Modification of arms patch of double layer printed antenna for partial discharge detection

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Abstract. Partial discharge is a local electrification phenomenon that partially connects the insulation between the conductors and occurs either on the surface of the conductor or inside the conductor (void). PD generates several phenomena that accompany the occurrence of PD, such as impulse currents, hot light radiation, electromagnetic waves, mechanical waves, and chemical processes. This phenomenon is captured to know the existence of PD. One of the PD measurements uses the UHF method, i.e., by measuring the waves generated by the partial discharge. The antenna is one form of antenna developed from a square microstrip antenna with symmetrical T-shaped tethering. Antenna parameters can result in changes in return loss and VSWR measurements. The parameter change is done on three parameters, i.e. (A, B and G) showing the difference to the reference antenna. The experimental results show a change in antenna bandwidth.

1. Introduction
Partial Discharge is an event of electrical spark release occurring in part of the insulation system as a result of a high potential difference in the insulation. Partial discharge measurements can be detected by the various method. The antenna can detect partial discharges through waves emitted by an insulating material that undergoes partial discharge. Partial discharge wave frequency is in the range 300MHz-3GHz. So far various types of antennas and sensors have been developed to detect PD [1-11]. It is needed to design an antenna with better performance. In this research, it will be designed the antenna with the wider bandwidth for partial discharge measurement.

The research method used a reference from the antenna form that had been made with the appropriate characteristics for the partial discharge measurement. The antenna reference is simulated in the software to see parameter results such as Return loss and VSWR. Dimensions on the shape of the antenna are simulated with three different sizes so that it can compare the three simulation results. From all comparison of the result of simulation got optimum dimension from the antenna. The optimum dimension is used as the result of the experiment of all dimensional changes that have been done because the optimum design of the antenna parameter is the best result of the experiment has been done.
2. Numerical Design

2.1. Design of Antenna

In this study, the antenna design according to the reference became a proposal for simulation experiments [12]. Based on reasons for simplicity and possible further development, a T-shaped monopole antenna with a resistive load is selected as the initial design of the proposed antenna. Some physical parameter investigations such as additional sudden transitions to the arm, circular patch placement, and ground plane modifications are implemented into existing designs to achieve an optimal design.

Proposed antenna parameters such as arm length (A), transition angle (B), resistive load length (G), investigated through parametric studies with reflection coefficient (S11) are used for performance indicators for each parameter.

![Figure 1. Front view of the reference antenna design and its dimensions.](image1)

![Figure 2. Rear view of the reference antenna design and its dimensions](image2)

Table 1. Reference dimensions of proposed antenna.

| Variabel   | Dimensi |
|------------|---------|
| A          | 50 mm   |
| B          | 150 deg |
| C          | 2 mm    |
| D          | 1 mm    |
| E          | 0.5 mm  |
| F          | 3 mm    |
| G          | 6.5 mm  |
| H          | 60 mm   |
| I          | 15 mm   |
| J          | 6 mm    |
| r          | 22 mm   |
| Resistive loading | 82 ohm |

The shape of the reference antenna has a wideband yield of 50MHz-2.30GHz which is capable of being implemented to detect the PD signal. The frequency of the PD signal is in the 300MHz-3GHz range. This indicates that the antenna range is still suitable for use on PD measurements because the PD frequency range is in the antenna frequency range. Here are the results of the measurement of Return Loss and VSWR reference antenna that can show the performance of an antenna.
2.2. Simulation of Reference Antennas
The reference design of the antenna is simulated in the simulation software. Software used to test each form of an antenna made so that the working frequency range of the antenna is known. The results of the measurement of Return Loss and VSWR based on the simulation software are shown in Figure 3, where the design refers to the reference antenna.

![Figure 3. Return loss Results of Antenna](image1)

![Figure 4. VSWR Results of Antenna](image2)

Figure 3 and Figure 4 show the simulation results using CST software. Results obtained working frequency range (VSWR <2 and Returnloss <-10dB) antenna 50MHz-2.30GHz. The frequency results, the antenna can detect the PD signal, because the PD signal frequency range is still present in the antenna frequency range.

3. Numerical Results and Analysis
3.1. Arms Patch Simulation Results
The Arm dimension has parameters A, B, and G. The parameters investigated are the length and width of the arms (A, B and G). The experiment begins with setting A in a constant value of 50mm, then conducts a parameter study to obtain the optimum value A. With Optimum A, parameter studies are performed again to obtain the optimum values of B and G. Figures 5 and 6 show the effects of various parameters A, B and G to the reflection coefficient and figures 7 and 8 show the effect of various parameters A, B, and G to VSWR.

