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Optimization of DBD based Plasma System for Radar Cross Section Reduction

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***Abstract:** The concept of radar cross section reduction has become very important subject for the designers giving deep attention to methods of reducing detectability. The low detectability of aircraft from hostile radar sources can be practically achieved through radar absorbing coating (RAM/RAS), shaping, engineered materials or plasma. The techniques such as shaping, RAM coating have bandwidth constraints. Plasma-based stealth also referred to as active stealth technology is an alternative method which is under research. Plasma-based shielding is based on the fact that plasma being dispersive media absorbs the incident electromagnetic (EM) radiation before it is scattered by the target.*

Dielectric Barrier Discharge (DBD) is known to be an efficient technique of plasma generation w.r.t. energy consumption and device complexity. In other words, depending on atmospheric pressure, electron density, plasma frequency, ambient temperature and several other parameters, DBD plasma can behave as an absorber or a reflector of incident EM waves. This paper reviews is upon radar cross section reduction techniques and dielectric barrier used for plasma generation.

Keywords: Radar cross section, plasma, plasma stealth, Dielectric barrier discharge.

I. INTRODUCTION

The low detectability of aircraft from hostile radar sources can be practically achieved through radar absorbing coating (RAM/RAS), shaping, engineered materials or plasma. The techniques such as shaping, RAM coating have bandwidth constraints. It has been reported that inhomogeneous plasma layer acts as frequency selective medium, and can be used for RF shielding over wide frequency range. In particular, plasma-based stealth also referred to as active stealth technology is still a frontier subject of research. Plasma-based shielding is based on the fact that plasma being dispersive media absorbs the incident electromagnetic (EM) radiation before it is scattered by the target. Further the plasma-air interface being continuous in terms of electrical dimensions, results in reduced radar signatures as compared to the target surface, which poses a sharp discontinuity for the incident wave. Plasma cloud [1] covering the structure such as aircraft may give rise to other signatures such as thermal, acoustic, infrared, or visual. Thus it is a matter of concern that the RCS reduction by plasma enhances its detectability due to other signatures. This needs a careful approach towards the plasma generation and its EM wave interaction. Further the parameters of plasma that can be controlled to reduce the target detectability, which need to be identified and optimized.

Dielectric barrier discharges (DBDs) are plasmas generators [2] in configurations with an insulating (dielectric) material between the electrodes which is responsible for a self-pulsing operation. DBDs are a typical example of non-thermal atmospheric or normal pressure gas discharges. Therefore DBDs are a relevant tool in current plasma technology as well as an object for fundamental studies. A dielectric barrier discharge generating plasma can have an electrical equivalent model[3], which is designed using MATLAB Simulink [4] . Here in this paper we present a electrical model that is used to show the plasma generation in the form of a graphical outcome.

II. ELECTRICAL MODEL

A. DBD Electrical Circuit

The electrical model or designing of Dielectric barrier discharge (DBD) [6] has been carried out using the MATLAB Simulink tool. To investigate and examine the electrical behavior of a DBD [7], it is always advantageous to have an electrical equivalent representation of the DBD system[8]. For plasma generation system, there is always an electrical equivalent network. The electrical equivalent network model can be easily analysed, simplified by circuit analysis technique and implemented in most circuit simulation tools, thus it is always useful to draw an equivalent electrical network for a given plasma generation source. These plasma generation sources are a part of the plasma reactor system. Utilizing the equivalent network model, the system equations governing the discharge can be easily obtained in a simplified manner and with a more detailed understanding. The electric circuit model provides theoretical fundamentals to determine the temporal development process of all the electrical quantities in the discharge gap from the measured external voltage and external total current. The purpose of electrical equivalent circuit approach was to account for the fact that the basic DBD configuration is a capacitive electric circuit network.

