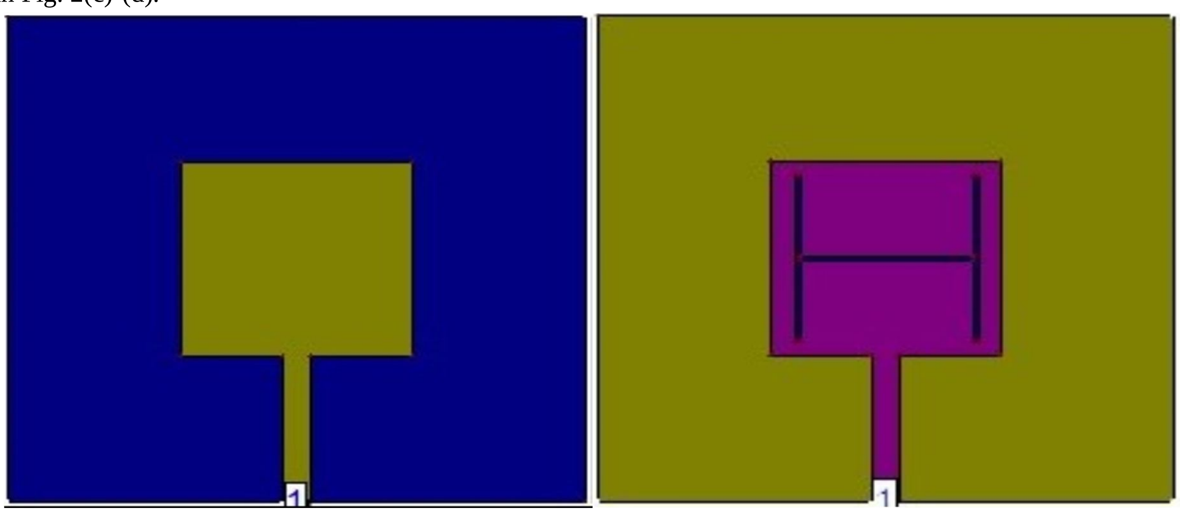
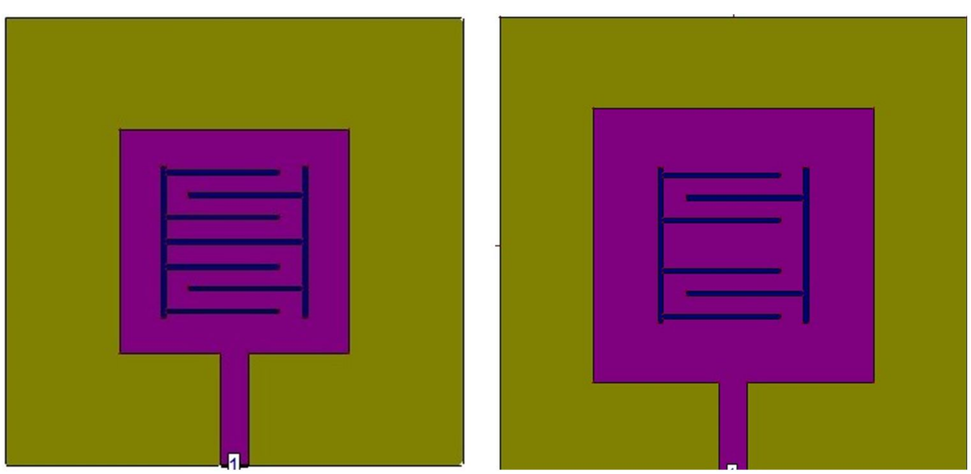


Fig. 1. Front and side views of proposed Tri-band Hybrid DRA

The proposed hybrid antennas are developed based on the designs and the relavant field analysis is presented in Fig. 2(a)-(b). The proposed Tri-band hybrid antennas with inter-digital structure and modified inter-digital structure within the H-slot are presented in Fig. 2(c)-(d).



