Experimental investigation of a flexible 3D printed ring resonator for Bluetooth applications

Chahat Jain[1], Balwinder S. Dhaliwal[2]and Rupinder Singh[3]

[1]*Guru Nanak Dev Engineering College, Ludhiana, India*
[2]*National Institute of Technical Teachers Training and Research, Chandigarh, India.*
[3]*National Institute of Technical Teachers Training and Research, Chandigarh, India*

Abstract

This article presents in detail the design and analysis of a 3D printedring resonator operating for bluetooth applications. To develop accurate and useful products, 3Dprinitng technology has come out as a very attractive method over conventional etching and chemical processes in developing complicated structures while maintaining the same performance with respect to the conventional ones. Thus, this article presents a systematic approach for designing and developing 3D printed ring resonator with the help of flexible Acrylonitrile Butadiene Styrene (ABS) material using the 3D printing technology. It is also termed as ‘Additive manufacturing’ because the final product is made by adding on layers of material one on one in the additive process. In this article, a ring resonator has been designed using ABS material as substrate and copper tape as the conductor for the patch and ground plane. The designed prototype resonates around 2.45GHz having $S_{21}$of -43.68 at the first resonance which is in good agreement with the simulated results. Also, an extensive bending analysis of this antenna for convex as well as concave configurations has been analysedwhichsupports that an appreciable S_{21} value can be achieved for its utility in various conformal Bluetoothapplications.

Keywords

3D printing, flexible antenna, additive manufacturing, Ninjaflex, ABS (acrylonitrile butadiene styrene), fabrication,Microstrip patch antenna (MPA)

1. Introduction

In the recent few years there has been an extensive increase in the design of 3D printed structures for RF applications in industry as well asinacademia since it offers reasonable cost, fabrication easiness and conformability.Newer advances in wireless communication applications have imposed unequalleddemands for antenna circuitrieshaving the capability of operating in various wideband spans of frequency with small sizes and thin form factors[Mirzaee et al., 2015]. Primarily, 3D printing technology has evolved out to be a Silicon Valley start-up, Carbon Inc, that enabled various shape and size objects to risefrom a liquid media continuously, therebyframing a new approach to additive manufacturing[Srivastava, 2017].This technique reduces the consumption of adhesives that are required for combining parts so as to get a finished product, hence supporting a nimble production which is difficult to achievethrough the use of conventional techniques of manufacturingthatsurely involves the usage of costly materials and extortionate machinery set up [Kaur and Saini, 2018].As 3D printing involves the plastic based packaging of products, various issuesthatcome up

International Conference on Emerging Technologies: AI, IoT, and CPS for Science & Technology Applications, September 06–07, 2021, NITTTR Chandigarh, India
EMAIL:chahatjain26@gmail.com (A. 1); bsdhaliwal@ymail.com (A. 2); rupindersingh78@yahoo.com (A. 3)
ORCID: Not Available (A. 1); 0000-0001-5092-017x(A. 2); Not Available (A. 3)

withsuchpackagings are: (1) Quality deterioration due toenvironmentshaving moisture (2) At high frequencies, roughness and texture of the surfacegreatly affects the reliability of the product.

This article initially starts with a brief description of the antenna 3D printing based antenna design methodology followed by the discussion of materialswhichare used to fabricate such products. Following section includes an in depth discussion of results preceded by the viable challenges and there probable solutions for future enhancements in this new field.

2. Method and Materials

Basic concept in this article is to model a flexible ring resonator that is 3-D printed through the technique of fused deposition modelling (FDM) using ABS material.

2.1 Structure Design

The overall structure's dimension is calculated using the standard equations [Yang et al., 2017]. The microstripstructurehasbeenchosen due to its low profile structure and ease of design realizability.ABShas been used to 3D print the substrate.For the final assembly, the ring resonator and the ground plane were cut out of 0.08 mm thick copper tape. The antenna is designed using CST Microwave studio 2019. The fabricated prototype is fed using microstrip edge mounted F R/A (Female right angle) connector. Figure 1 shows the design of a ring resonator in CST microwave studio. A detailed view of the fabricated antenna prototype is shown in Figure 2.

