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Investigation of Log Periodic Dipole Array Printed Antenna for Recognizing Incipient Discharges in Power Transformer

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***Abstract*— Incipient Discharge (ID) online checking is a powerful mechanism for assessing insulation imperfections in power transformer. Nowadays, ultra high frequency (UHF) identification technique has gained more attention by researchers for online PD signals diagnosis. In this paper, a broad bandwidth log periodic dipole array (LPDA) printed antenna was designed. The antenna parameters were examined by ANSYS HFSS Software. The incipient discharge experiments were conducted on four distinctive mannered insulation fault models with the designed LPDA antenna. The results of experimental tests reveal that the designed LPDA antenna is appropriate and efficacious for real time PD signals diagnosis in transformers.**

Keywords—incipient discharge; ultra-high frequency method; log periodic dipole array.

I. Introduction

The Partial discharge assessment is well accepted technique for high voltage power apparatus to detect the incipient faults with in the insulation system [1]. Nowadays UHF method is the best effective mechanism for PD diagnosis when compared to other methods due to intense sensitivity and signal to noise ratio [2]. This detection method utilizes UHF antenna to recognize the PD signals from the PD source.

Antennas are the key element for UHF online PD monitoring system. At present different types of UHF antennas used for the measurement of incipient discharges. A Planar Archimedean spiral two wire antenna and its implementation for PD diagnosis are presented in [3]. The Archimedean spiral antenna design and its distinct PD measurements were shown in [4].

An antenna of upturn cone shaped was reported in [5] to detect incipient defects in mineral oil. Literature [6] introduced a micro-strip patch antenna for internal faults identification. A radio frequency antenna was developed to recognize the internal defects in mineral oil and its quality evaluation purpose [7]. A Hilbert fractal fourth order antenna was designed for detection of online faults in transformers [8].

This paper presents the LPDA Printed antenna for diagnosis of PD. The LPDA antenna was developed and validated by HFSS software. Then this antenna is utilized on our own PD testing platform.

II. Idea and Mechanism

A. Antenna Configuration

1. Configuration of LPDA Antenna

The fulfilment of LPDA antenna is usually governed by following aspects.

a. The length of the dipole (L)
b. The distance between the elements (d)
c. The width of the dipole (w)
d. The angle between the dipoles.
e. The space constant
f. The geometry constant
g. The substrate dielectric constant.
h. The substrate thickness (k)
i. The feeding technique
j. The position of feeding point.

The top and bottom side of the designed LPDA is shown in Figure 1 and 2. The effect of the design variables are considered while running the simulation.

2. ANSYS HFSS Software and Execution

HFSS was utilized to further survey the end result of additional contributing elements. The simulated return loss result of the un-optimized LPDA antenna in multiple bands, reveals that good directivity. Besides, the best values of substrate thickness & dielectric constant and feeding position have been evaluated carefully.

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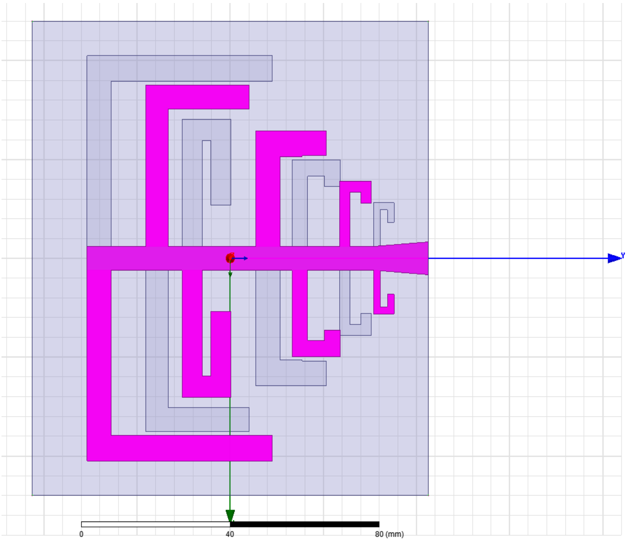