(a) Ant. 1: Rectangular Hybrid-DRA with on top copper metal layer (b) Ant. 2: Rectangular Hybrid-DRA with H-Slot



(c) Ant.3:Rectangular Hybrid-DRA modified Interdigital slot (d) Ant. 4: Rectangular Hybrid-DRA with Interdigital structure

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Fig**.** 2**.** Different design ivariations of proposed Hybrid DR Antennas

A copper metal layer is laid on top of the DRA forming a Hybrid antenna (Ant. 1), which resonates at lower resonant frequency of 3.47 GHz and a new radiating mode is excited with the same size of the antenna [8]. It is observed that by loading the DR with a copper metal, the resonance shifts from higher to lower frequency. An H shaped slot (Ant.3) with a width of 0.5 mm is etched on top copper layer of the Ant. 1 and parrallelly a magnetic field is portrayed, which is oriented horizontally to y-axis and is uniform.

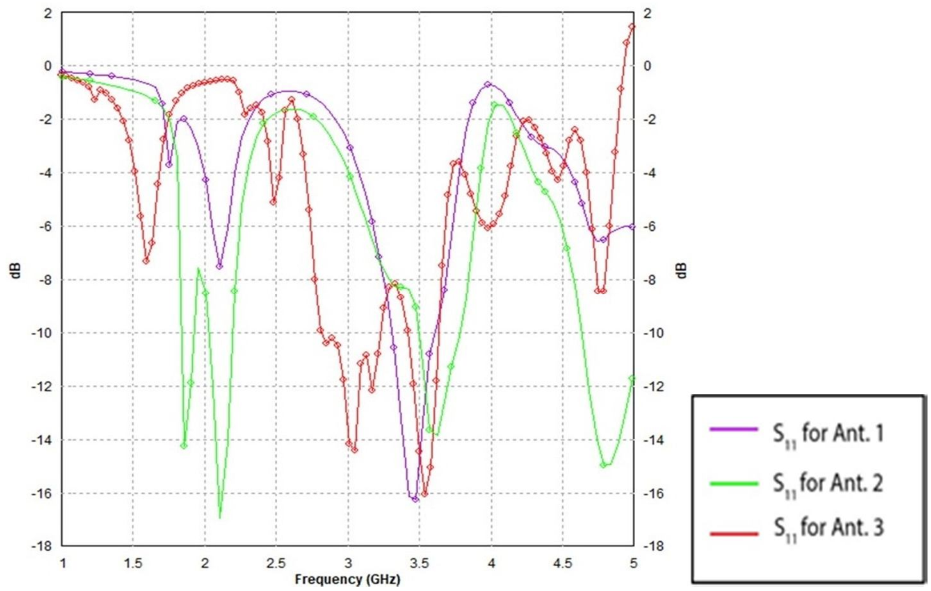


Fig .3. S11 comparison for all the variations presented (Ant.1 to Ant. 3)

The inter-digital structure is formed by symmetric and parallel coupled-line resonators, which is used for miniaturization of proposed antennas and it is evident by producing lower order resonant frequencies for Ant. 3 and 4. S11 comparisons for the antennas (Ant.1 - Ant.3) are plotted in Fig. 3.

The Ant. 2 is modified by inter-digital structure to produce triple bands at 3.52 GHz, 3.57 GHz and 4.19 GHz. The upper most resonance in Ant. 3 is a circularly polarized band, and it is due to the asymmetric nature of proposed modified Inter-digital structure, where two higher order modes are orthogonal and exhibits 90-degree phase difference.

Further, by adjusting the dimension gap 'G', the Ant. 3 is modified in to Ant. 4 (by eliminating horizontal slot in the H-slot) to provide another lower operating frequency band (2.86 GHz) with a total of three bands at 2.86 GHz, 3.27 GHz and 3.97 GHz. The confined nature of radiation pattern distributions within the structure of Ant. 3 and 4 is due to the modified Inter-digital structure and it also produces the lower order resonances without change in the overall antenna size. Hence the combination of DRA and metal loaded with modified inter-digital structure results the compact multi-functional antennas for sub 6 GHz wireless applications. The return loss of Ant.4 with parametric variation of gap ’G’ is represented in Fig.4.