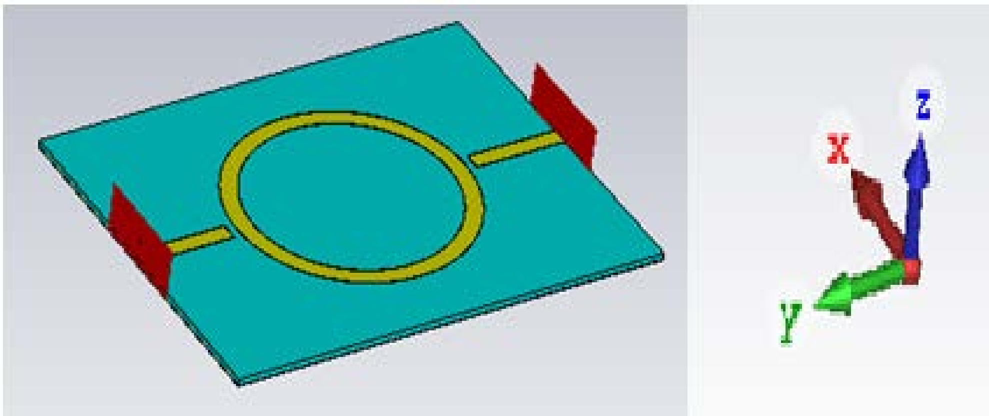
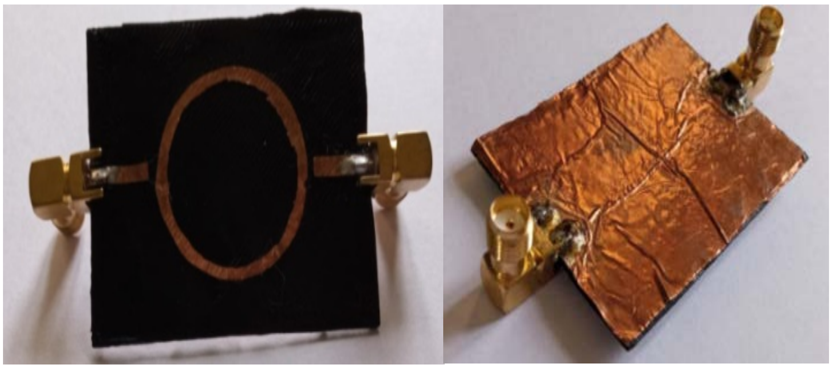


Figure 1: Ring resonator designed in CST microwave studio 2019



(a) (b)

Figure 2: Ring resonator on ABS substrate (a) Front View (b) Back View

2.2 Methodology for 3D printing design and analysis

The technology used for 3D printing the substrate is fused deposition modelling (FDM). The substrate is printed on Ultimaker's 3D printer. Figure 3 shows a detailed systematic process flow for the ring resonator's design and its flexibility analysis. Initially the structure is dimensionally analysed in CST microwave studio suite 2019 where it is designed for optimal performance in terms of its S_{21} characteristics. Subsequently, the procedure for 3D printing is followed which includes ABS filament preparation on Twin screw extruder and 3D print the design using the model designed in CAD. For experimental verification of results, the prototype is fabricated and tested on VNA.

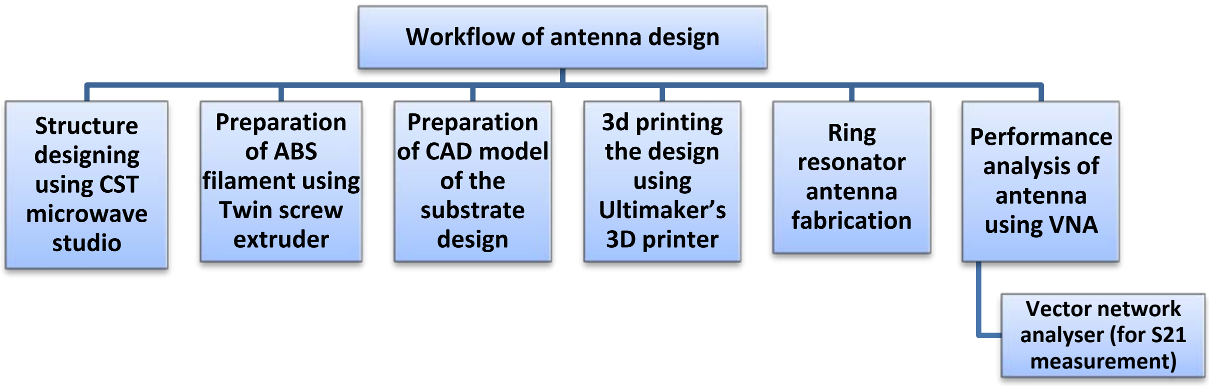
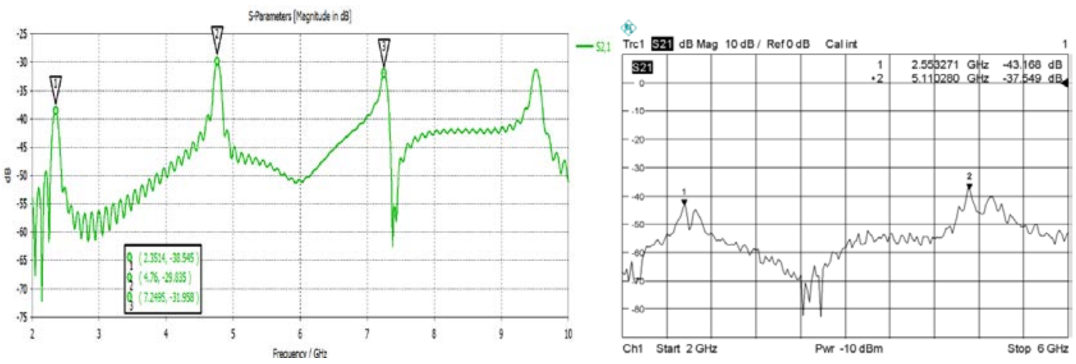