Fig. 1. Top side of the designed LPDA antenna

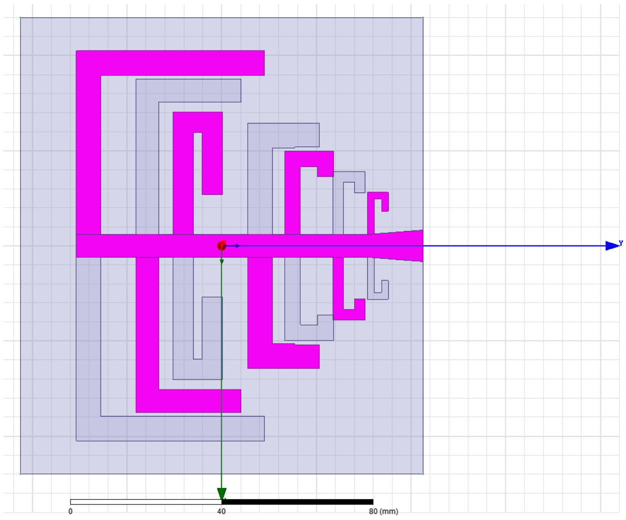

Fig. 2. Bottom side of the designed LPDA antenna

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The design limits of the proposed LPDA antenna are given below

- The length of the dipole (L = 140 mm)
- The width of the dipole (w = 110 mm)
- The substrate thickness (k = 3.2 mm)
- The substrate dielectric constant (4.4)
- Coaxial feeding technique (50 ohms)

The Return loss of the un-optimized LPDA antenna is depicted in Fig 3. The return loss shows the multi bands in the operating frequency range of 0.5 to 2.2 GHz. The simulated radiation patterns of the designed LPDA antenna at 500,1000,1500,2000&2200MHz frequencies are shown in Fig 4(a- e).

