

# Modelling PD in Cavities and PD-based Degradation Mechanisms

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## Introduction

- Micro cavities are currently considered unavoidable during polymeric insulation manufacturing.
- Ageing and degradation affects caused by them are generally considered to follow the root which starts from partial discharge (PD), to pitting and electrical treeing, and finally leads to the breakdown of the insulation bulk.
- In fact, bow-tie electrical treeing from cavities has not yet been observed experimentally. Instead, other failure modes such as thermal runaway are usually seen.
- This work considers the ageing and degradation process of polymeric insulations induced by partial discharge, to experimentally study the PD behaviours related to ageing and degradation, the degradation process, the final breakdown mechanisms, and the relationship between them.
- Multiple identical samples are simultaneously stressed in this work, ideally, other samples should carry different level of degradation sites when one fails. PD behaviour data are periodically collected along the way.
- Samples involved in this work are epoxy resin disks with single spherical cavity, LDPE disks with single cylindrical cavity, LDPE disks with multiple spherical cavities created by foaming agents.

## Sample Preparation and Setup

The epoxy resin samples prepared are from D.E.R. 332 resin from Sigma Aldrich, and Jeffamine D-230 hardener from Huntsman. The resin-hardener mixture proportion is 1000:334 by weight.

Resin-hardener mixture should be mixed, injected into the moulds, and degassed on a constant temperature of 50° C. It should then go into the curing process at 100 ° C.

During the curing process, a void can be injected using a precise syringe within a small window in terms of timing when the mixture is with a proper viscosity to take the needle in and to keep the void injected.

A post curing process at 100 ° C will complete the sample preparation process.

The epoxy samples are disks with 41.5mm diameter, 2.5mm thickness, and with an 1mm diameter cavity in the middle.

Test samples are held in between a 15mm diameter ground mushroom electrode, and a 130mm diameter high voltage electrode. Figure 1 shows the setup of the test rig.