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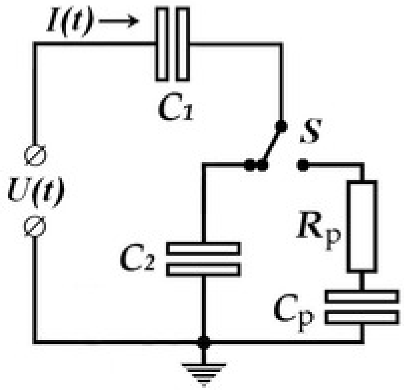
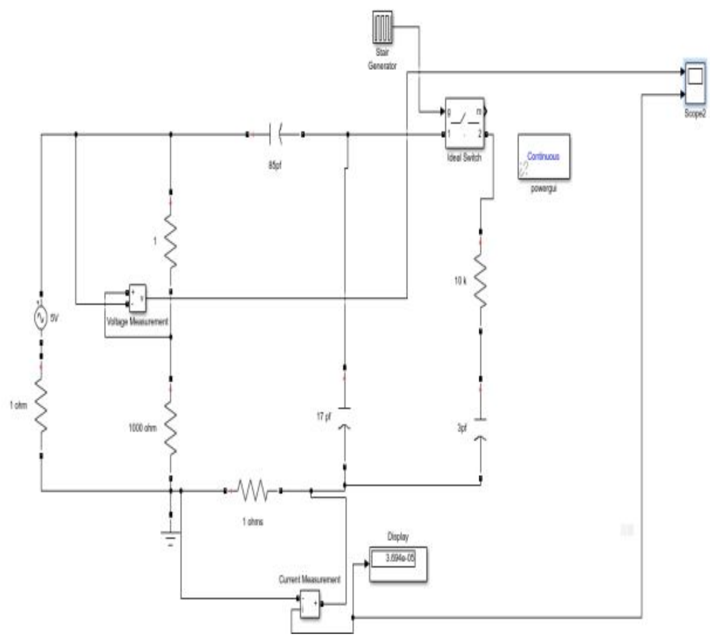


Figre 1 Electrical circuit of Dielectric barrier discharge

III.DBD MATLAB SIMULINK MODEL

Simulink, developed by MathWorks [10], is a graphical programming environment for modeling, simulating and analyzing multidomain dynamical systems. Its primary interface is a graphical block diagramming tool and a customizable set of block libraries. It offers tight integration with the rest of the MATLAB environment and can either drive MATLAB or be scripted from it. Simulink is widely used in automatic control and digital signal processing for multidomain simulation and Model-Based Design. Therefore in Simulink any type of simulation can be done and the model can be simulated at any point in this environment.



Figre 2 Simulink model of dielectric barrier discharge

Figure is an electrical equivalent of a DBD circuit shown in figure 1, Matlab Simulink helps us design an equivalent design or model of the dbd electrical circuit. Using the model the results for various frequencies and voltages were obtained.