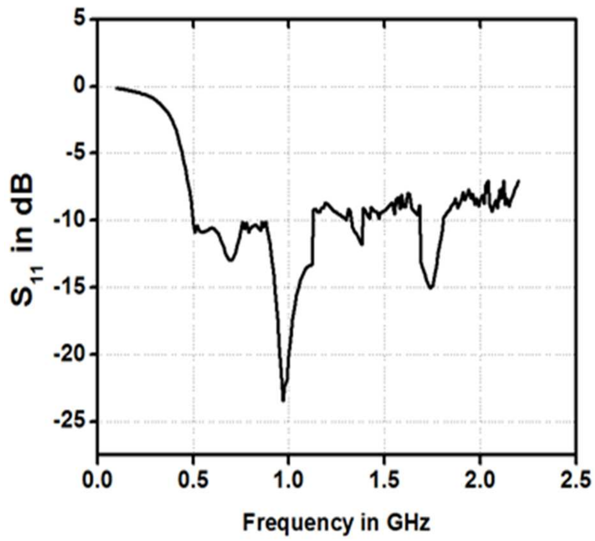

Fig. 3. Return Loss of the unoptimized LPDA antenna

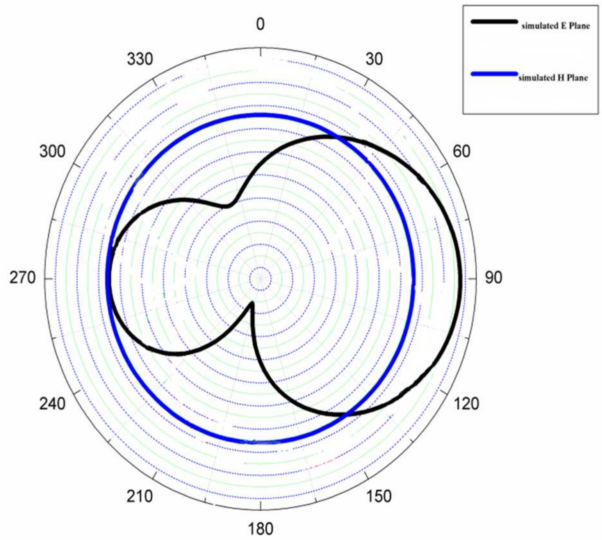

Fig. 4. (a) Simulated Radiation Pattern at 500 MHz

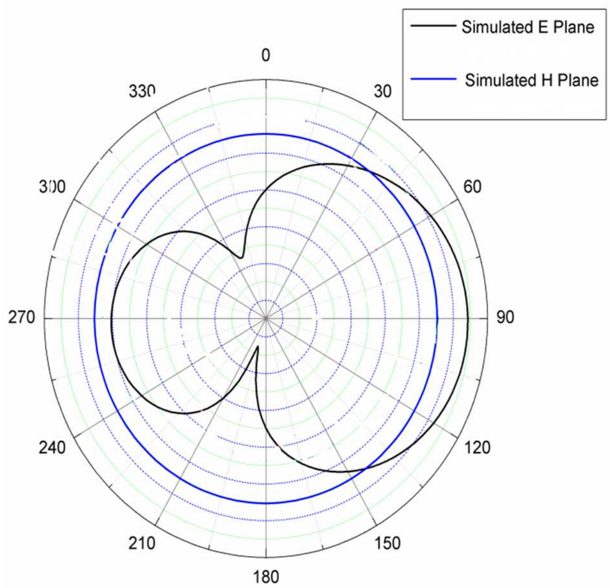

Fig. 4. (b) Simulated Radiation Pattern at 1000 MHz

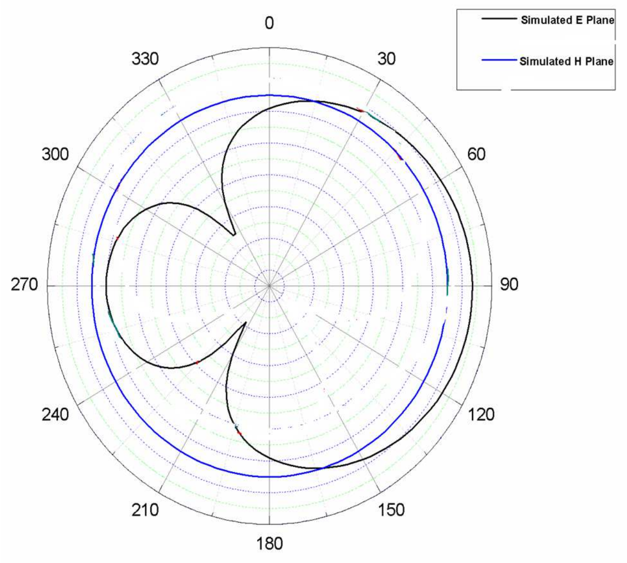

Fig. 4. (c) Simulated Radiation Pattern at 1500 MHz

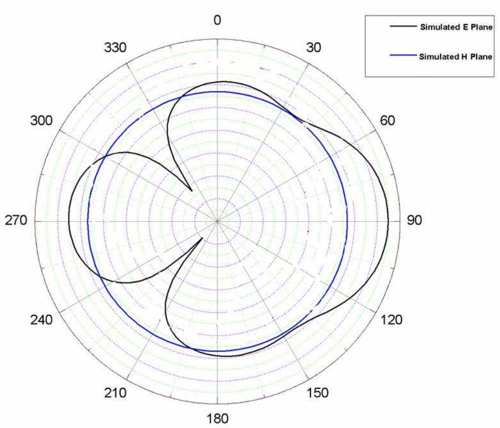

Fig. 4. (d) Simulated Radiation Pattern at 2000 MHz

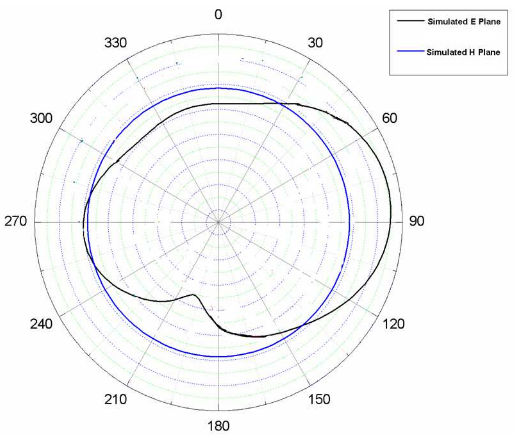

Fig. 4. (e) Simulated Radiation Pattern at 2200 MHz

B. *Experimental Test Platform*

Generally, the incipient discharges are produced inside the power transformer. The experimental test platform is designed based on the characteristics of the incipient discharges. The two important segments are HVAC source i.e., generates high voltage AC supply up to 100kV,50Hz test transformer and test cell constitute of transformer oil and electrode structure of respective discharge model to produce incipient discharges.

III. Experiment Results and Discussion

The proposed antenna is used for the four different incipient discharges of the experimental test platform. The incipient discharges were captured by the designed antenna and these signals were fed to mixed domain oscilloscope (MDO 4104) using coaxial cable. Its bandwidth is 3GHz and sampling rate is 6.25 GS/s. The layout of the experimental test platform is shown in Figure 5.