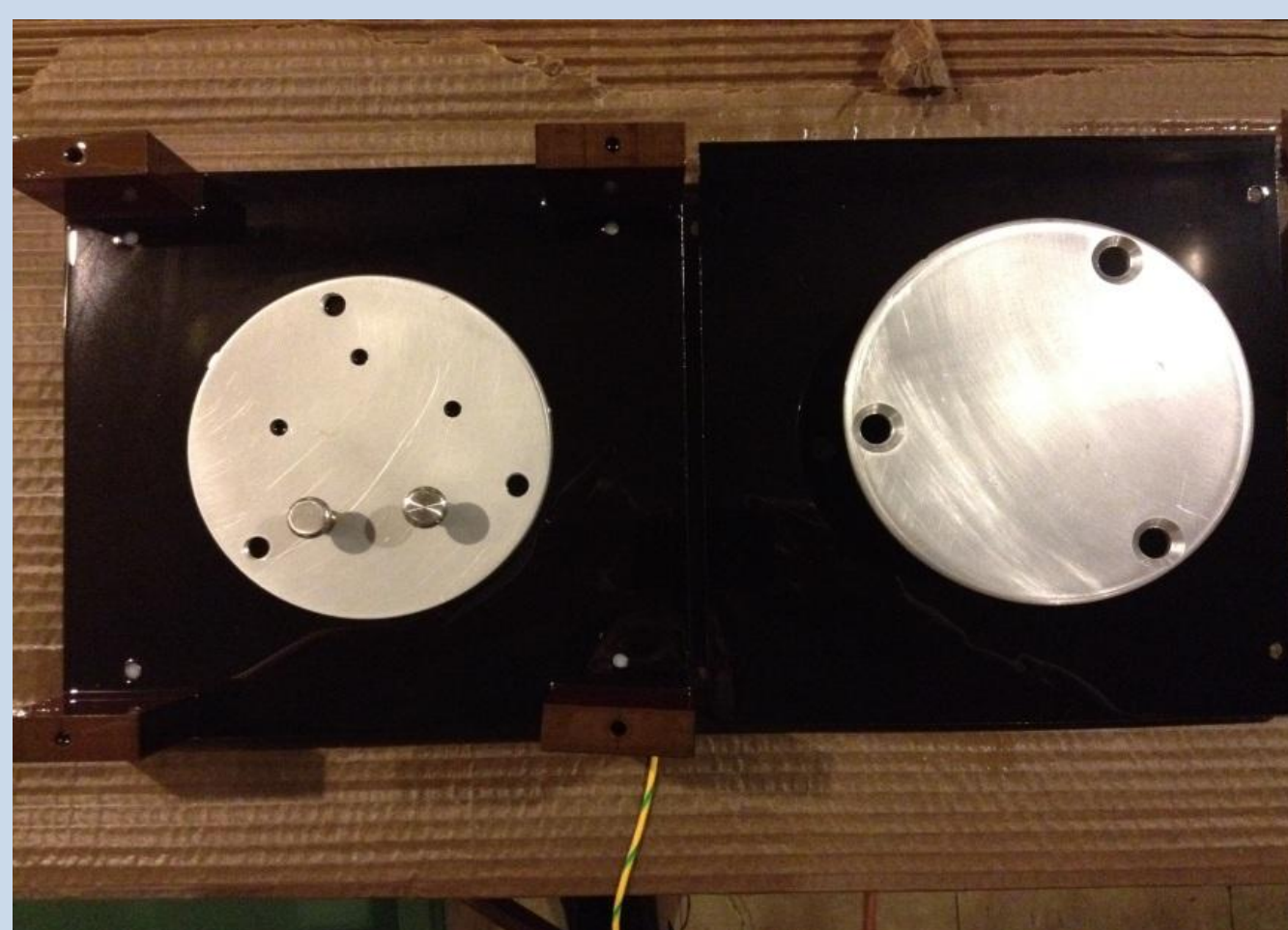


Figure 1 – HV, mushroom, and ground electrodes with test rig.

## Experimental Setup

The PD measuring unit used is PDBasell manufactured by TechImp Spa, Italy. PDBasell is a fully digital system, specifically designed for laboratory PD measurements.

Figure 2 shows the full setup of the experiment. It is constructed with a high voltage supply, a high voltage filter, a coupling capacitor, the test specimen, and PD measuring unit with a coupling device. High voltage connections are constructed with copper tubes, and ground connections are constructed with copper wires. PD measuring units feed measure signals into a personal computer through fiber optic cables.

The voltage source is from 0kV to 20kV, voltage ramp speed control is also provided. The coupling capacitor is 1nF.

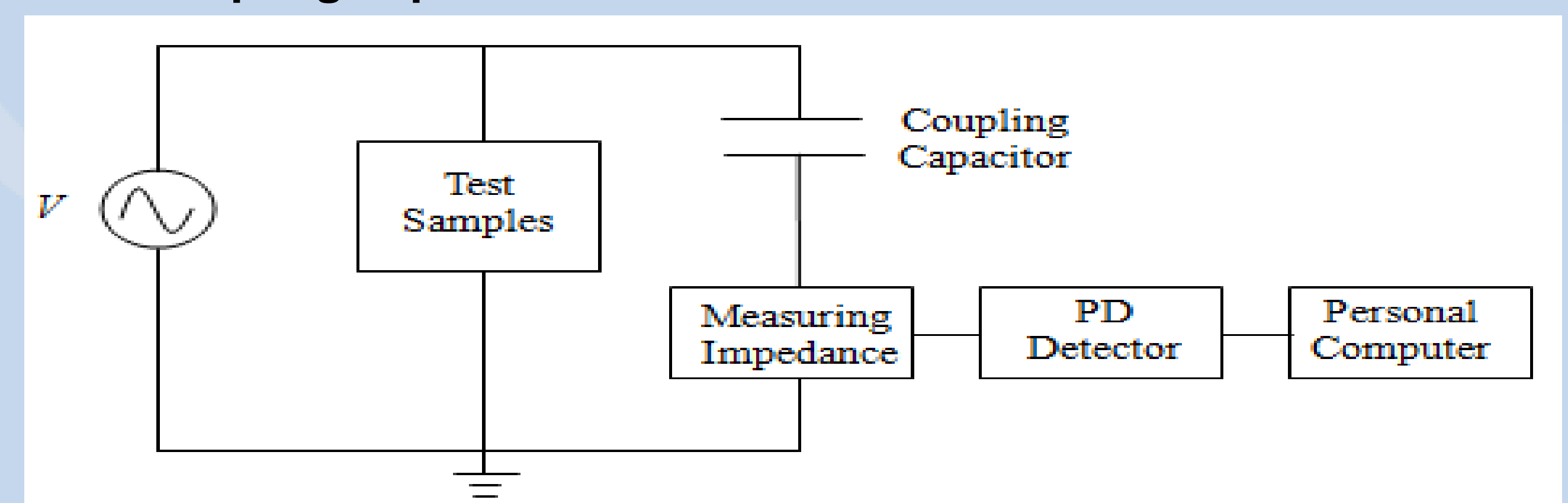


Figure 2 – Full setup of multiple samples stressing experiment.