![Figure 5. Results of reflection coefficient on parameters of AB](image3)
Figure 6. Results of reflection coefficient on parameters of G.

Figure 7. VSWR results for changes in AB parameters.

Based on the result of measurement of parameter change AB seen in the graph of the reflection coefficient in the figure. Size changes above or below the reference value (50) change the results of the reflection coefficient very significantly. Can be seen on the picture at 45mm and 55mm have almost the same frequency at the return loss below -10dB. The same thing happens to VSWR when the value changes to 45mm and 55mm which almost has a graph that is not much different from the reference.

Table 2. Measurement Results Dimension AB

| No | Dimension | Bandwidth     | Return Loss  | VSWR      |
|----|-----------|---------------|--------------|-----------|
| 1  | 45 mm     | 50 MHz – 2.28 GHz | 50 Mhz – 2.28GHz | 50 MHz – 2.30 GHz |
Table 3. Dimensional Measurement Results G

| No | Dimension of G | Bandwidth          | Return Loss       | VSWR          |
|----|----------------|--------------------|-------------------|---------------|
| 1  | 1 mm           | 50 MHz – 2.34 GHz  | 50 Mhz – 2.34 GHz | 50 MHz – 2.36 GHz |
| 2  | 2 mm           | 50 MHz – 2.30 GHz  | 50 MHz – 2.30 GHz | 50 Mhz – 2.32 GHz |
| 3  | 3 mm           | 50 Mhz – 2.27 GHz  | 50 Mhz – 2.27 GHz | 50 Mhz – 2.30 GHz |

From the measurement results, the optimal AB at 55mm with antenna bandwidth of 50MHz-2.39GHz while G is optimal at 1mm size with a bandwidth of 50MHz-2.34GHz. This indicates that the change of AB and G changes the bandwidth not too far to the value of the reflection coefficient and the VSWR antenna.

3.2. Analysis of Simulation Results

Based on the simulation results obtained the results of any changes in both parameters A, B da G. When the value of AB is 50mm which is a reference value shows a reflection coefficient graph that reaches the range 50MHz-2.30GHz. When the parameter value AB is changed, there is a change in the antenna reflection coefficient value below -10dB, although the change is still very small. The best reflection coefficient range between the three experimental parameter values was at the 55 mm AB parameter. The graphic changes are quite significant when there is a change in the frequency hole of 0.5GHz-2GHz. In this frequency range, the graph shows the higher the width of the AB value can result in the reflection coefficient graph closer to -10dB. But for the bandwidth of the antenna at the largest parameter value of 55mm, the graph shows the improvement of the antenna bandwidth range. The same thing happened to the VSWR antenna, at the bandwidth of 50MHz-2.3 GHz there is a fairly significant frequency range that is in the range of 0.5GHz-2GHz. At this frequency range, the change in the parameter value of AB may result in VSWR approaching or even exceeding the value of VSWR <2.

The G value parameter indicates the change of the resistive load length on the antenna. The experimental change of G parameter values resulted in changes in the reflection coefficient graph and VSWR antenna. Bandwidth results will show a small change; bandwidth antenna is 50MHz-3.34GHz which is the best result among 3 G values at the time of change. However, a significant change in G value changes impacts the 1GHz-2GHz frequency range. In that frequency range, the reflection coefficient, and VSWR charts if the value of G is made even greater in value, it is likely that the reflection coefficient and VSWR graphs in the range exceed the existing standard or even that frequency is not included in the antenna bandwidth range if the value is not fit or made larger.

The optimum parameter value of AB is 55mm with bandwidth antenna 50MHz-2.30GHz while the optimum G parameter is 1mm with 50MHz-2.34GHz antenna bandwidth.

4. Conclusion

The numerical design of the proposed antenna for PD detection has been proven through the investigation of its physical parameters. The antenna that has a compact size of 72.8 mm x 60.0 mm has been implemented on an FR-4 Epoxy substrate with a permittivity of 4.3 and a thickness of 1.6 mm. It is shown that every part of the antenna is proposed. Proposed antenna parameters such as arm...
length (A), transition angle (B), resistive load length (G), have their respective roles in building overall antenna performance. The parameter change only increases the frequency range not too large. From the results of the investigation, it has been shown that the antenna has a large working bandwidth of 50MHz-2.34GHz for a VSWR value of less than 2.

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