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3-D Printed Antennas: A Review

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Abstract:
This paper provides understanding of 3-D printing techniques for different antennas using different materials. Antennas suffer a lot of drawbacks such as in gain, system range, efficiency and bandwidth especially when the size of antenna is reduced less than quarter wavelength. But with 3D printing, designers can create complicated structures with the higher degrees of freedom than the conventional methods maintaining same performance. The design of antennas using 3-D printing method has been progressively more required both in academic world and industry since it offers, lighter-weight, time-efficient, environmentally friendly and also cost-effective option than conventional manufacturing techniques. Stereo- lithography, Fused Deposition Modeling and Selective Laser Sintering are most widely used 3D printing techniques.

Keywords: 3-D printing, Stereo-lithography, Fused Deposition Modeling, NinjaFlex, Acrylonitrile Butadiene Styrene.

I. INTRODUCTION

In the course of recent decades, individuals have turned out to be more aware of the ability of 3D printing technologies. 3D printing technologies often referred to as additive manufacturing. Some have named 3D printing technology to be the next huge advancement of this era. 3D printing technologies are procedure of delivering a physical model of an object from a digital model. This is done by adding on layers of material one on one in the additive process. A 3D object is the end product which builds up from the layering of many thin films. This innovation is like having a paper printer on each office work area. This ability takes into account fast prototyping of an object with boundless outline, and the control to plan and manufacture is given to individual users. This method can eliminate many factors, for example, reduce the usage of adhesive material required for the combination of parts, reduce the waste material, fast and speedy production, and help in designs which are not feasible using conventional manufacturing processes and usage of expensive and excessive machinery [1]. One of the immense advantages of 3D printing machine is the capacity to deliver complicated 3D geometries rapidly and effortlessly and at generally the cost of plastic. 3D printing permits expanded plan adaptability for creating hardware, microwave circuits and antennas. It has achieved a level of development which enables the printing of functional parts. Once the plastic parts are produced they are covered with conductive material, a procedure called metallization [2]. Numerous issues of down to earth intrigue include misfortune or constriction because of good, yet not impeccable conductors. In this manner, extra appraisal of various metallization forms must be performed. Specialists have demonstrated that it is possible to metallize plastic with the goal that the object increases some metal qualities. However, none of these studies provide any information on how well these metallized plastic structures perform with high power signals [3, 4].

II. 3D PRINTING TECHNIQUES

Extrusion, powder, resin and material jet are some 3-D printing techniques. In extrusion the layer by layer object is formed by melting and deposition of filament on 3-D printer. In powder technique the object is directly formed into the resin tank of 3-D printer and in this technique stereo-lithography (SLA) is broadly used which work on the principle of photo-polymerization. In resin technique firstly the material (powdered) is melted or sintered by laser and then allowed to get bonded together to form a solid structure. Figure 1 shows the different types of techniques of 3-D printing [5].

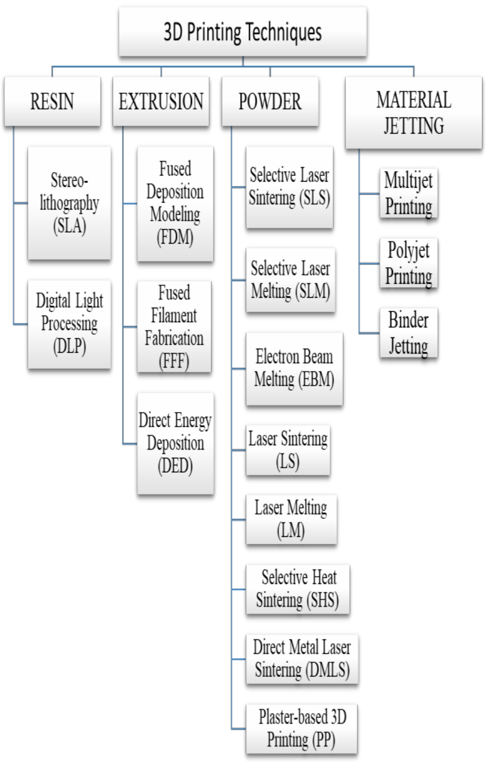
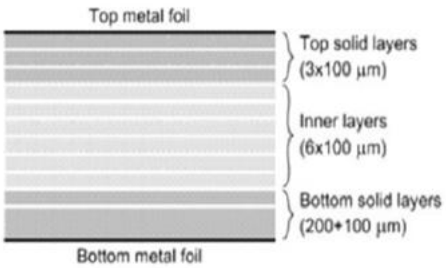