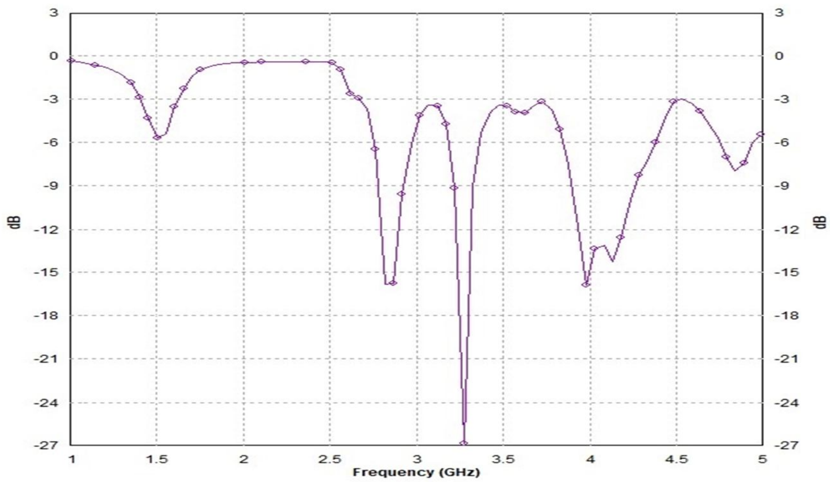


Fig. 4. Return loss plot for Interdigital structure by eliminating horizontal slot in the H-slot (Ant. 4)

III. RADIATION PATTERNS AND SIMULATION RESULTS

The antenna design and simulation are done by using IE3D software. IE3D is a commercial electromagnetic simulator produced by Mentor Graphics company. The output graphs like VSWR, Radiation patterns and gain patterns were plotted using this software.

A. Voltage Standing Wave Ratio (VSWR)

VSWR is a measure that numerically describes how the antenna impedance is matched with transmission line impedance. The VSWR values of tri-band hybrid DR antenna (Ant. 3) for (3.52 GHz) are 1.7748, for (3.57 GHz) the VSWR value is 1.7265, and for (4.19 GHz) the VSWR is 1.6029. The VSWR values of tri-band hybrid DR antenna (Ant. 4) for (2.86 GHz) are 1.569, for (3.27 GHz) the VSWR value is 1.10903, and for (3.97 GHz) the VSWR is 1.4362. The VSWR plot for proposed antennas is shown in fig 5.

