ATLAS
LARG Note - 46
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Spark Discharge in Normal and High Resistive Coated Electrodes

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August 1996

1 Introduction

In the baseline design of the ATLAS hadronic endcap (HEC) LAr calorimeter GaAs preamplifiers (PA), operated in the LAr, are foreseen. With the rather small sampling ratio in the HEC calorimeter, the minimization of the white and coherent noise contribution is of great importance. One of the key questions is the protection of the PA in case of a HV discharge of a gap due to a spark. As already shown in [1] the EST electrode structure limits the charge to the bare charge generating the gap voltage. Electrodes with high resistive coating (HRC) offer a further limitation of the current/voltage at the PA input level.
We have studied in a specific test the difference of the response to a HV spark in a standard gap using a normal electrode structure or an HRC electrode structure.

2 Test Setup

The Fig. 1 shows the test setup: a typical single gap structure of the hadronic endcap calorimeter has been realized using two Cu electrodes of the typical HEC pad size ($C_d = 130\ pF$). The gap can be operated in different gas atmospheres, with most of the tests being done in an air atmosphere. When simulating the normal electrode structure,and only then, we have added an additional HV blocking capacitor C_B of 1 nF. Because we did not simulate the EST structure, the actual charge dumped into the PA input is substantially larger than in the EST option [1]. But the critical element in the PA input is the coupling capacitor: a high voltage pulse destroys this capacitor even at a very low total charge. To simulate the HRC electrode structure, one Cu plate has been modified: an HRC kapton layer [2], as used in the prototype HEC module with a typical resistivity of $\sim 500\ k\Omega/\sqcap$, has been glued to the Cu plate and the blocking capacitor C_B has been removed. An additional pin with a sharp edge was mounted on the opposite Cu plate. The distance from the pin head to the opposite plate could be varied from the nominal gap width (1.8 mm) up to 0. Thus a HV spark could be induced for any given HV setting. The nominal HV applied was 2 kV, the input HV resistor has been varied from 500 $k\Omega$ to 10 $M\Omega$.
The RD33 GaAs chip [3] has been used for the tests. The PA was connected via a 50Ω impedance transmission line. The nominal impedance of the PA is 20 Ω, thus an additional resistor of 30 Ω has been added in series in order to raise the input impedance to 50 Ω.
To test the PA performance, a pulse generator with the proper RC network has been used for the calibration, simulating the triangular current pulse as expected from the current flow in the 1.8 mm wide gap. The pulse shape at the input of the PA has been monitored on the oscilloscope via a passive HV probe.

3 Results

3.1 Normal Electrode Structure

The Fig. 2 and Fig. 3 (time scale 400 ns and 20 ns) show the response of a gap discharge due to a spark at the PA input. With the HV operating value of 2 kV, the input signal has an amplitude of about 2 kV. In consequence, the input capacitor of the PA and the input transistor have been destroyed.

3.2 HRC Electrode Structure

The Fig. 4 and Fig. 5 (time scale 400 ns and 20 ns) show the corresponding response of a spark at the PA input in case of an HRC electrode structure: the typical amplitude is of the order of 2 V. Clearly this amplitude depends on the characteristics of the spark: a discharge over a larger surface will cause a somewhat larger amplitude. But in reality the situation is close to the setup used in this test.

We have varied the spark position across the given pad area, without any significant change in the amplitude. Given our setup, the position closest to the HV input line that could be reached, was $\sim 2-3\ cm$. We have operated the gap also in a "permanent sparking mode". The main effect was a small reduction of the amplitude of the PA input signal.

In all these operations the PA was operated under normal power. No damage has been observed. The Fig. 6 (time scale $2\mu s$) shows the calibration pulse at the PA input before the spark tests. The upper Figure shows the rectangular pulse at the pulse generator output, the lower Figure shows the triangular calibration pulse after the shaping network.

The Fig. 7 (time scale 20 ns) demonstrates the proper operation of the PA before the spark tests: the upper Figure shows the calibration pulse at the pulse generator output, the lower Figure shows the response at the PA output, in both cases before the spark tests. The Fig. 8 shows the direct response of a gap discharge due to a spark, observed at the PA input (upper Figure) and at the PA output (lower Figure). The time scale is 100 ns per unit. The Fig. 9 shows the calibration pulse at the pulse generator output (upper Figure) and at the PA output (lower Figure) after the spark tests. The time scale is 20 ns per unit. The PA response is as expected and shows no difference relative to the response prior to the spark tests.

4 Conclusion

The HRC electrode structure has been compared to a normal electrode structure with respect to gap discharges via sparks. In contrast to the normal electrode, the HRC electrode provides an essential HV protection of the cold GaAs PA, limiting any input voltage to a level of $\sim 2\ V$ for a gap voltage of 2 kV.

References

[1] P.M. Mockett, Spark Discharge in an EST Electrode Structure, ATLAS CAL-NO-33, January 1996.