Fig 6 shows the four different test electrodes for the generation of different incipient discharges. The particle movement incipient defect model has a 1mm diameter aluminium ball, top electrode is sphere shaped aluminium and the bottom electrode is concave shaped aluminium shown in Fig. 6(a). The corona incipient defect model has a copper wire needle attached to top electrode aluminium and flat aluminium bottom electrode shown in Fig. 6(b). The two particle incipient discharge model has two different particles aluminium ball and copper bead, the top electrode is sphere shaped aluminium and the bottom electrode is concave shaped aluminium shown in Fig.6(c). The floating incipient defect model has copper pin at the centre of the pressboard, the top electrode is sphere shaped aluminium and the bottom electrode is concave shaped aluminium shown in Fig. 6(d) and Figures 7-10 shows the time domain and the corresponding frequency domain of PD signals produced by different discharge models detected by log periodic dipole array antenna.

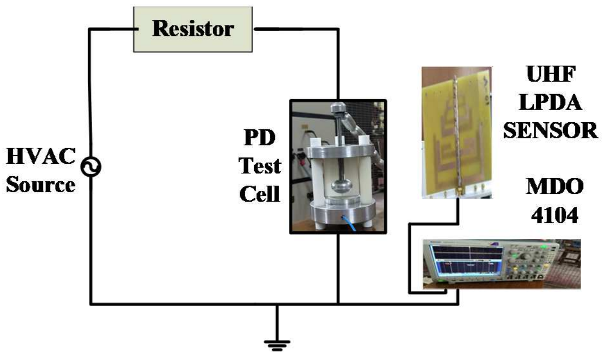

Fig. 5. Layout of the incipient discharge experimental test platform

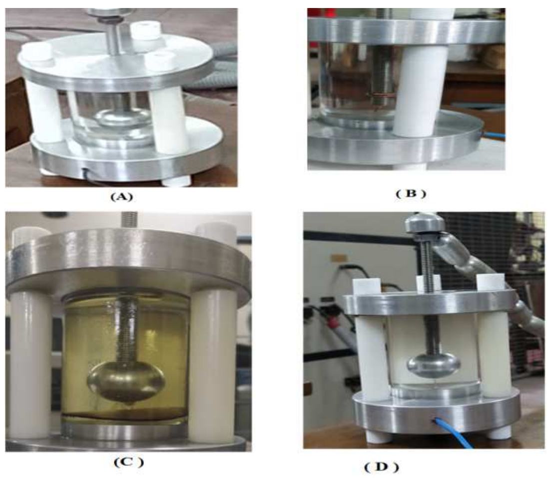

Fig. 6. Four different PD Test cells snapshot used for detection of (a) particle movement, (b) corona, (c) floating incipient discharge and (d) conducting defects.

