Compact Hybrid Dielectric Resonator with Patch Antenna Operating at Ultra-High Frequency Band

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***Abstract*- This paper describes the design of the hybrid dielectric resonator with patch antenna operating at Ultra-High Frequency band. At this particular band, the size of the antenna is excessively big, thus consuming bigger space. As a kind of hybrid antennas, which consist of two different antennas integrated on a single body, the design achieved more compact design, especially the patch antenna. The design was designed and simulated using CST Microwave Studio. The patch antenna's size is reduced about 50 % while the dielectric resonator antenna's size is about the same size as the estimated dimension. The hybrid antenna managed to obtain a gain of 2.8 dBi and capable of achieving wide bandwidth, around 49 %.**

I. Introduction

Microstrip patch and dielectric resonator antennas have often been compared with each other, due to the capability of the dielectric resonator antennas (DRAs) to replace the microstrip patch antennas in various applications. By employing the hybrid antenna design as proposed in [1], both antennas are combined, resulting in single antenna with dual-frequency operation. A single antenna that is small in size and can provide the dual-frequency or multiband operations are highly desired [2] due to cost reduction and less area occupied by that particular antenna. Patch antennas are often used in various applications since it is low-profile, can be mounted on a flat surface and ease of fabrication [3]. However, the size of the patch antennas increased tremendously at low frequencies, below 1 GHz, up to fifteen centimeters.

Several techniques were used in order to reduce the size of the antenna such as meandering [3], using high permittivity substrates [4], and shorting pins [5].

$$W = \frac{c}{2f_c}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (1)$$

$$L = \frac{c}{2f_c\sqrt{\varepsilon_{r_{eff}}}} - 2\Delta L \qquad (2)$$

The length and width of the basic rectangular patch antennas are calculated theoretically using (1) and (2), where c is the speed of light, f_c is the operating frequency, ε_{reff} is the effective dielectric constant and ΔL is the length approximation. At 0.85 GHz, the calculated length and width of the antenna are 11.92 and 13.95 cm by using ε_r = 2.2 and substrate thickness of 1.575 mm, which is considered big. Alternatively, a compact patch antenna can be designed by introducing the ground, which reduces the dimension of the antenna from half-wavelength to a quarter-wavelength, which is equivalent to 7.5 cm.

Normally, within the same operating frequency, the size of the DRAs are smaller than microstrip patch antennas due to the influence of the value of the dielectrics used, thus enable the DRA to be placed symmetrically on the top of the patch antenna in this configuration. Identical to the patch antennas, the compact dielectric resonator antennas can also be designed using several approaches such as shape modification [6], using high dielectric constant [7] and metal loading [8]. The dimension of the DRA approximated using (3);

$$F = \frac{2\pi a f_c\sqrt{\varepsilon_r}}{300} \qquad (3)$$

Where F is the normalized frequency, a is the length that parallel with y-axis, f_c is the operating frequency, and ε_r is the dielectric constant. At 0.85 GHz, the length and width of the DRA are the same, which is 4 cm, while its height is 1.33 cm.

Even several techniques can be used to create a compact design, both patch antennas and DRAs still experience narrow bandwidth, for example, due to the usage of materials with high dielectric constant, ε_r. The bandwidth degradation can be avoided using slot-feeding techniques, in addition to the size reduction. However, the slot itself will become big; with the length of about 12 cm around 1 GHz. The hybrid antennas often have a dual - frequency operation, one frequency for each antenna. The bandwidth can be further increased by merging both frequencies, resulting in wider bandwidth. In this design, the DRA will cover higher frequency while lower frequency will be covered by the patch antenna in order to create a compact hybrid antenna design. Two circular slots were used to feed both the patch antenna and the DRA, where upper slot is used to feed the DRA while lower slot is used to feed the patch antenna, instead of normal rectangular slot in order to reduce the space consumed by the slot itself.

In the previous design [9], dual-frequency resonance is recorded in 5.40 and 6.18 GHz which later merged to produce a wide bandwidth of 23.5 %, from 5.14 to 6.51 GHz, where the patch antenna with the dimension of 1.5 x 1.5 cm^2, resonates at lower frequency (5.4 GHz), while the DRA with the dimension of 1.27 x 1.27 x 0.95 cm^3 resonates at a higher frequency (6.18 GHz). Similarly, the patch antenna resonates at lower frequency while the DRA resonates at a higher frequency, achieved a bandwidth of 49.88 %, from 0.8 to 1.2 GHz where the size of the patch antenna is only 5.1 x 5.1 cm^2, while the size of the DRA is only 4.27 x 4.27 x 2.45 cm^3.

II. ANTENNA CONFIGURATION

As mentioned in the previous section, the hybrid antenna consists of two different antennas which are the patch antenna and the DRA, fed by two different slots, the upper and lower slot. In short, this antenna has three layers stacked up together. Starting from the bottom layer, it consists of the feed substrate, followed by the patch antenna with its substrate at the middle layer, and the DRA at the top layer.