## Results and Discussion

### Interference Study and Distinguishing PD Signals from Multiple Samples

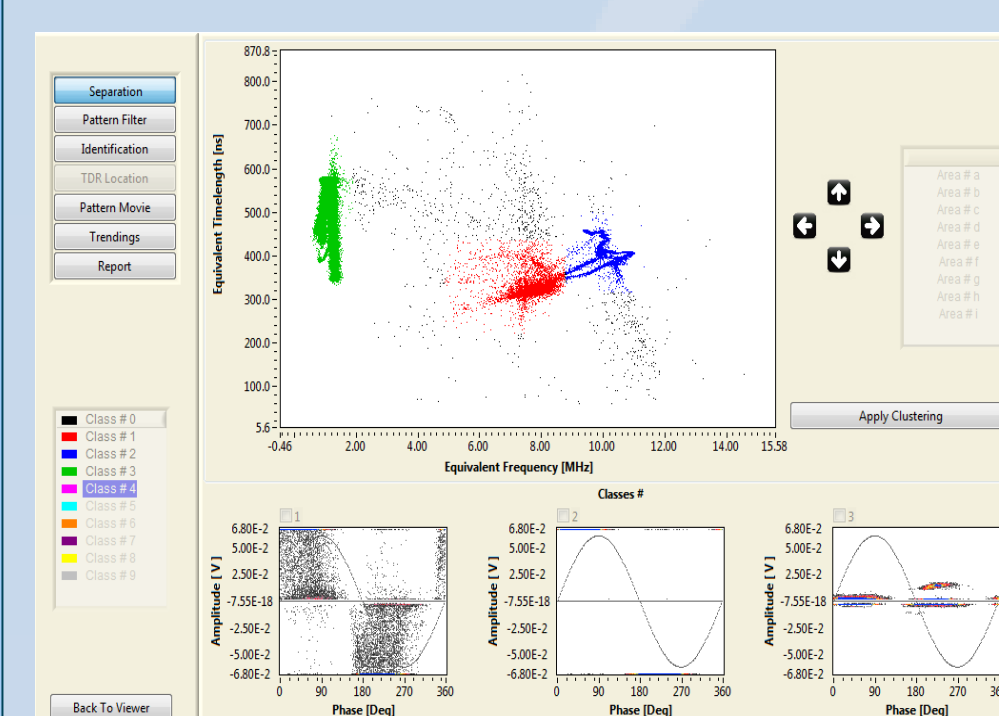


Figure 3 – pC Level Superposition PD Signal from Two Samples

