A Compact Hybrid Liquid Antenna for Wi-Fi Applications

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***Abstract*—In this paper, a hybrid antenna is introduced for multi-band applications. The proposed antenna overcomes the problems associated with designing dual/multi-band antennas with a compact size of ≤ ½ λ_0 in the overall dimensions. A liquid dielectric resonator antenna and a ME - dipole configuration is considered together for this to realize multi-mode operation achieving decent broadside gain and efficiency.**

Keywords – Dielectric resonator, Wi-Fi applications, hybrid liquid antenna, ME dipole.

I. Introduction

With the advent and tremendous developments in the wireless industry, there is a need for compact designs within wireless systems. Owing to the necessity, much research is focused on antennas with very compact dimensions [1]. Dielectric resonator antennas (DRAs) provide an advantage to address this need as they come with several merits such as smaller size, good efficiency, and improved bandwidth overall than the conventional antennas. Over the years many theories, geometries, and techniques have been proposed to realize compact and electrically small DRAs [2] & [3]. But, due to the never-ending demand for the wireless spectrum, dual-band and multi-band DRAs came into the limelight. Over the years many dual-band and multiband DRAs were proposed. Many works in this area have a common problem of large size in terms of the overall antenna dimensions. For instance, in [4] & [5] dual-band DRAs were presented but the designs had large ground planes nearly around one-wavelength of the operating frequency, lacking compactness. Some works on dual/multi-band DRAs focused on reducing the ground plane to about half-wavelength in a way to achieve compactness. These designs had their problems associated with either low gain in the higher bands, low radiation/total efficiency, or sometimes back radiation for the higher band modes. One such work is presented in [6].

The proposed work overcomes these problems by introducing a way that can retain the modes in both the lower band and the higher band with good far-field characteristics while at the same time restricting the overall antenna dimensions to less than half-wavelength of the operating frequency.

II. Proposed Hybrid Antenna Design

The design consists of a hemispherical DRA (HDRA) as seen in Fig. 1. It is intended to work for both the Wi-Fi bands at 2.4 and 5 GHz. For this, a liquid material that is formed by mixing half-portion concentrations of Acetone and Toluene (combined permittivity 'ε_r' = 10) constitutes as main radiating element. The HDRA works in its fundamental TE_{111} mode. This TE_{111} mode is similar to that of the HEM_{11} mode of the cylindrical DRA. It is a broadside mode. The E – field concentration of the TE_{111} mode is shown in Fig. 2. The height of the HDRA is about 17 mm and is placed on a ground plane with a size of 50 × 50 (in mm). This make the overall antenna dimensions to be ≤ ½ λ_0 ('λ_0' is the wavelength at 2.4 GHz). The first resonance is formed at around 2.6 GHz which is due to the fundamental TE_{111} mode. The DRA is excited using an aperture coupling feeding technique with the help of a microstrip line. Therefore, this feed mechanism is also responsible for another resonance at around 2.45 GHz due to the aperture in the ground plane making it the slot mode. These two realized resonances namely the DRA mode and the slot mode are combined by adjusting the length of the slot.

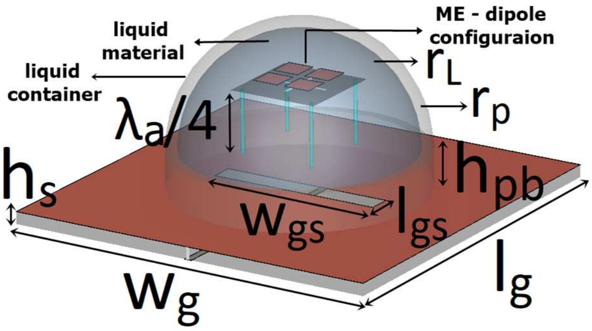

Fig. 1. Proposed hybrid antenna with parameters r_p = 17.5 mm, h_{pb} = 5 mm, r_L = 15 mm, $(w_g \times l_g)$ = 50 × 50 (in mm), h_s = 1.6 mm, $(w_{gs} \times l_{gs})$ = 22 × 3 (in mm).

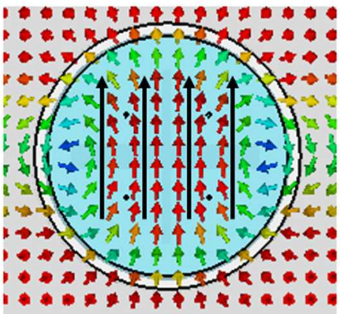

Fig. 2. The fundamental TE_{111} mode of HDRA

A decent realized gain of above 5.5 dBi is seen for both the realized DRA mode and the slot mode. Now, steps were performed to check for the HDRAs ability to realize dual/multi-band operation.