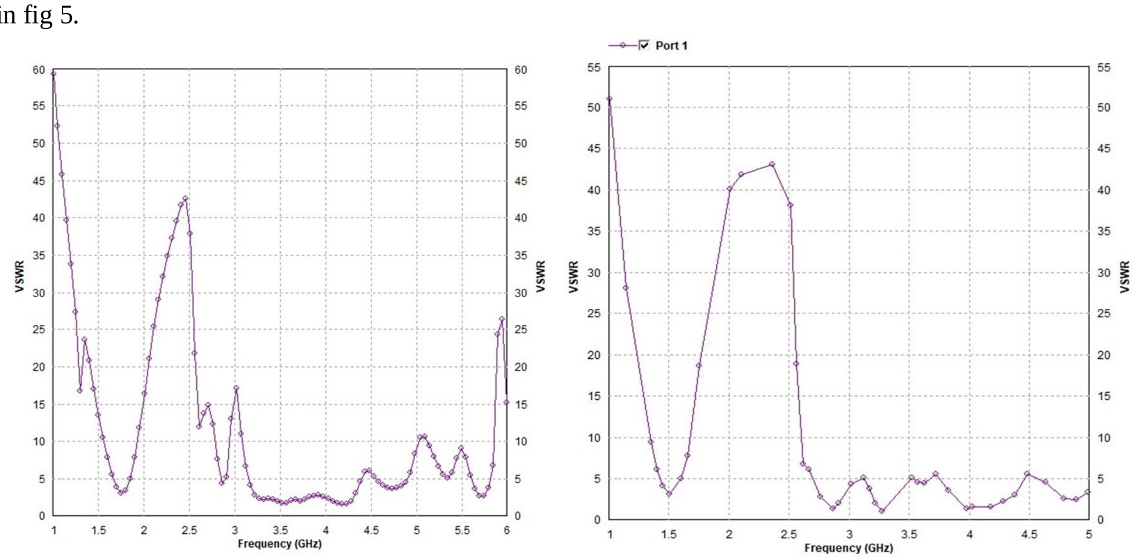


Fig. 5. (a) VSWR of Tri-band Hybrid Antenna (Ant. 3) (b) VSWR of Tri-band Hybrid Antenna (Ant. 4)

B. Gain

Antenna gain describes how much power is transmitted in the direction of peak radiation to that of an isotropic source. The gain values of tri-band hybrid dielectric resonator antenna (Ant. 3) for (3.52 GHz) is 3.96dB, for (3.57 GHz) is 4.63dB, for (4.19 GHz) is 4.18dB. The gain values of tri-band hybrid dielectric resonator antenna (Ant. 4) for (2.86 GHz) is 2.04dB, for (3.27 GHz) is 4.46dB, for (3.97 GHz) is 4.56dB. The Gain plot for proposed hybrid DR antennas is shown in Fig. 6.

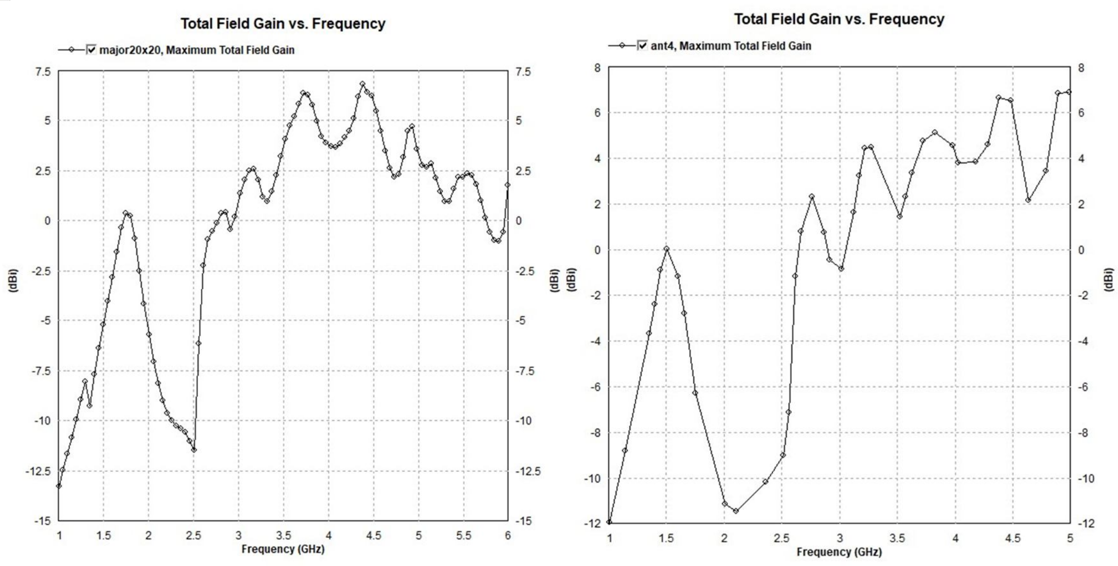
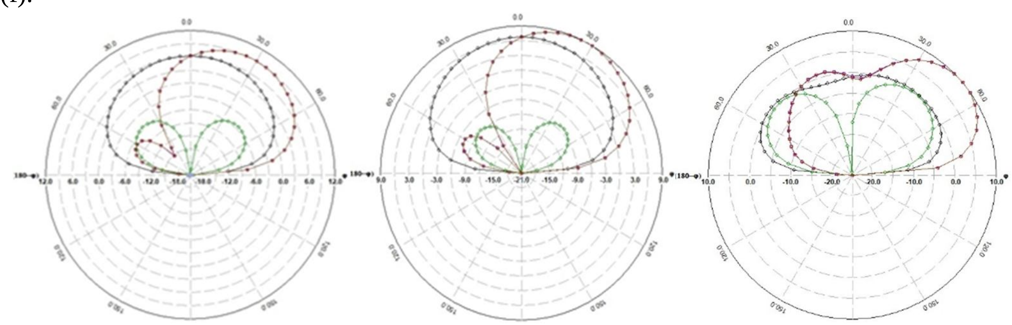