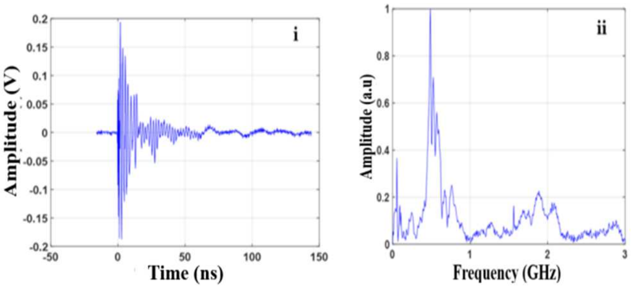

Fig. 7. Time domain UHF signal produced due to particle movement defect in the transformer oil (ii) Normalized FFT of (i).

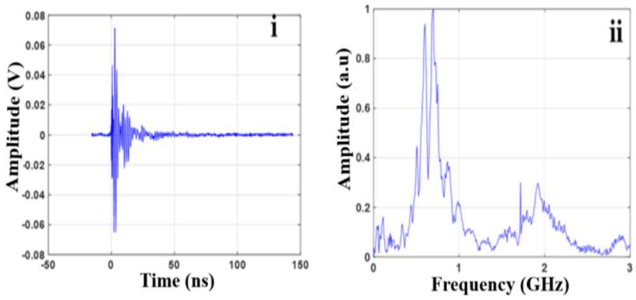

Fig. 8. (i) Time domain UHF signal produced due to corona defect in the transformer oil (ii) Normalized FFT of (i).

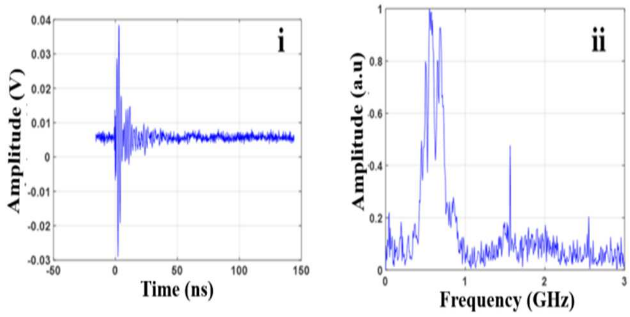

Fig. 9. (i) Time domain UHF signal produced due to two particles (aluminum ball & copper pin) defect in the transformer oil (ii) Normalized FFT of (i).

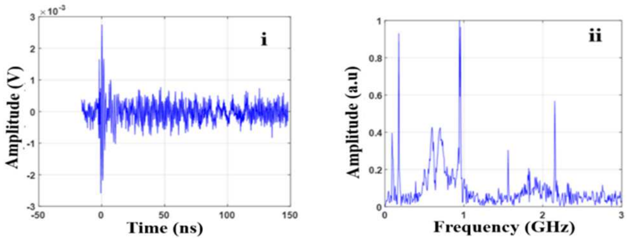

Fig. 10. (i) Time domain UHF signal produced due to floating defect in the transformer oil (ii) Normalized FFT of (i).

IV. Conclusion

This Paper presents the experimental evaluation of different incipient discharges diagnosis using LPDA antenna. The return loss of the un-optimized LPDA antenna working band from 0.5 - 2.2 GHz. The simulated 2D radiation patterns of the designed LPDA antenna at five different frequencies are also shown. The experimental and simulation results reveal that the designed LPDA antenna is suitable and apt for PD signals detection. It is economical way to identify incipient faults and save money for electrical companies and manufacturers.

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