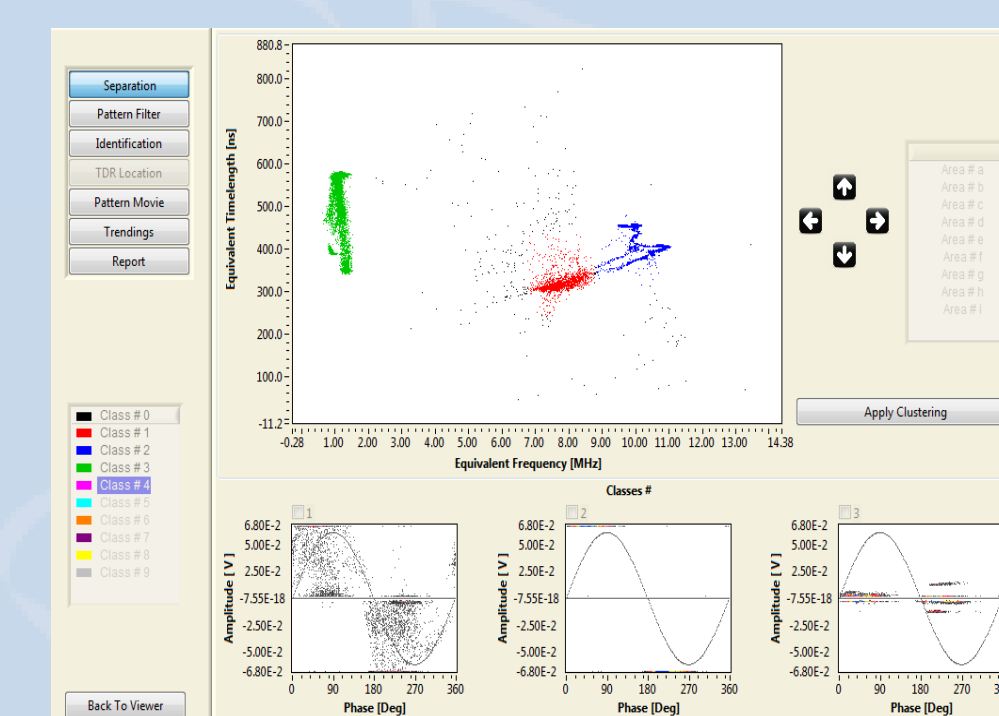


Figure 4 – pC Level PD Signal from Sample A

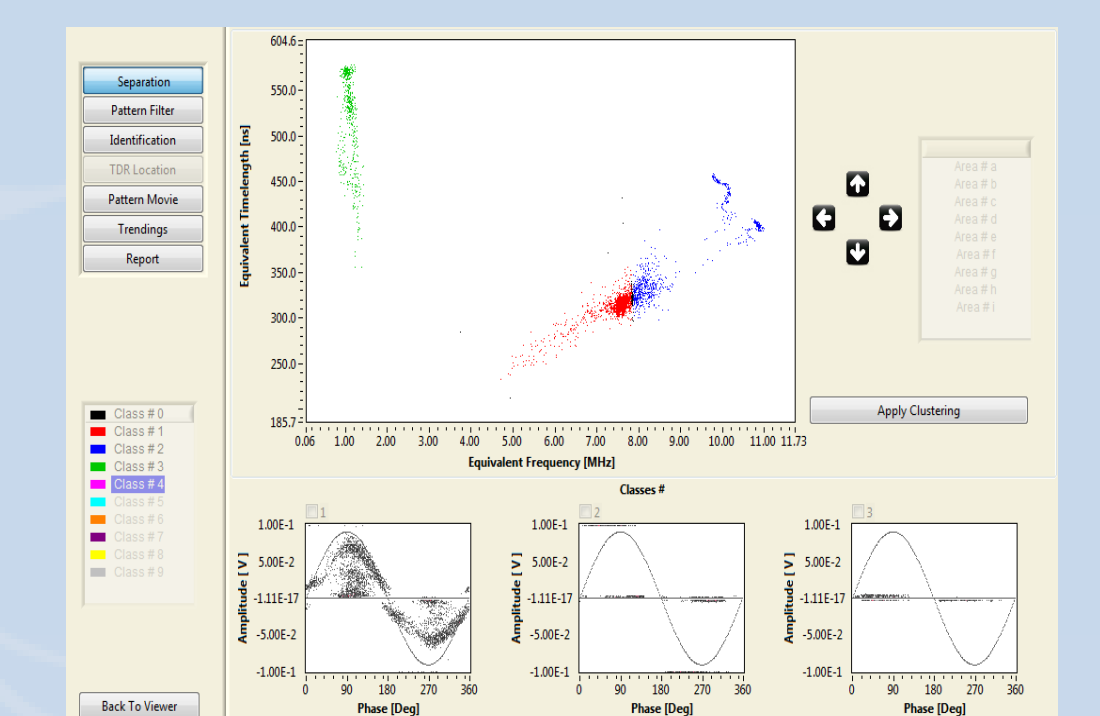


Figure 5 – pC Level PD Signal from Sample B