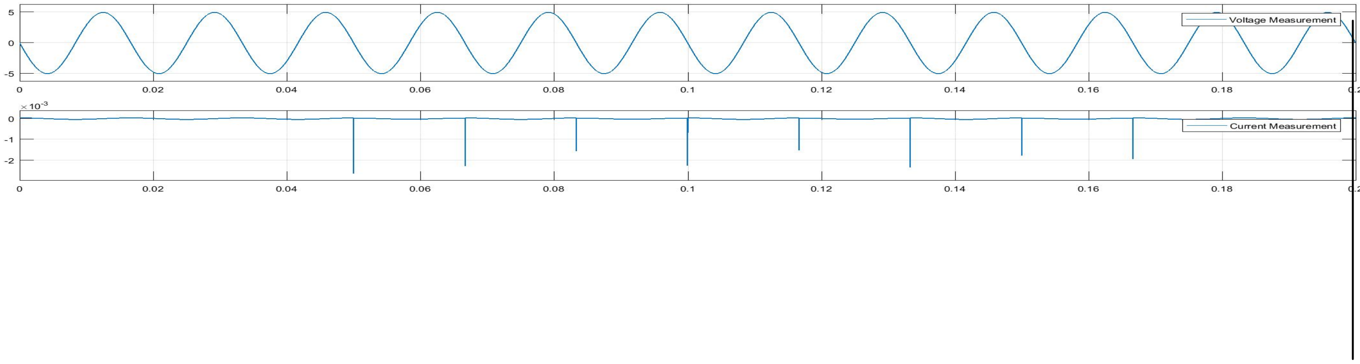
IV. WORKING OF THE SIMULINK MODEL

There are two regions of operations for a DBD[9] circuit. One before breakdown and another after breakdown. If the applied voltage is not high enough to cause the breakdown the discharge does not occur and the circuit is said to be in OFF state. When the voltage raises upto the level required that causes breakdown ionization takes place so the circuit is said to be in ON state. The ionization process causes discharge current to increase and limiting the gap current that peaks up n down.

In the electrical equivalent model the ON and OFF state is controlled by the switch, .this switch is used to control the open and close mechanisms that fluctuates the circuit discharge and non-discharge states.

V. RESULTS AND DISCUSSIONS

The equivalent electrical circuit of the DBD is modeled using the MATLAB Simulink . the voltage is increase from to and relevant frequencies are given accordingly to obtain the peaking of current when for that certain voltage the breakdown occurs. There are results obtained for voltage 5 KV , frequency 60 Hz, voltage 8KV , frequency 600Hz and voltage 10KV , frequency 6KHz.



Figre 1 Simulation result of current peaking at 5KV , frequency 60Hz

Figure 1 shows the current peaking at voltage 5KV and frequency 60 Hz,similarly the peaking of current is seen at voltage 8KV and frequency 600Hz. We also studied the discharge that happens at voltage 10KV and frequency 6KHz and its result is shown in figure 3.