[2] M. Blagov, A. Komar, A. Snesarev, M. Speransky, V. Sulin, M. Yakimenko, Production and Testing of Registrating Electrodes for Liquid Argon Hadronic End-Cap Calorimeter of ATLAS Detector, Contribution to the VI International Conference on Calorimetry in High Energy Physics, Frascati, June 1996.

[3] W. Braunschweig et al., Performance of the TGT Liquid Argon Calorimeter and Trigger System, MPI-PhE/96-05, March 1996 and submitted to *Nucl.Instr.&Meth.*.

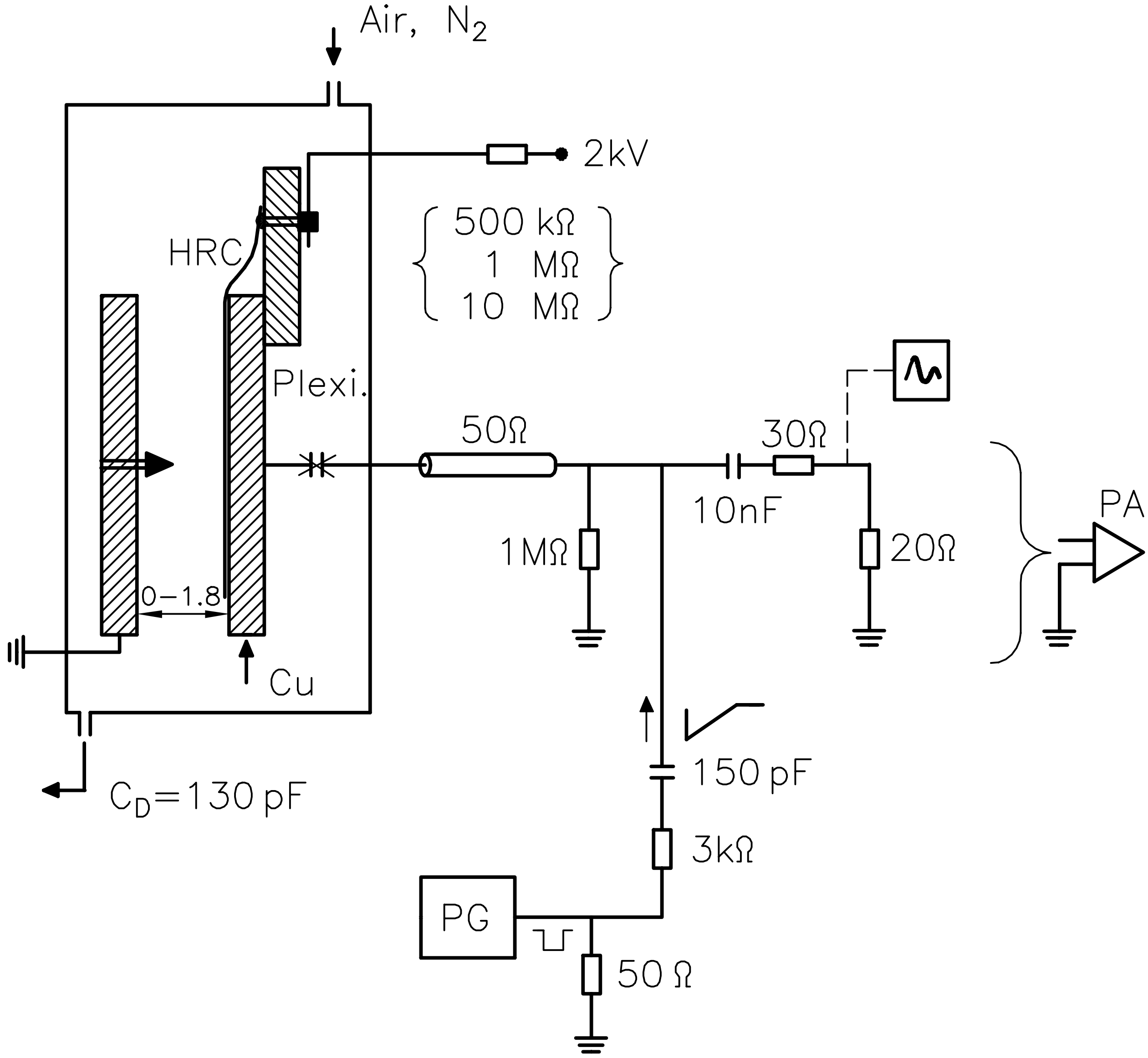

Figure 1: Test setup for the study of a HV discharge of a gap due to a spark.

