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# Analysis of flexible antenna performance on partial discharges detection

Affendi N A M<sup>1,2</sup>, Amirruddin M<sup>1,2</sup> and Ahmad S<sup>1,2</sup>

<sup>1</sup>School of Electrical System Engineering, Unimap, Arau, Perlis, Malaysia

<sup>2</sup>Centre of Excellence for Renewable Energy, UniMAP, Arau, Perlis.

Email: nuradyani@unimap.edu.my

**Abstract:** This paper reports a short finding on the use of a flexible substrate in the design of Partial discharge (PD) detection antenna. This flexible antenna was designed and simulated using CST Microwave Studio to detect corona discharge which is one types of PD that occur in power transformers. The flexible substrate that been used in designing the antenna is paper that has permittivity of 3.2 and the chosen frequency is between 300MHz until 3GHz. The overall dimension is 208×168×1.6 mm<sup>3</sup>. The simulations of the antenna's return loss were conducted under two conditions; 1) flat and 2) bending along H- planes. The result were been analysed to understand the performance of paper properties, so that practical system requirements are met. This implies that the performance of paper antennas can be used in the PD field with altering some of the characteristic to upgrade its performance.

## 1. Introduction

Flexible antennas are highly in demand for modern communication systems and have a large spectrum of applications in wireless communication where antennas are attached to various electronic curved surfaces. However, some materials are difficult to place or mounting and this lead to an investigation using a flexible and lightweight substrate that could be strength twisted and return to its original shape that can meet the requirement. Flexible substrates have a large spectrum of applications in wireless communication where antennas are attached to various electronic curved surfaces. In order to ensure for economic application, research had been done on several flexible substrate which are cheaper and reasonable price. However, one of the difficulties is to find a suitable flexible substrate that can be used and replace the existing rigid substrate. [1].

One of the available flexible substrate is paper which is an organic-based substrate and is widely available in the market. Photo paper is used as a substrate because it has good sustainability and strength compare certain such as epoxy resins and other else. Paper has a low surface profile (small thickness and light weight). With an appropriate coating, it is suitable for fast printing processes, such as direct-write methodologies, instead of the traditional metal etching techniques [2]. Paper can reduce the power loss of the substrate has good loss factor which is around 0.07 at 2.45 GHz [3].

As this research was intended to prove that the validity of using paper as a flexible substrate for PD detection (Corona discharge), it was decided to build the antenna using the best and successful approach. A microstrip patch was chosen due to its comparatively simple design geometries, low profile, conformable to non-planar surfaces and inexpensive.

The location of PD is unpredictable that make the method to locate PD become difficult to be detected. There are certain parts of transformers cannot be measured because of its structures that cannot be penetrated by antennas. The existence of PD in transformers may cause serious problems to

the insulation systems. PD will create plasma discharges channel that will deteriorate with heat and carbonized the insulation system slowly until reach the conductor [4]. One of PD type is a corona discharge. The designed antenna is focused to detect corona discharge which is one types of PD that may cause failure to the insulation windings in the HV transformers tank. The materials used by the existed antenna also become main problem that caused the antenna are not portable and cannot be bent. The range of the frequency where the PD can be detected lies on UHF frequency from 300MHz until 3GHz meanwhile the dominant frequency band emitted by corona lies between 0.625MHz until 1250MHz [5].

## 2. Antenna Design

Here, the antenna demonstrates a simple inset feed rectangular microstrip patch antenna that was designed to detect the corona discharges. There are several parameters that must be considered such as resonance frequency ( $f$ ), permittivity ( $\epsilon_r$ ) and thickness ( $h$ ) of the substrate [6]. After selection of the parameters, a few changes in dimension based on the calculation, the proposed antenna is shown in Figure 1. The permittivity that used in this work is 3.2. The resonant frequency of the antenna to be operated and analyzed is being decided based on the partial discharges frequencies emitted. In this work, the chosen frequency is between 300MHz until 3GHz. The height of the dielectric substrate is designed as minimum as possible in order to reduce the weight of whole antenna which is 1.6 mm.

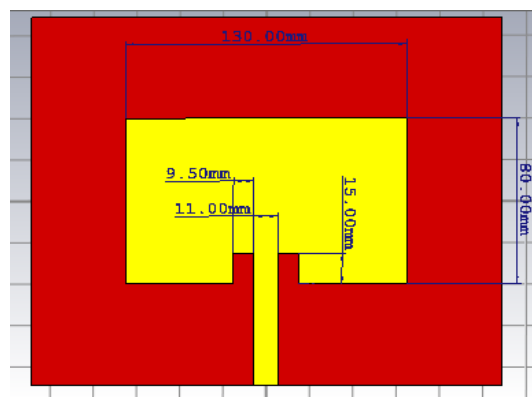


Figure 1. Geometry of proposed antenna

Table 1. Dimensions parameters

Paramater	Dimension (mm)
Antenna	
Width, $L$	130
Width of feedline, $W_f$	11
Length of inset point, $d$	15
Gap of feedline, $G_{pf}$	9.5
Substrate	
Thickness, $t_s$	1.6
Width, $W_g$	217.6
Length, $L_g$	177.6