Figure 3: Process flow for the ring resonator's design

3. Results and discussion

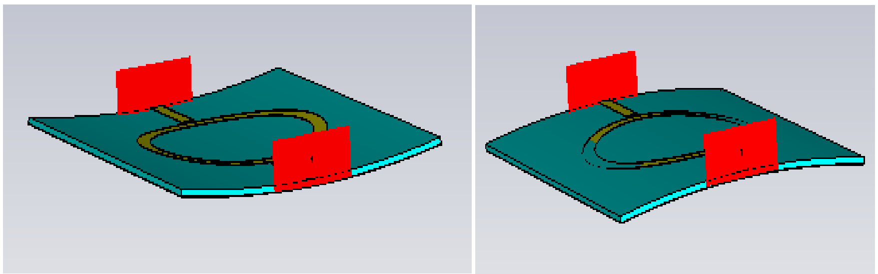
Figure 4shows the S_{21}analysis of the simulated &fabricated ring resonator prototype without any subjection to conformability. Figure 5 shows the bending analysis performed in the software which was verified through the experimental analysis of prototype.

Antenna's resonance without bending:



(a) (b)

Figure 4: S_{21} parameters without any bending (a) Simulated (b) Experimental



(a) (b)

Figure 5.(a) Concave bending at an angle of 20^0 (b) Convex bending at an angle of 20^0

Table 1
Detailed analysis of structure's conformability

Confor mability type	Angle of bending	Simulated results				Experimental results			
		1^{st} resonance (GHz) f_1	2^{nd} resonance (GHz) f_2	S_{21} (dB) at f_1	S_{21} (dB) at f_2	1^{st} resonance (GHz) f_1	2^{nd} resonance (GHz) f_2	S_{21} (dB) at f_1	S_{21} (dB) at f_2
None	0^0	2.35	4.76	-38.54	-29.83	2.55	5.11	-43.16	-37.54
Concave	5^0	2.35	4.76	-38.54	-29.83	2.55	5.11	-43.16	-37.54
	10^0	2.35	4.70	-38	-29	2.55	5.11	-43.62	-35.24
	20^0	2.39	5.36	-38.68	-30.79	2.55	5.11	-41.00	-39.41
Convex	5^0	2.422	4.72	-39.13	-30.07	2.55	5.11	-43.62	-35.24
	10^0	2.42	4.65	-39.53	-29.41	2.50	5.01	-38.63	-46.54
	20^0	2.56	4.51	-38.63	-29.50	2.55	4.95	-41.67	-30.75
None	0^0	2.35	4.76	-38.54	-29.83	2.55	5.11	-43.16	-37.54

Through Table 1, It can be observed that the antenna's performance doesn't deteriorate even on bending it at various angles (5^0,10^0,20^0), thus confirming its application to the Bluetooth range. Also, the simulated and experimental results show good agreement with each other.

4. Conclusion and Future scope

3D printing has emerged as an attractive new technology which has the ability to turn up as a quantum leap to meet the high end expectations and presumptions of the research and technology community. This article, therefore, reports on the flexibility analysis of 3D printedantenna applications. A 3D printed substrate to be used for designing of antenna for Bluetooth applications has been analysed for bending effects. Also, the prototpye presents good agreement between the simulated and experimental results for all the convex and concave bending analysis. Hence this article supports the utility of such substrates for Bluetooth based applications. In future experimentationscan be included that pose the usage of 3D printing techniques that are hybridised for high dimensional precision and better finishing. Therefore the future visualizessuch kind of antennas which can be integrated in 3D stacked packageswith digital and analog components andcombinatorialserveas a 3D printed package for various industrial utilities.

5. Acknowledgement

Authors feel privileged toexpress indebtedness to MoE, Govt. of India for the sanction of TEQIP-III grant to Guru Nanak Dev Engineering College. Also, authors express their heartfelt thanks to Dean RIC,I.K. Gujral Punjab Technical University (IKGPTU), Kapurthalaand Principal, Guru Nanak Dev Engineering College for providing necessary facilities to carry out this research work.

6. References

[1] Yang, Li, et al. "RFID tag and RF structures on a paper substrate using inkjet-printing technology." IEEE transactions on microwave theory and techniques 55.12 (2007): 2894-2901.

[2] Mirzaee, Milad, et al. "Developing flexible 3D printed antenna using conductive ABS materials." 2015 IEEE International Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting. IEEE, 2015.

[3] Liang, Min, et al. "3-D printed microwave patch antenna via fused deposition method and ultrasonic wire mesh embedding technique." IEEE Antennas and Wireless Propagation Letters 14 (2015): 1346-1349.

[4] Lee, Jian-Yuan, JiaAn, and Chee Kai Chua. "Fundamentals and applications of 3D printing for novel materials." Applied materials today 7 (2017): 120-133.

[5] Srivastava, V. K. "A reviev on advances in rapid prototype 3D printing of multi-functional applications." Sci. Technol 7.1 (2017): 4-24.

[6] Kaur, Arashpreet, GarimaSaini, and M. E. Scholar. "3D printed antennas: a review." Int J EngSciComput 8.3 (2018).