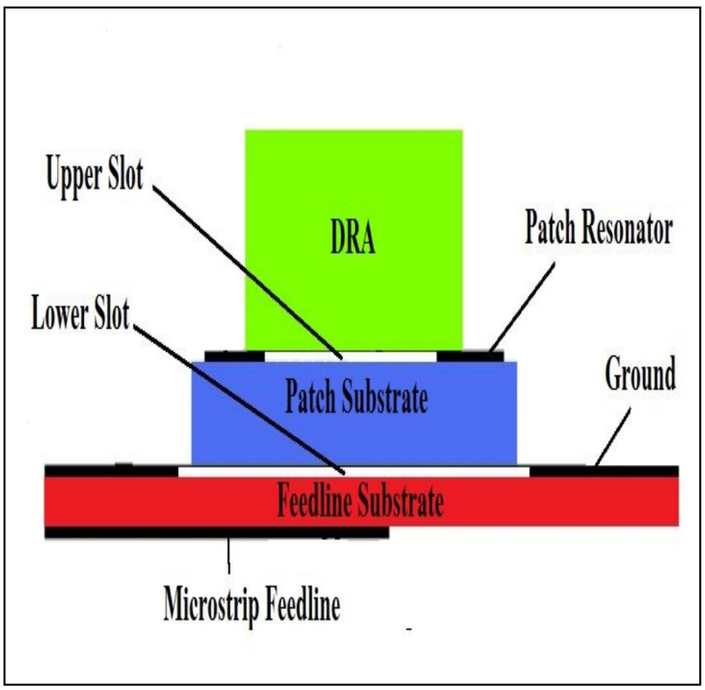

Figure 1: Side View of the Proposed Hybrid Antenna

Figure 1 shows the layout of the hybrid antenna. This kind of excitation is known as electromagnetic coupling (EMC) since there is no physical contact between the feeder and the radiating elements. Both slots are circular, where the length of normal slot is equivalence to its diameter. Lower slot has a radius, R_l of 34 mm while the upper slot has a radius, R_u, of 22 mm. Other related parameters are summarized in Table 1.

Table 1: Summarized Parameters of the Hybrid Antenna

Antenna Parameters	Values
DRA • ε_r • l x *w* • *h*	9.2 42.7 mm x 42.7 mm 24.5 mm
Patch Substrate • ε_r • l x *w* • *h*	2.2 60 mm x 60 mm 1.575 mm
Patch Resonator • l x *w*	51 mm x 51 mm
Ground • l x *w*	80 mm x 80 mm
Feed Substrate • ε_r • l x *w* • *h*	10.2 80 mm x 80 mm 1.27 mm

III. RESULTS AND DISCUSSIONS

The introduction of this hybrid antenna concept provides the solution in obtaining compact antenna design with the capability of achieving wide bandwidth. Figure 2 shows the resonant frequencies of both antennas. Based on Figure 2, it can be seen that the patch antenna covered lower frequency (0.6 GHz), which represented by the solid line, while DRA covered higher frequency (0.95 GHz), which represented by the dotted line. By comparing the size of both antennas with their respective theoretical values, it can be seen that the size of patch antenna in this configuration is smaller, nearly 50 % size reduction while the DRA is almost of the same size. By comparing both antenna's dimensions with the previous compact antennas, it seems that some of the previous antennas have smaller size, but they have a very narrow bandwidth, below 10 %. By using this configuration, both frequencies can merge, resulting in a new frequency response with wide bandwidth, as shown in Figure 3.