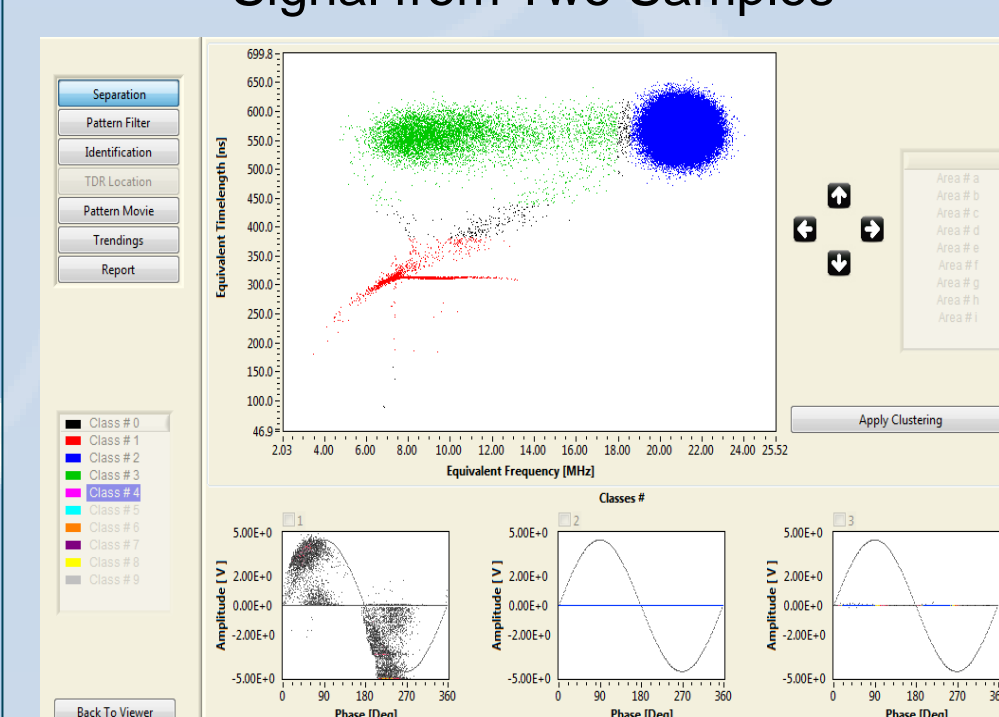


Figure 6 – nC Level Superposition PD Signal from Two Samples

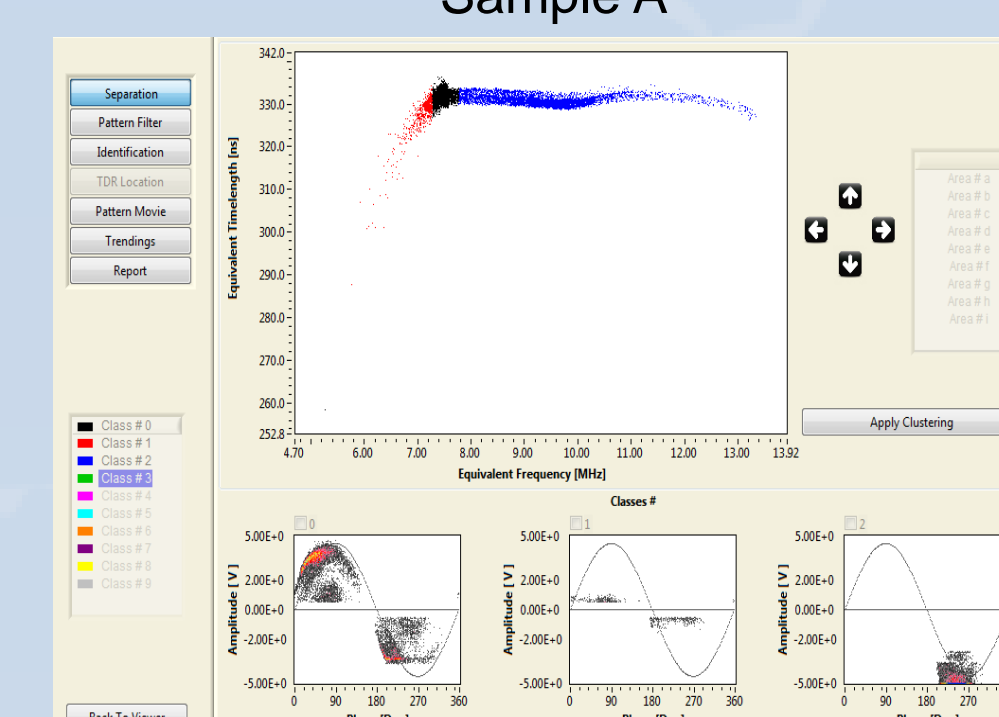


Figure 7 – nC Level PD Signal from Sample A (1)

