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Design and Realization of 3D Printed Electromagnetic Pulse Probe

Mücahid Taha Mersin[1,2], Filiz Güneş[1], Ekrem Demirel[2]
[1]Department of Electronics and Communication Engineering,University of Yıldız Technical, TURKEY
[2]EMI-EMC Testing and Evaluation Laboratory,TUBITAK BILGEM, TURKEY
Corresponding Author: Mücahid Taha Mersin

Abstract: *In this paper, design and realization of a 3D printed D-dot type probe is studied for measurement of Electromagnetic Pulse (EMP). D-dot probe is firstly designed in a 3D Electromagnetic simulation tool CST. Next, the 3D modelled probe design is realized with the usage of 3D printing technology and its experimental performance is measured. The 3D printed D-dot probe prototype is tested in accordance with the requirement of RS105 test using an EMP generator and a GTEM cell. The experimental results of the proposed 3D printed D-dot probe then are compared with a counterpart commercial probe and it is found that the response of both probes are have similar characteristics for the EMP signal. Thus it can be concluded that the proposed method is a prototyping method for the EMP probes of the desired level in a fast and cost efficient ways.*
Keywords: *D-Dot probe,EMP Measurement, 3D printer.*

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I. Introduction

With the rapid development in the field of defence science and technology, the electromagnetic environment has become even more complicated due to the high technology electronic equipment and systems. In national defence science the design of novel and higher performance systems is at most importance both in means of defence and counter attacks. One of the techniques to disable the enemies'complicated electronic systems is by overloading their electrical systems with an instantaneous high level energy fields, Electromagnetic Pulse (EMP). Due to their fast rise time, high power EMP can create an interference/disturbance on the electronic equipment's such as RADAR or any communication device, and prevent their functioning or even damage them [1].

The EMP systems can be used to prevent functioning of electronic systems within the range of the EMP. While small range EMP systems and High Power Microwave (HPM) can be created by using high performance batteries or reactive chemicals reactions, EMP with a large effect radius can be achieved by detonation of a nuclear bomb in high altitude. High-Altitude EMP (HEMP) or natural phenomena's such as thunder and lightning can also create a high power electromagnetic field that can cause damage on electronic systems. Thus, measurement of these electromagnetic fields has a very important value on HPM and HEMP researches [2-5].

In literature there had been series of work on design and realization of high power transient electromagnetic field sensors such as E-field, B-Dot, D-Dot. Due to its simple structure, small size and fast response time, D-Dot type sensor are one of the most commonly used EMP sensors [6]. MIL-STD-461E RS105 test standard was developed for the simulation of HPEM effects to military equipment's by the United States Department of Defence. [3]. Accurate measurement of an EMP sensor' performance is a challenging problem because of the EMP's high power and their short time response. Since the D-dot probes are often preferred because of their omnidirectional sensing capability, one of the common methods for measurement of the EMP is D-dot.

D-Dot is a differential EMP sensor that converts differential E-field strength into the load voltage. In Fig.1 a general schematic of D-Dot sensor and the equivalent circuit are given. The conversion relations of E-field to load voltage by a D-Dot sensor within its operation range can be defined in Eqs. (1-3) [7-8].

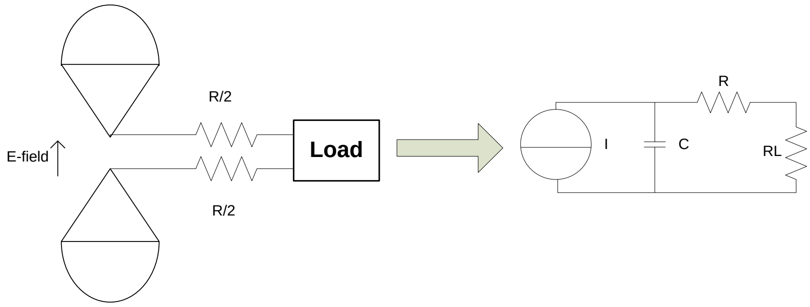


Figure 1: Schematic of D-dot Probe and its equivalent circuit

$$V_L(t) = R.A_{eq}.\varepsilon_0 \frac{\partial}{\partial t} E(t) \quad (1)$$

$$E(t) = k\int V_L(t)dt = K.Y(t) = \frac{1}{R.A_{eq}.\varepsilon_0} Y(t) \quad (2)$$

$$A_{eq} = -\frac{h^2\pi(1-(\tan\frac{\theta}{2})^2)}{\ln(\tan\frac{\theta}{2})} \quad (3)$$

Where, R: is the matching impedance usually 50 ohms, ε_0: Vacuum dielectric constant, K: Calibration coefficient, A_{eq}: Equivalent area.
Fast and accurate prototyping process of microwave devices are at most importance for low cost design process. One of the most recent innovation for fast, low cost and accurate prototyping is 3D printing technology [9-12]. 3D printing is a method of manufacturing in which materials, such as plastic or metal, are deposited onto one another in the form of layers to produce a three dimensional designs.