Fig. 6. (a) Gain of Tri-band Hybrid Antenna (Ant. 3) (b) Gain of Tri-band Hybrid Antenna (Ant. 4)

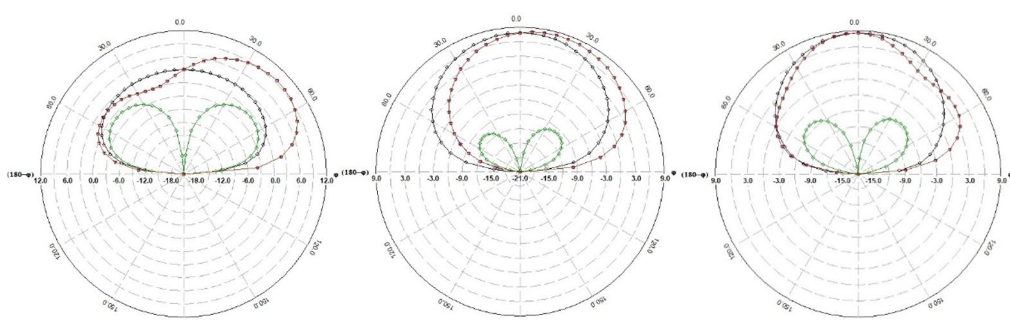
C. Radiation Pattern

Radiation pattern is a graphical representation of the radiation properties of antenna as a function of space coordinates. The radiation patterns of tri-band hybrid DR antenna (Ant. 3) for (3.52 GHz), (3.57 GHz) and (4.19 GHz) is shown in Fig. 7. (a), (b) and (c). The radiation patterns of tri-band hybrid DR antenna (Ant. 4) for (2.86 GHz), (3.27 GHz) and (3.97 GHz) is shown in Fig. 7. (d), (e) and (f).



(a) 3.52 GHz (b) 3.57 GHz (c) 4.19 GHz

Simulated radiation pattern (XZ and YZ plane) for proposed tri-band hybrid antenna at all the resonances



(d) 2.86 GHz (e) 3.27 GHz (f) 3.97 GHz

Simulated radiation pattern (XZ and YZ plane) for proposed tri-band hybrid antenna with modified H-slot at all the resonances

Fig. 7. Radiation Patterns of proposed tri-band hybrid dielectric antennas

Table. 1. Results of proposed antenna

S. No	Parameters	Ant. 3 Results			Ant. 4 Results		
1	Frequency (GHz)	3.52	3.57	4.19	2.86	3.27	3.97
2	VSWR	1.77	1.72	1.60	1.56	1.10	1.43
3	Bandwidth (MHz)	40	60	120	40	60	220
4	Gain (dB)	3.96	4.63	4.18	2.04	4.46	4.56
5	Antenna Efficiency (%)	30	70	36	14	41	34

IV. CONCLUSION

Tri-band rectangular hybrid antennas are proposed in this paper, for sub 6 GHz wireless applications. A modified inter-digital structure loaded on top of copper metal of DRA, in order to produce multiple lower order bands without effecting antenna size and the higher order bands. The proposed hybrid antennas resonate at 3.52 GHz, 3.57 GHz and 4.19 GHz (Tri-band) and 2.86 GHz, 3.27 GHz and 3.97 GHz (Tri-band). The respective gains provided by the Tri-band antennas are more than 3dBi at all the designated resonant frequencies. From the proposed antenna configurations, it can be concluded that, utilizing certain resonating structures, lower order resonances can be produced by having the control over the higher order bands.

V. ACKNOWLEDGEMENT

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