It is worth to mention that the increase of length will reduce the resonance frequency provided it is matched with input source impedance. So, when change length of patch (increase or decrease) the port of antenna must be redesign to keep on match. The variation in inset width changes the resonant frequency and needs to be adjusted simultaneously for achieved the antenna specification to optimize the performance. Hence, aforementioned parameters in Table 1 are used in these simulations

## 3. Antenna Simulations and Results

The performance of the antenna was simulated based on the results generated by the aforementioned software. As depicted by the simulated result in Figure 2, the antenna operates at 898 MHz with return

loss obtained is  $-41.45$  t this. Hence, this suggests that the design antenna shows a good performance and can be used to detect corona discharge. The bandwidth obtained from the simulation is 57.36 MHz.

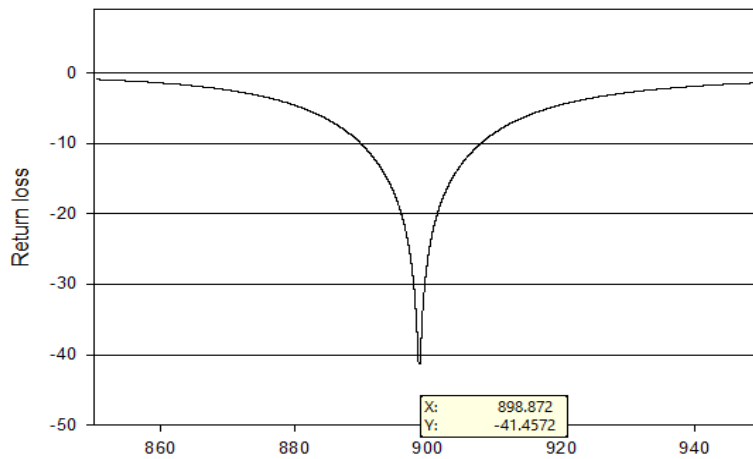


Figure 2. Simulated Return loss

Figure 3 shows the radiation pattern of the selected antenna. The red region is the z-axis of the antenna which represents the face of the patch antenna that received the most radiated frequency. This dependency of directional with patch area concurs with theory in (7-8). The radiation generates from the fringing electronic fields between the patch and the ground plane when the length of the patch is about half a wavelength long. The fringing electronic field is an effect of the electrons congregated at the surface of the conductor and the radiated power mostly is distributed from the edge of the patch [9].

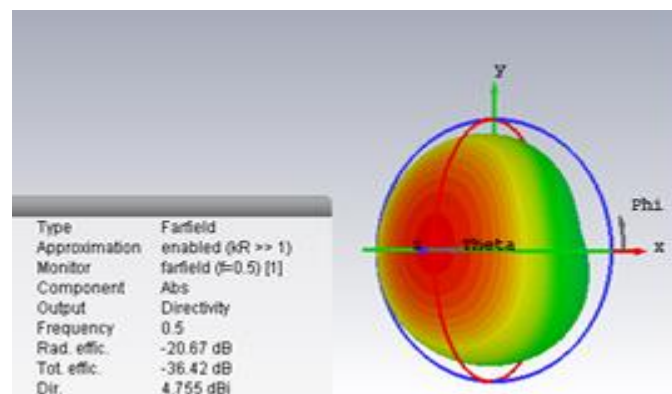


Figure 3. Gain pattern of the proposed antenna

Figure 4 below shows geometry of the bendable antenna. The flexibility of the substrate will decide the limits of the antenna's flexibility. Therefore, before proceeding to the pd application, the simulation on the performance of the antenna while been bending will be analyzed. Generally, the flexible antennas will suffer some type of distortion in their dimensions due to the conformability with any curved surfaces. Some researchers have noted that this scenario can alter the performance of an antenna [10-13]. Figure4 illustrates the bending directions along H-planes. The antenna was subjected to bending at angles  $40^\circ$ . When the antenna is bent, the radius of the cylinder is changed according to equation (1) [14]:

$$S = r \theta \quad (1)$$

Where, S is the arc length, r is the cylinder radius and  $\theta$  is the bending angle measured in radians.



discharge is reported for the first time. The shifts in the resonant frequencies and radiation patterns when bending the antenna are mainly caused by the discontinuity in the antenna geometry. While bending, parts of the patch antenna are being stretched that it leads to a distortion of electric field between the patch antenna and the ground plane. From this investigation, it can be summarized that care must be taken when designing antenna especially in bent configurations. Bending along the radiating edges will definitely result in performance degradation in terms of reflection coefficient. Moreover, it is also important that the antenna is operating with satisfactory reflection coefficient prior to comparison for other parameters, e.g., gain, efficiencies and radiation characteristics. The proposed antenna is currently in progress to build a prototype and will be reported in future.

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