Figure.1. 3-D printing techniques

III. LITERATURE SURVEY.

Moscato et al. [1] proposed the fabrication of antenna and microwave components using 3-D antenna. The features of additive manufacturing like fast prototyping, fully 3-D topologies, low fabrication cost and reasonable accuracy make this manufacturing technique suitable for electronic devices. NinjaFlex based flexible filament has been used to fabricate 3-D patch antenna. This type of materials has very good flexibility, mechanical strain and printability. The ring resonator technique is used to explore the electrical properties at 2.4 GHz. The proficiency of selectively varying the dielectric constant is experimentally verified by changing the density of material. The manufacturing technology is validated by prototyping another antenna i.e. square patch antenna. The NinjaFlex material based antenna is also subjected to different bending conditions to test its flexibility. This is shown in figure 2. Kimionis et al. [2] proposed the additive manufacturing technology to shape a 3D package for WSN node RF electronics. In order to reduce the fabrication time, methodology has been developed. It also reduces the requirement of supporting material, thus also helps in dropping the overall cost. The process involves 3-D printing technology for fabrication of planar structure and consequently to form conductors directly by utilizing inkjet printing on its surface. The "smart" shape-memory hinges are then heat activated to fold the structure to 3-D shape from planner structure in an origami fashion. In order to build confidence in the concept the complete system was established for high frequency multi-direction energy harvesting. RF signals which are from orthogonal directions can be captured using on-package inkjet-printed antenna. By using directional planar antennas these RF signals would not be captured. The work shown in this paper is the successful integration of inkjet- printed and 3-D printed origami for high frequency applications. Figure 3 and 4 shows a 3D cube and origami structures after fabrication, respectively.



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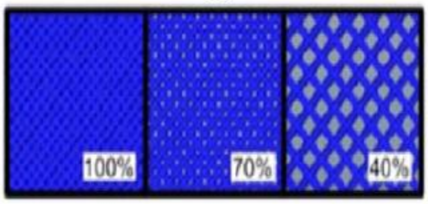

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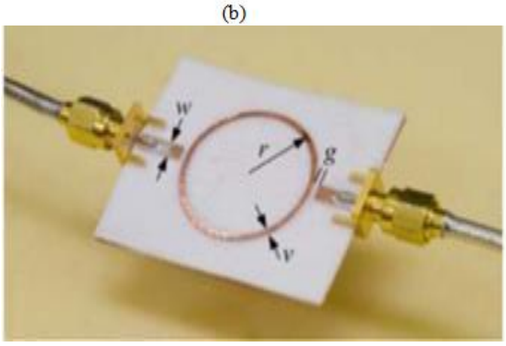

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Figure.2. NinjaFlex substrate with 3-D printing: (a) Printed layers stack; (b) Different infill percentage patterns; (c) Ring Resonator for the characterization of 70% infill Ninjaflex substrate [6].

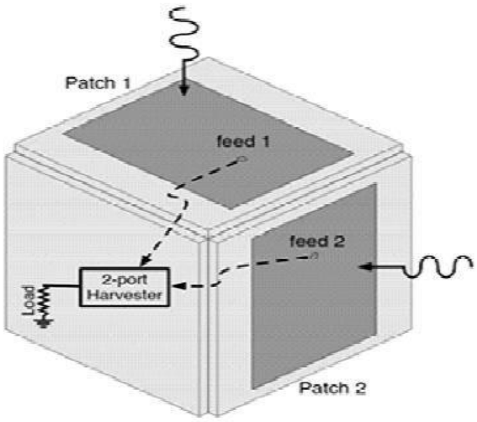
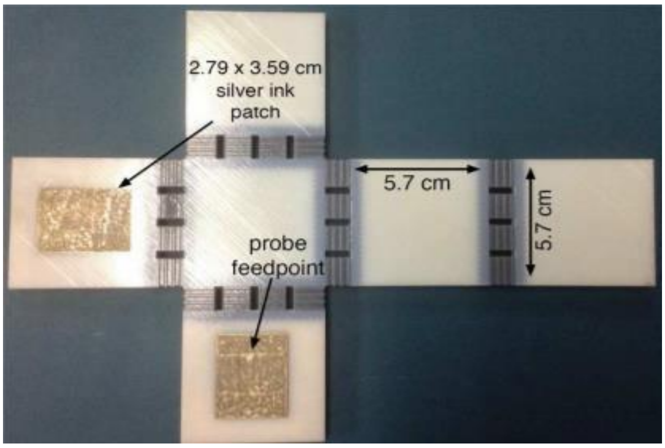


Figure.3.3-D cube for RF energy harvesting electronics.



