A Robust, Flexible and Frequency Reconfigurable Antenna with Flexible Superstrate and Substrate

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***Abstract*—This paper presents a frequency reconfigurable circular patch antenna having dielectric superstrate to tune the operating frequency and increase the realized gain of the antenna. The antenna is designed with highly flexible, robust and inexpensive materials. The antenna is basically a circular microstrip patch antenna having a flexible superstrate, the antenna is designed in such a way that the height from the patch surface to the superstrate can be varied, which subsequently changes the resonance frequency of the antenna. This mechanical reconfigurable technique appears to be a simple and effective method of frequency tuning operation of a flexible antenna. Moreover, the utilization of the superstrate improves the gain and efficiency of the antenna. Numerical investigations of the design are demonstrated in this paper.**

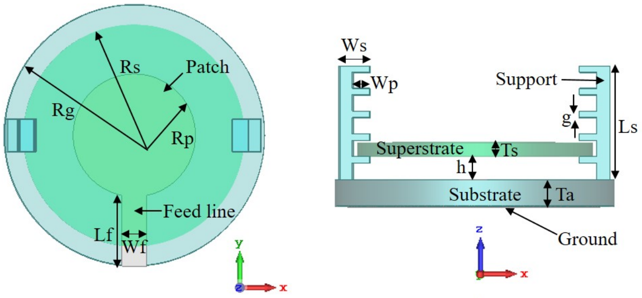
***Index Terms*—Circular, flexible, reconfigurable, robust, superstrate, transparent.**

I. INTRODUCTION

In last few decades, a remarkable advancement is witnessed in wireless communications. With this technological advancement and surging demands, new designs of antennas are rising accordingly. Many of these applications require specific type of antennas. To satisfy these specific requirements, new designs, materials and fabrication methodologies are emerging.

Frequency reconfigurable antennas are attracting tremendous interests in modern communication systems due to their capability of adjusting the operating frequency with the change of operating environments. Frequency tuning can be achieved either by integrating electronic components (PIN diodes [1], varactor diodes [2] or RF micro-electromechanical (RF-MEM) switches [3]) within the antenna or changing the physical structure of the antenna [4]. It can be noted that electronic tuning is associated with losses from the integrated electronic components and DC bias networks. In contrary, mechanical tuning is free from these drawbacks. In this work, frequency reconfigurable operation is achieved by simply adjusting the position of the superstrate.

Flexible antennas have growing interests in many applications, e.g., wearable technologies [5], Internet-of-Things (IoT), sensor networks etc. The development of flexible antennas is associated with some challenges, such as high loss of flexible materials, fabrication difficulty and poor RF performance. Textiles, carbon nano-tubes, copper tapes, and papers are the mostly used materials in the fabrication of flexible antennas. However, robust integration of flexible conductive and dielectric materials is the major realization challenge of flexible antennas. Recently, conductive mesh-polymer composite [6]–[8] is demonstrated as an effective solution for the realization of flexible antennas having excellent robustness in harsh physical deformations [9]–[12]. This composite material is used in this paper to design a new flexible and robust frequency reconfigurable antenna. The performance of the antenna is studied in this paper to evaluate its simple frequency tuning operation.



(a) (b)

Fig. 1. Geometry of the proposed antenna-(a) top view, (b) side view. (Rp = 7.5, Rg = 16, Rs = 13.5, Wf = 3, Lf = 8.7, Ta = 3, Ts = 1.6, Ls = 13, g = 0.75, Ws = 3.5, Wp = 2.) All dimensions are in mm.