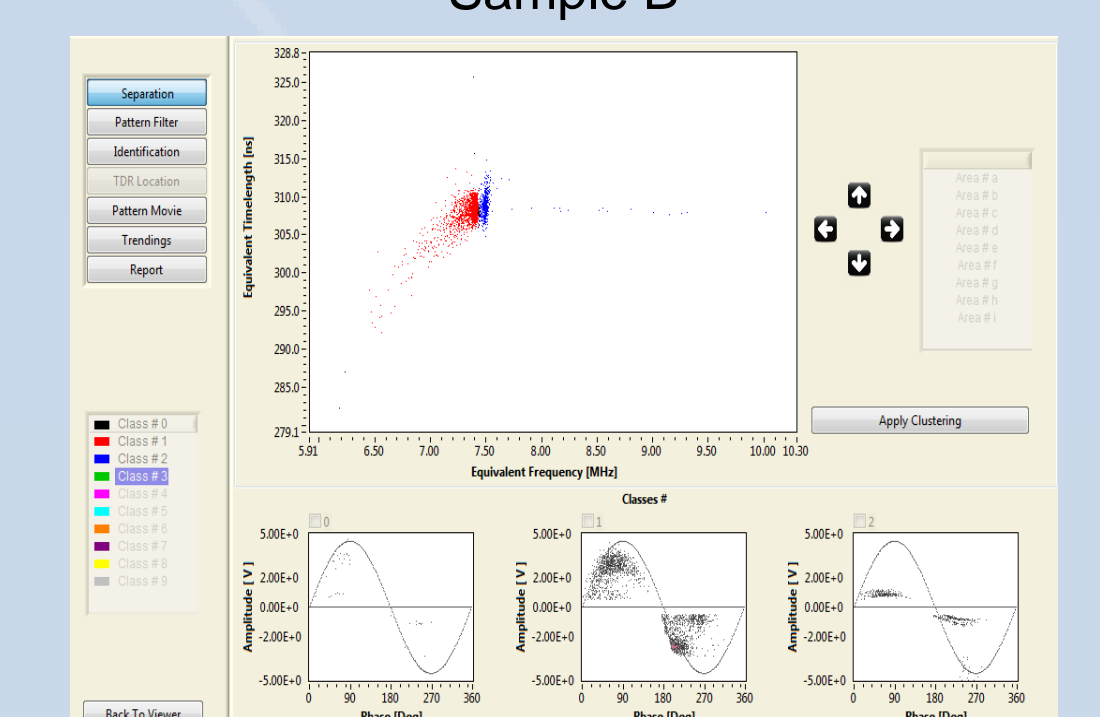


Figure 8 – nC Level PD Signal from Sample A (2)

### Multiple Sample Degradation Tests

- Reproduction of combined PD signals using individual samples proves that the samples are interference free from each other.
- Multiple sample simultaneous degradation can significantly improve the efficiency of the experiments, and ensure the experimental conditions are held constant.
- Data processing techniques are to be tested aiming to distinguish individual sample behaviours among all of them in a test.
- Alternatively, separating individual PD signals instead of using a common earth point can make sure that the data collected are useful and accurate.
- Long term continuous stressing with periodical data collection are undergoing to provide both PD behaviour data and damaged samples induced, to understand the relationship between the two.

## Conclusions and future work

- Void PD behaviour along side with PD induced degradation is the objective of this work. The final product will be a model combining the two.
- Multiple sample simultaneous test is proved to be dependable, it also brings the possibility to recognize single void PD from the other sources.
- Epoxy resin disk with syringe injected single spherical void, LDPE sandwich with single cylindrical cavity, and LDPE disk with multiple spherical cavities created by foaming agent will be put to test.
- A simulation model should be produced to include the knowledge of PD from cavities and degradation caused. The current idea is to implement the results from Sanche's study on hot electrons, Montanari's study on electron avalanches, combined with COMSOL for more accurate electric field simulation.