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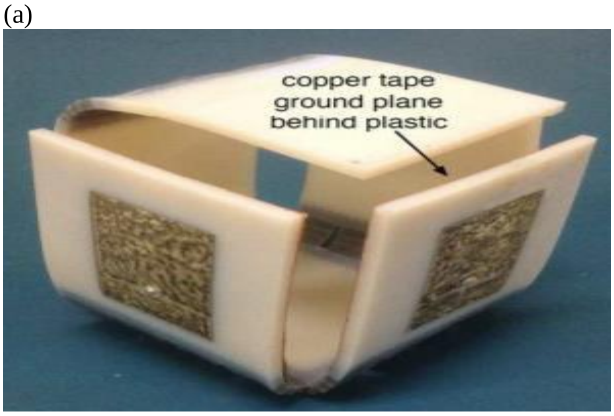


(b)

Figure.4. (a) Inkjet-printed an unfold 3-D printed cube; (b) "Origami"- folded cube [7].

Mirzaee et al. [3] proposed the fabrication of 3-D flexible antenna from conductive acrylonitrile butadiene styrene (ABS) materials using additive manufacturing technique. The application is demonstrated by designing and measuring a bowtie antenna shown in figure 5 with coplanar waveguide (CPW) feed structure. Makerbot dual 3D printer was used for fabrication of antenna and ABS filaments and flexible polylactic acid (PLA) for conductive and dielectric parts of the prototype antenna shown in figure 6. This prototype antenna is among the first antenna constructed from conductive ABS material. Agilent performance probe was used to measure the dielectric properties of the ABS filaments and PLA. The antenna possesses high flexibility, compact size and light weight. It also accomplishes 24.18 % wide bandwidth at 7.81 GHz at center frequency. The results show that conductive ABS appears to be promising choice for construction of 3D printed electromagnetic structures.

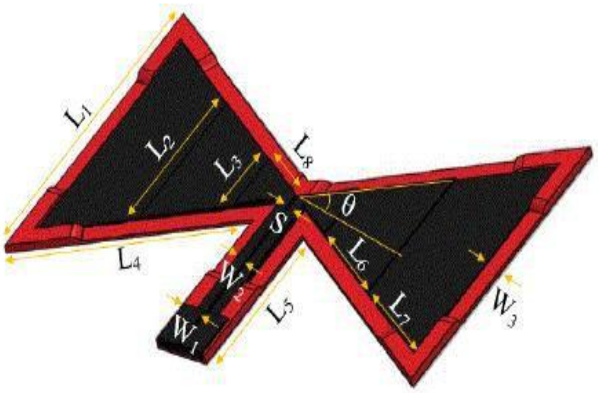


Figure.5. Prototype of the designed antenna.

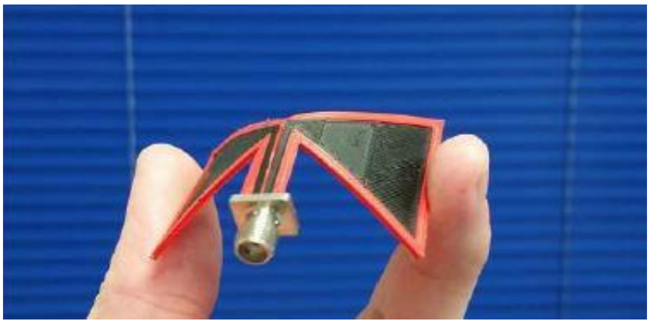


Figure .6. Bow-tie antenna after fabrication [8].

Farooqui et al. [4] demonstrated an antenna configuration consists of an antenna which is helical and is integrated with a lens. The antenna was fabricated by a novel blend of inkjet printing where metallic ink used is silver nano particle and 3-D printing of acrylonitrile butadiene styrene (ABS) which is a plastic material shown in figure 7. The peak gain is increased to 16.4 dBi at 9.4 GHz by the integration of lens. The fabricated antenna functions in end-fire mode and emits a left hand circularly polarized pattern. The antenna with lens provides % 3-dB axial ratio bandwidth. The integration of the lens and printing handling make this antenna to provide high gain performance with economical manufacturing.

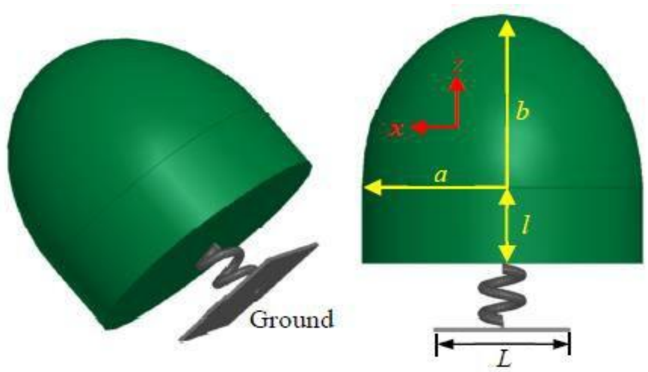


Figure. 7. Helical antenna design integrated with lens [9].