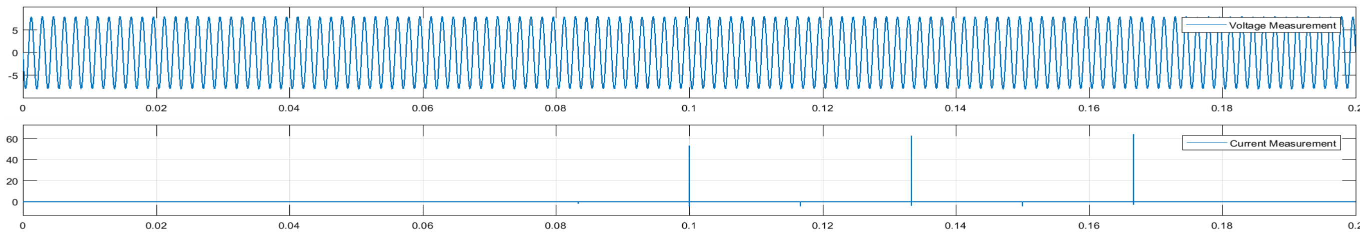


Figure 2 Simulation result of current peaking at voltage 8KV,frequency 600Hz

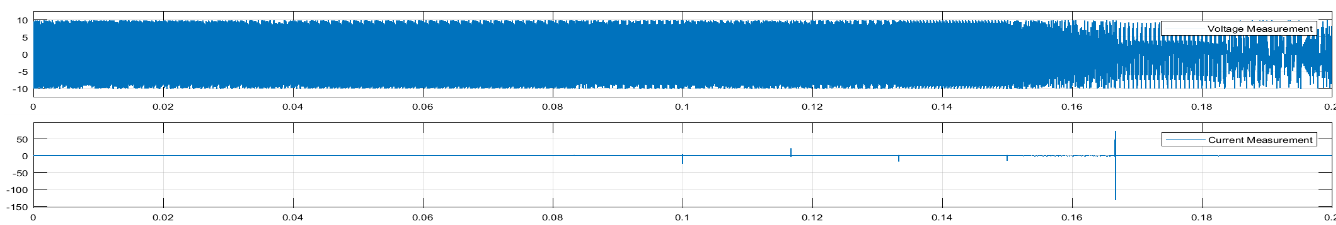


Figure 3 Simulation result of current peaking at voltage 10KV,frequency 6KHz

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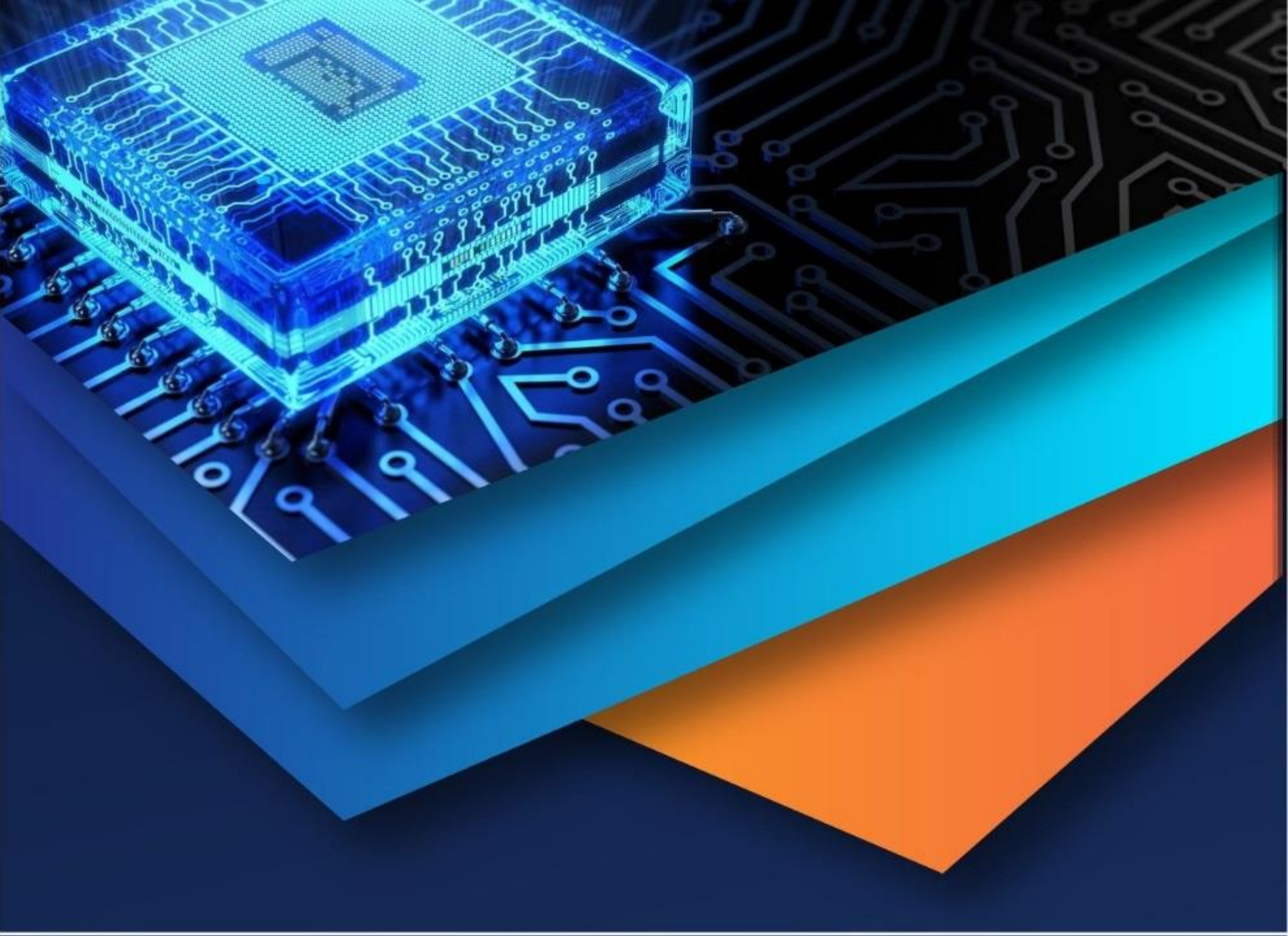

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