II. ANTENNA DESIGN

Fig. 1 shows the topology of the proposed design. The design consists of a circular patch, a circular dielectric substrate, a circular ground plane and a circular dielectric superstrate. Due to circular shape, the antenna has rotational symmetry. Transparent conductive mesh fabric VeilShield, available in Less EMF Inc, USA, is used in the patch and ground plane, and Polydimethylsiloxane (PDMS) is used in the substrate. VeilShield has 72% transparency and 0.1 Ω/sq sheet resistance. The permittivity of PDMS is 2.75 and loss tangent is 0.04 at 6 GHz. In [8], it was demonstrated that VeilShield-PDMS composite is highly flexible and durable, so our proposed antenna is also highly flexible and robust. PDMS-ceramic composite is used in the superstrate, the permittivity of PDMS can be increased by mixing it with $SrTiO_3$ ceramic powder [13]. In this work, the permittivity of PDMS-ceramic composite is considered 10 and loss tangent 0.04. The structure (made from PDMS) to hold the superstrate is shown in Fig. 1, it can be seen that the position of the superstrate can be easily adjusted by simply placing it in the desired slot.

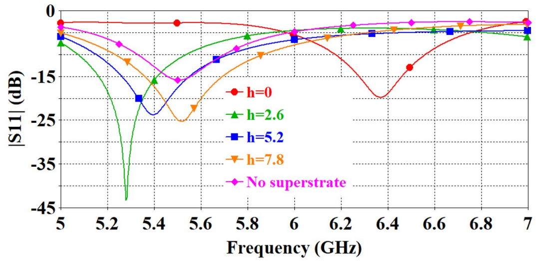


Fig. 2. $|S_{11}|$ at different positions of the superstrate.

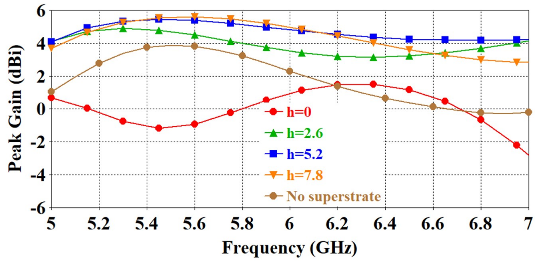


Fig. 3. Peak gain vs frequency for different positions of the superstrate.

III. NUMERICAL INVESTIGATION

The reflection co-efficient of the antenna is illustrated in Fig. 2 for 5 states of superstrate, i.e., without superstrate and placing the superstrate at 0 mm, 2.6 mm, 5.2 mm and 7.8 mm distance apart from the patch. It is ascertained that the resonance frequency changes with the change of superstrate position. About 1 GHz frequency shifts is visible here, which certainly demonstrates the effectiveness of the proposed idea. All the simulation analysis of this work are conducted in CST Microwave Studio 2017.

The gain and efficiency of the antenna are shown in Fig. 3 and Fig. 4 for different positions of the superstrate. Fig. 3 exhibits good gain response at all states, a maximum 5.58 dBi gain is achieved at 7.8 mm position of the superstrate, this value indicates the improved performance of the proposed antenna compared to other flexible antennas which suffer from low gain due to the lossy nature of flexible materials. The maximum gain without superstrate is 3.8 dBi, so advantage of using superstrate is explicit. Fig. 4 indicates good efficiency at all superstrate positions, nearly 15% improvement in efficiency is visible after using the superstrate.

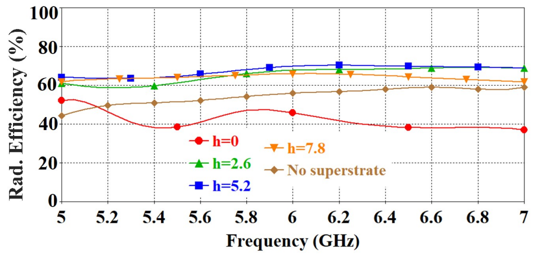


Fig. 4. Radiation efficiency vs frequency for different positions of the superstrate.

IV. CONCLUSION

A superstrate based flexible frequency reconfigurable antenna is exhibited in this paper. The proposed antenna demonstrates a simple and effective method of frequency reconfigurable technique. The promising performance of the antenna indicates the effectiveness of the proposed design. Utilization of the dielectric superstrate improves the gain and efficiency of the antenna, which appears to be an effective technique of performance improvement of lossy flexible antennas. It is ascertained that the proposed design can be a promising candidate of frequency reconfigurable flexible antenna.

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