Herein in order to reduce the cost of prototyping process of the D-Dot probes both in means of time and cost, the 3D printing technology is used. From the experimental results one can conclude that the proposed 3D printed D-dot probe is working according to the desired levels. The proposed prototyping methods also achieve the goal of fast and low cost prototyping of D-Dot type probes. In the next section of the work the design process and simulated results of the D-Dot probe are studied which then is also supported by the experimental results obtained from the 3D printed prototyped design and a commercial used D-dot probe, and finally the work ends with a brief conclusion section.

II. Design and Simulation

In this section design and simulation results of the D-dot probe is studied. Generally D-dot probes are divided into two groups as free field and ground field probes. In this study, free field probe structure is used. After being produced with a 3D printer, the outer parts are covered with copper band and thus conductivity is provided. 3D printer material is used as Abs (Ɛr = 2.5. the 3D model of the D-dot probe in CST environment is presented in Fig. 2.

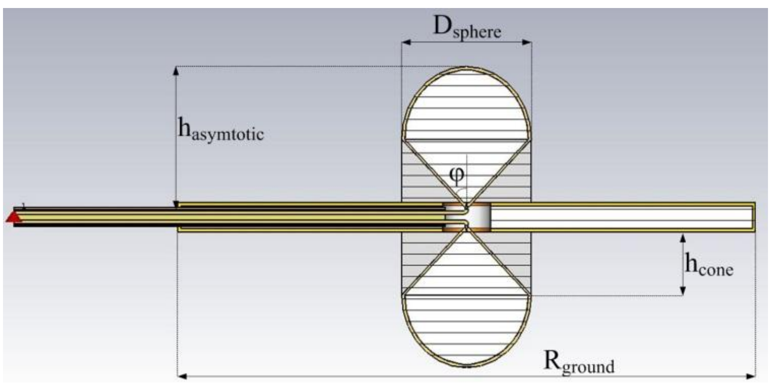


Figure 2: 3D model of D-dot Probe in CST

Where: Dsphere=43mm, hasymtotic=42mm, Rground=192mm, hcone=18.5mm, and φ =470.

In Fig. 3, the simulation results of the 3D modeled probe are investigated for an incoming normalized EMP signal which is generated according to the standards of RS105 test. As it can be seen from the Fig. 3, the designed 3D model can measure the incoming EMP signals after the integration. In the next section, the experimental results of the 3D printed probe will be given.

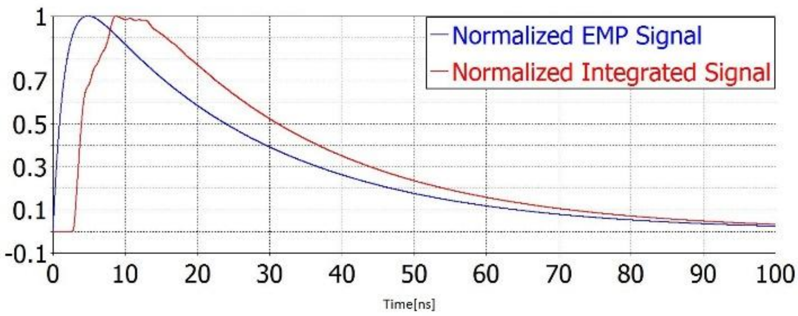


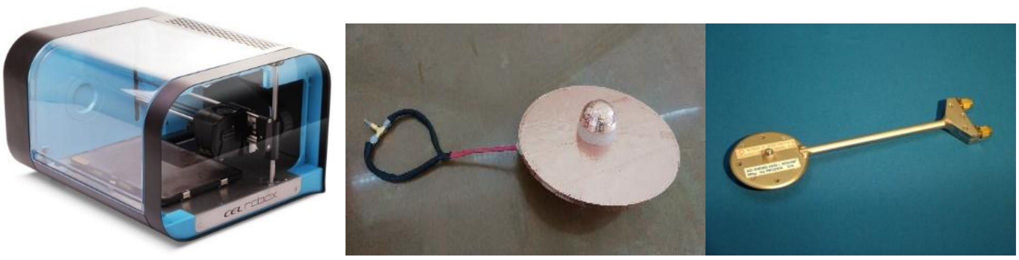
Figure 3: CST Plane Wave Signal and Normalized Integrated

III. Experimental Results

In this section the measurement of the prototyped D-Dot probe is studied. Measurements are made in the GTEM (Giga Hertz Transverse Electromagnetic) cell alongside of a suitable EMP signal generator for RS105 test given in Fig. 4.

Figure 4: Measurment setup of GTEM, EMP generator and Control unit

Herein, 3D model of the probe design is exported in ".STL" file format, so that the CEL Robox® Micro [13] (Fig. 5a) can create its code for printing of the prototyped D-Dot probe (Fig. 5b). In Fig. 6, the experimental results of the 3D printed probe is compared with a commercial used D-dot probe [14]. The results given in Fig. 6, are obtained via the integration of the output signal from the both probes. The delay within the measured signal of probes are due to their placing in the GTEM cell. As it can be seen from the measurement results, the proposed 3D printed D-dot probe is has similar response. Thus, the proposed low cost prototyped D-dot is a suitable design to be used in RS105 test and verification process.