Arnal et al. [5] described the multi-material and multilayer 3-D printing technique which syndicates micro-dispensing and fused deposition modelling. Apart from this miniaturized micro-strip band pass filters, switched-line phase shifter and high impedance CP dipole antenna (surface-backed) all functioning at 2.45 GHz band was also shown as in figure 8. RF front-end components performance exhibits noticeable prospective for 3-D manufacturing technology in grasping conformal structural electronics, light weight and high quality.

Kohler et al. [6] demonstrated WR10 horn antenna shown in figure 9 and three different types of material used for the fabrication of this antenna. The quality of the three different material nearly same in visual inspection. The different material is considered to detect the difficulty to print PLA comprising copper due to its high thermal conductivity. It was likewise certain that the antenna design configuration could have been more perplexing as the 3D printing of these antenna did not represent any troubles from a plan perspective.

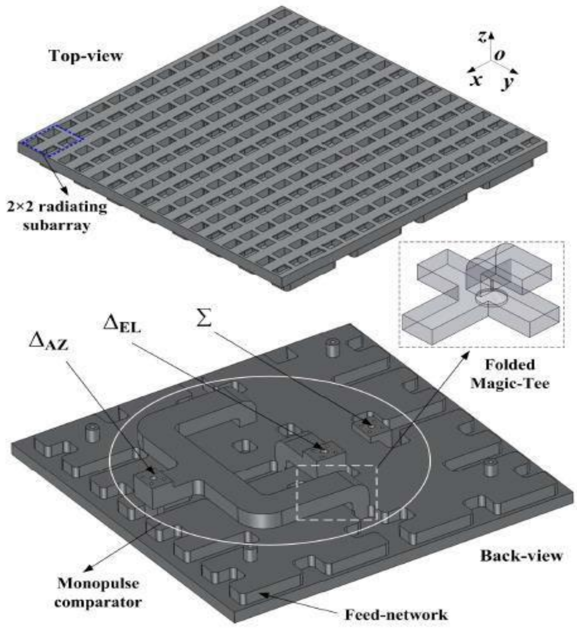
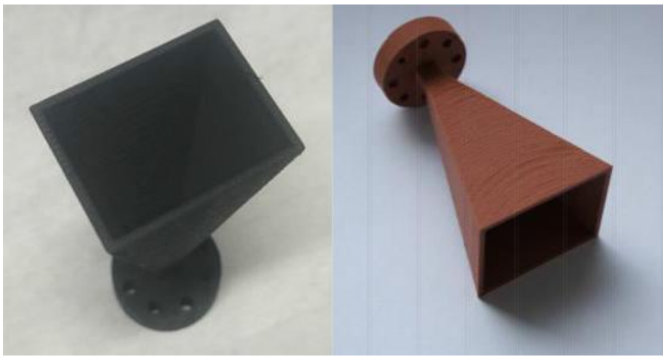


Figure.8. Configuration of the monopulse array [10]



(a) (b)

Figure.9. (a) Electrically conductive ABS horn antenna. (b) Thermally conductive PLA containing 35% copper [11].

McKerricher et al. [7] demonstrated the prospects for fabrication of electronics in general and radio frequency electronics using inkjet print 3-D integrated with conductive metal. In this work both the silver conductor and plastic material are deposited using inkjet printing. The validity of the process is provided by fabrication of 2.4GHz patch antenna. A very smooth inkjet-printed plastic surface is obtained having root mean square roughness less than 100 nm. In order to minimize the material requirement antenna was designed with honeycomb substrate shown in figure 10. This also provide other benefits like decrease in dielectric loss, dielectric constant and weight. The fabricated antenna is exclusively inkjet-printed and provide a good efficiency of about 81%. The use of honeycomb substrate enables to decrease the weight by 20 times compared to solid substrate and on other hand it also increases the efficiency by 15 %.