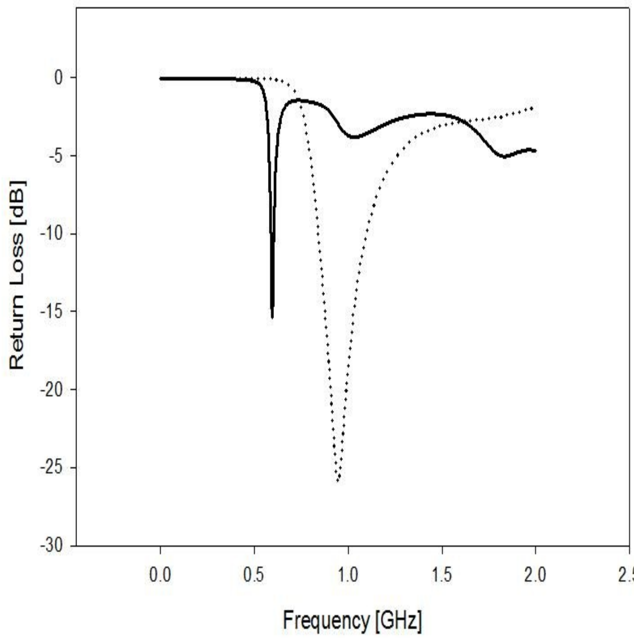

Figure 2: Frequency Response for both Patch Antenna and DRA

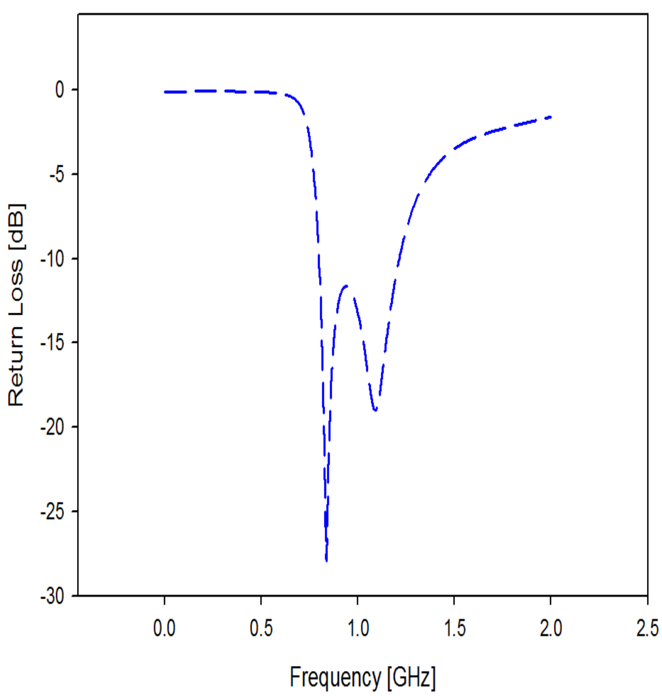

Figure 3: Overall Frequency Response of the Proposed Hybrid Antenna

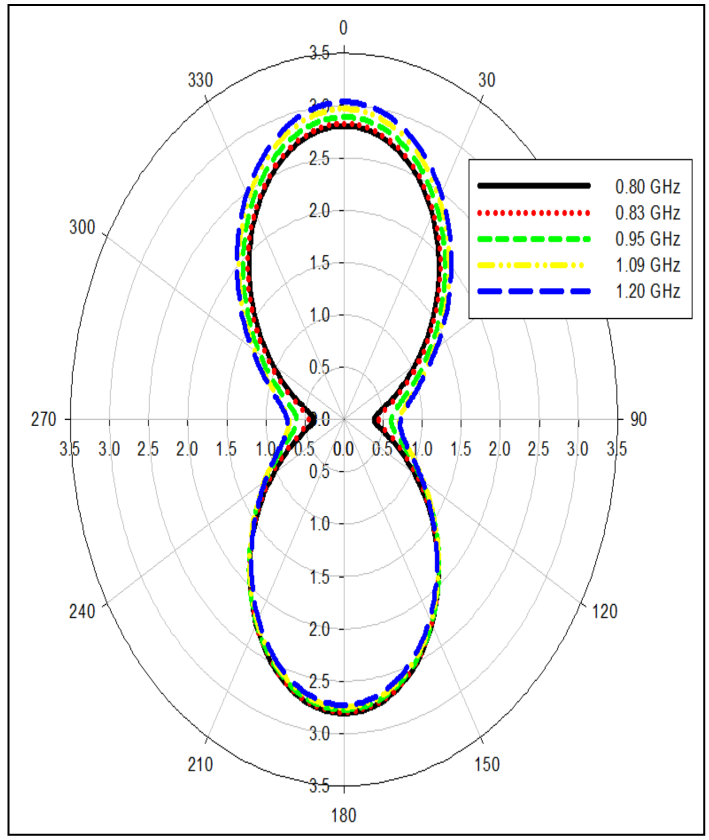

Figure 4: The Simulated Radiation Pattern of the Proposed Hybrid Antenna

The hybrid antenna radiates like a dipole-antenna, due to the presence of the slots, through the whole bandwidth with a gain that varies around 2 to 3 dBi as shown in Figure 4. The size of the patch antenna can be further reduced by using one of the techniques mentioned, especially meandering, but it is crucial to ensure that the bandwidth will not be degraded. Same thing applies to the DRA, which size can be reduced by loading metals on top of it. Using high permittivity materials as the patch substrate can reduce its size, but this is not applicable in this design due to the presence of a dielectric mismatch between the DRA and the feed line substrate with the patch substrate. Dielectric mismatch is also one of the causes of the bandwidth degradation.

IV. Conclusions

A compact hybrid antenna was designed and simulated using CST Microwave Studios. The size of the patch antenna is 50 % smaller compared to theoretical estimation while the size of the DRA almost the same. The hybrid antenna has a wide bandwidth, around 49.88 %, from 0.8 to 1.2 GHz with a gain of 2.8 dBi. The design will be later fabricated in order to measure its performance.

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