(a) **(b)** **(c)**

Figure 5: (a) Manufacturing platform [13], (b) 3D Printed D-Dot Probe, (c) commercial used D-dot probe [14].

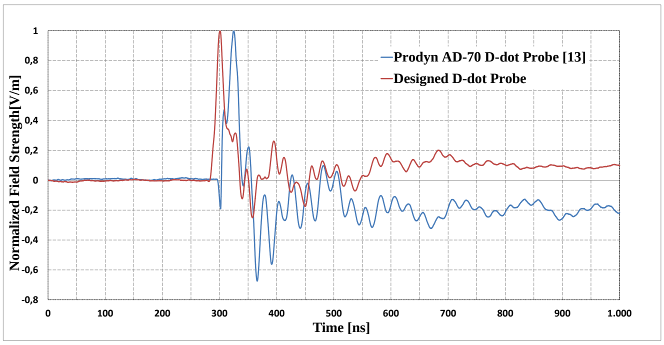


Figure 6: Measured EMP signal

The first paragraph under each heading or subheading should be flush left, and subsequent paragraphs should have a five-space indentation. A colon is inserted before an equation is presented, but there is no punctuation following the equation. All equations are numbered and referred to in the text solely by a number enclosed in a round bracket (i.e., (3) reads as "equation 3"). Ensure that any miscellaneous numbering system you use in your paper cannot be confused with a reference [4] or an equation (3) designation.

IV. Conclusion

Herein a novel prototyping method with 3D printing technology is proposed for reducing the cost of prototyping process of the D-Dot probes both in means of time and cost. From the comparison of both theoretical and experimental results one can conclude that the proposed 3D printed D-dot probe works according to the desired levels. As a result the prototyped design is a suitable design to be used in RS105 test and verification process.

Acknowledgements

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References

[1]. B. H. Zhou, B. Chen, L. H. Shi, EMP and EMP Protection, National Defense Industry Press, Beijing, 2003.
[2]. IEC 61000-2-9, Description of HEMP Environment radiated Disturbance, International Electrotechnical Commission, 1998.
[3]. MIL-STD-461E, Requirements for the Control of Electro-magnetic Interference Characteristics of Subsystems and Equipment, Department of Defense, USA, 1999.
[4]. R. Hoad, N. J. Carter, Rends in EM susceptibility of IT equipment, IEEE Transactions on Electromagnetic Compatibility, Vol. 46, Issue 2, 2004, pp. 391-396.
[5]. C. E. Baum, From the electromagnetic pulse to highpower electromagnetics, Proceedings of the IEEE, Vol. 80, Issue 6, 1992, pp. 789-817.
[6]. Wei B., Gu Y. C., Zhou R.G., Yang L., Wang X., Design, calibration and measurement of D-dot monitor for Yang accelerator water transmission line[J]. High Power Laser and Particle Beams, 2007, (05):830-834.
[7]. IEC 61000-4-33 Electromagnetic compatibility (EMC) – Part 4-33: Testing and measurement techniques – Measurement methods for highpower transient parameters, September 2005.
[8]. Yang C, Test Technology and Application of High power Electromagnetic Field [D].Beijing: Tsinghua University,2016:27
[9]. Mehmet A. Belen, Peyman Mahouti, (2018), "Design and realization of quasi Yagi antenna for indoor application with 3D printing technology", Microw Opt Technol Lett. 2018;60 (9):2177-2181. https://doi.org/10.1002/mop.31319
[10]. Yunus Can Toy, Peyman Mahouti,Filiz Güneş and Mehmet A. Belen ,"Design and Manufactering of an X-Band Horn Antenna using 3-D Printing Technology", 8th International Conference on Recent Advances in Space Technologies, 19-22 June 2017, İstanbul, TURKEY
[11]. Belen MA. Stacked microstrip patch antenna design for ISM band applications with 3D-printing technology. Microw Opt Technol Lett. 2018; 1–4. https://doi.org/10.1002/mop.31603
[12]. Mahouti P, Belen MA, Güneş F, Yurt R. Design and realization of multilayered cylindrical dielectric lens antenna using 3D printing technology. Microw Opt Technol Lett. 2019;1–4. https://doi.org/10.1002/mop.31720
[13]. CEL Robox® Micro manufacturing platform with Dual Nozzle FFF Head - RBX01, http://cel-uk.com/3d-printer/printers/rbx01-297.html. Available on [19.01.2019]
[14]. AD-70 D-dot probe (Electric Field Sensors) PRODYN technologies, www.prodyntech.com/products/d-dots-electric-field-sensors/, Available on [19.01.2019]

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