The results (not shown here) suggested that the conventional HDRA suffered from improper modes and low realized gain in the higher band around the 4 GHz to 5.5 GHz range. The higher band is only properly realized for ground plane dimensions close to one-wavelength. But at this wavelength, the slot mode diminishes. Also, one-wavelength size makes the ground plane large, making the overall antenna not compact. Therefore, in order to overcome this problem, a design method is proposed. This method uses the advantages that liquids offer. One of the natural properties of any liquid is additional components can be placed within them due to the fluidic nature. Taking this advantage into consideration metal plates are introduced within the HDRA at a height of $\lambda_a/4$ ('$\boldsymbol{\lambda_a}$' is the wavelength at 5 GHz) from the feeding source. The bottom metal plate has a cross-shaped slot which forms the magnetic dipole configuration. The top plate is a combination of four individual patches attached to the bottom plate through individual vias. They form electric dipoles. This setup within the HDRA gives rise to a ME – dipole configuration which is, in turn, responsible for additional resonances around 2.8 GHz (due to electric dipole) and 4.2 GHz (due to magnetic dipole). Apart from this, the top and bottom metal plates as a whole work as rectangular patch antenna as the fields which are trapped between the top and bottom metal plate undergo reflections and escape through the edges of the plates. This behavior is seen in the working of a patch antenna. Due to this, additional modes namely TM_{10} mode and the higher-order TM_{21} mode are realized. These discussions can be seen in Fig. 3 and the complex impedance characteristics are shown in Fig. 4. One of the important aspects of this proposed design is that there is no necessity to separately excite the incorporated secondary design inside the liquid HDRA to excite the modes associated with ME-dipole or the patch antenna. The fields which are coupled inside the liquid HDRA due to the microstrip line, and the aperture feed are responsible for exciting the metal plates configuration within the liquid HDRA.

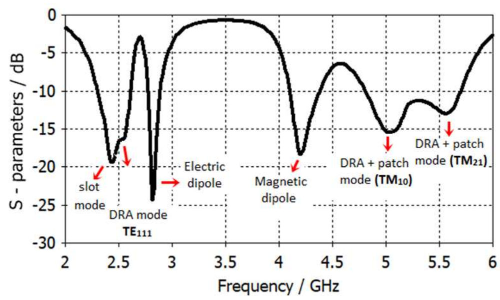

Fig. 3. Reflection coefficient plot of the proposed hybrid antenna.

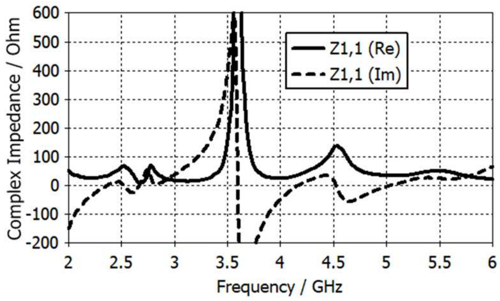

Fig. 4. Complex impedance plot for the proposed antenna.

Realized gain comparison is carried out in Fig. 5. It is evident that the proposed hybrid antenna achieved a gain of over 6 dBi in the higher band region which once served as the region with a low realized gain. This is because the fields which were subjected for forming the higher-order modes in the conventional liquid HDRA underwent improper half-wave variations due to the reduced ground plane resulting in low gain higher-order modes. This is overcome in the proposed model, as the fields are changed to broadside modes due to the presence of the metal patches and the bottom plate.

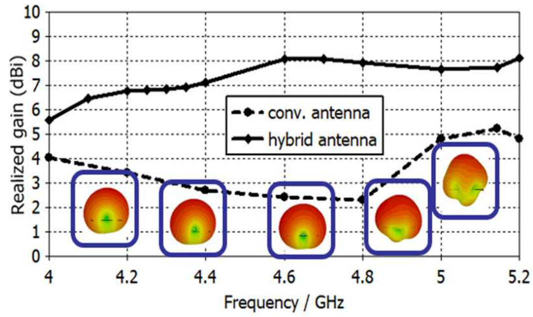

Fig. 5. Realized gain improvement in the higher band. Comparison between conventional HDRA and the proposed liquid hybrid antenna.

III. Conclusion

A hybrid antenna is introduced that projects multi-band behavior. The fundamental DRA mode and the slot mode cover the lower band. The higher band is realized using the ME – dipole and the additional patch antenna configuration taking the advantage of the fluidic behavior of the liquids. This proposed method overcomes the difficulties in realizing the dual/multi-band characteristics with the conventional DRAs with compact dimensions of less than or equal to half-wavelength of the operating frequency with decent far-field characteristics. Therefore, this antenna can be a highly useful design for Wi-Fi applications at both the 2.4 GHz and 5 GHz frequency ranges. The measurement results of the proposed hybrid antenna will be discussed at the workshop.

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