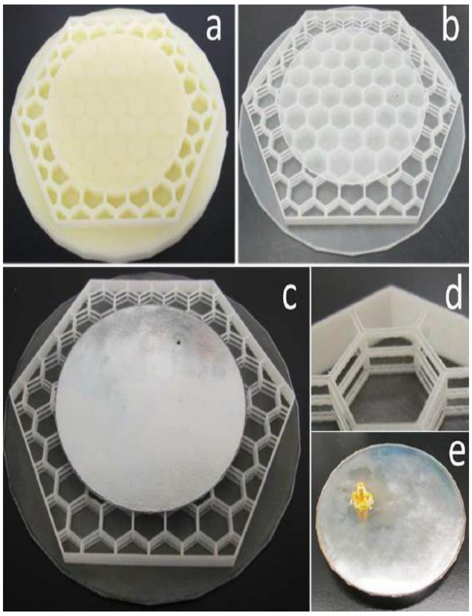
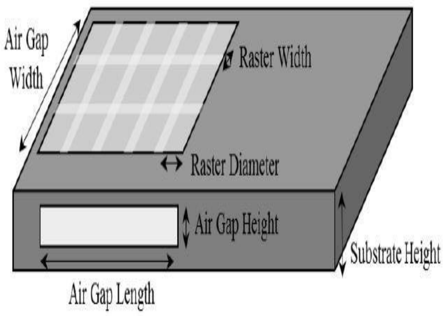


Figure.10. 3D multijet printed structure with (a) wax support material, (b) remaining polymer shell after melting the wax, (c) final antenna with inkjet-printed silver ink, (d) zoomed-in view of honeycomb, and (e)back of antenna with probe feed [12]. Baines et al. [8] presented a novel method for appreciating improved bandwidth micro-strip patch antennas (MPAs) by using 3D Printed Acrylonitrile Butadiene Styrene substrates. MakerBot Replicator 2X is used for 3D printing these substrates and subtractive manufacturing techniques for cavity- backed MPA designs shown in figure 11. Different cavity structures instigated and tested to recover the structural robustness of the substrate and MPA. The bandwidth was improved by 90% by introducing air cavity into the substrate. Some design also improved the gain by 1.2dB. This approach will be helpful in numerous applications to improve and include multiple cavities and erratic geometries into a synthetic substrate resulting in variable dielectric properties.



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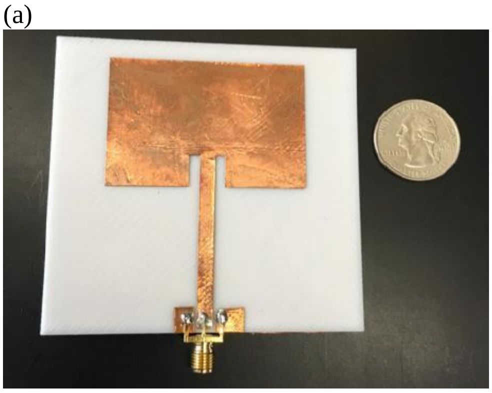

(b)

Figure.11. (a) Configuration of the microstrip patch antenna; (b) MPA after fabrication [13].

Table.1.Table for the comparative analysis of different antennas and material used.

SR NO.	ANTENNA TYPE.	MATERIAL USED.	FREQUENCY USED.	OUTPUT PARAMETERS.
1.	Patch Antenna	ninja flex filament	2.4 GHz	Gain = -3.8 dBi. Antenna Efficiency= 18%
2.	Patch Antenna and Unfolded Origami Cube.	thermoset shape memory polymers(vero white and grey60)	2~2.6 GHz.	Insertion Loss = 45 dB. Gain= 4 dBi. B.W =100 MHz.
3.	Bow-tie antenna with CPW	PLA and ABS material	7.81 GHz	Return loss= -23 dB. B.W= 24.18%.
4.	Helical antenna.	ABS material.	9.4 GHz.	Gain= 16.4 dBi. B.W= 3.4%. Return loss = -38 dB.
5.	Dipole antena	Thermoplastic ABS with copper	2.45 GHz	Conductivity= 1.15e6. ABS has sufficient power handling capabilities.
6.	Horn antenna	Conductive ABS & Conductive PLA, Amphora Polymer	-	Designing with ABS is very easy.
7.	Patch antenna	Wax material, UV-cured polymer and a silver nano particle	2.4 GHz	Gain= 8dBi. Radiation efficiency=81 %.
8.	Microstrip Patch Antenna	ABS material	2.4GHz	B.W= 1.95%. Gain= 5.65 dBi.

IV. CONCLUSION

In this paper different techniques for 3D printing antennas are studied. It has been seen that even the complex design of antenna is easy to manufacture using 3D printing. Antennas made using 3D printing techniques have their numerous applications in vast areas like Bluetooth, Wi-Fi, medical sector. This paper provides a survey of various antennas fabricate using 3D printing with different techniques as it offers, lighter-weight, time-efficient, cost-effective, environment friendly option than conventional manufacturing methods.

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