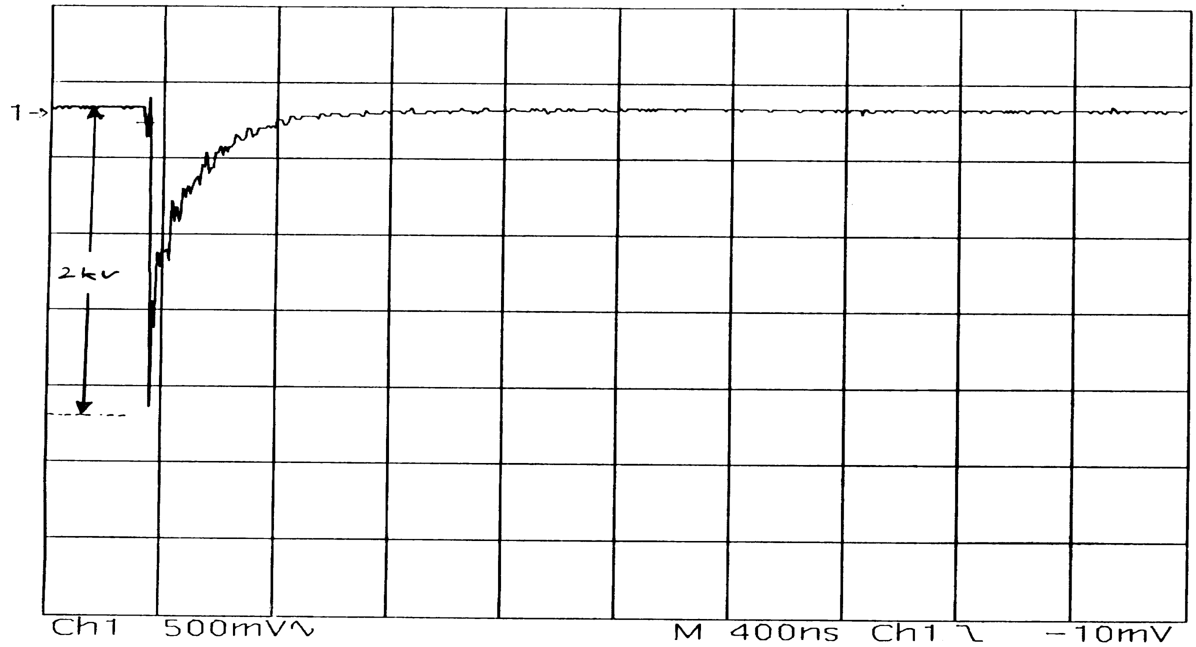

Figure 2: Response of a gap discharge due to a spark in case of a normal electrode structure. The PA input signal has an amplitude of 2 kV. The time scale is 400 ns per unit.

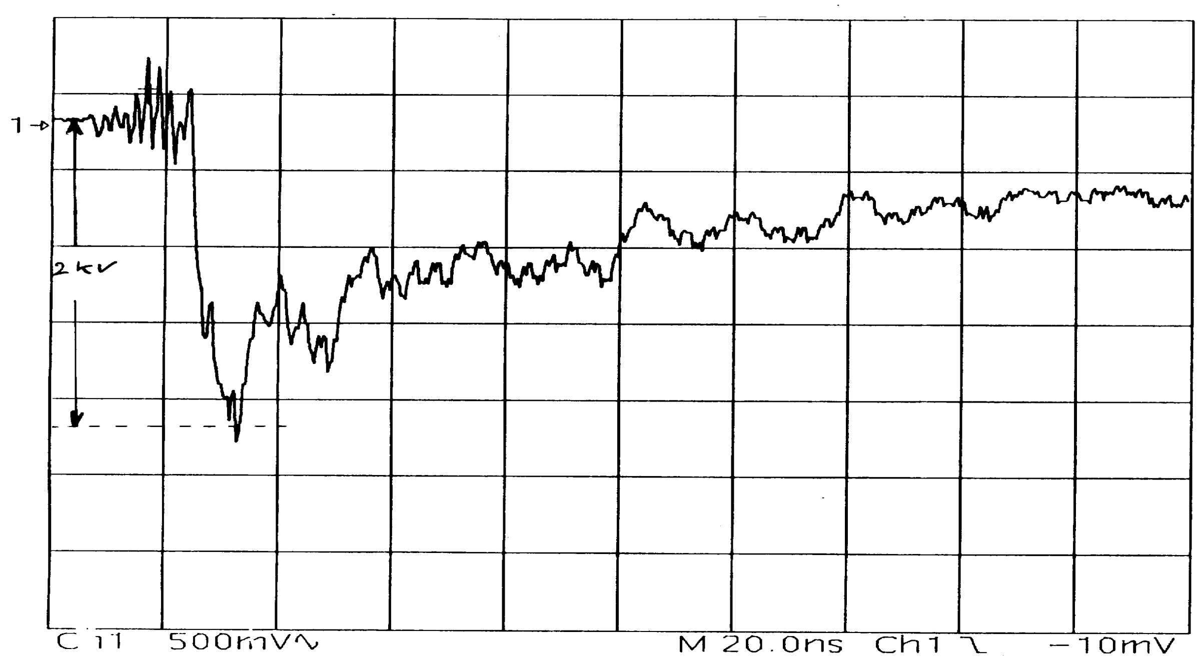

Figure 3: Response of a gap discharge due to a spark in case of a normal electrode structure. The PA input signal has an amplitude of 2 kV. The time scale is 20 ns per unit.

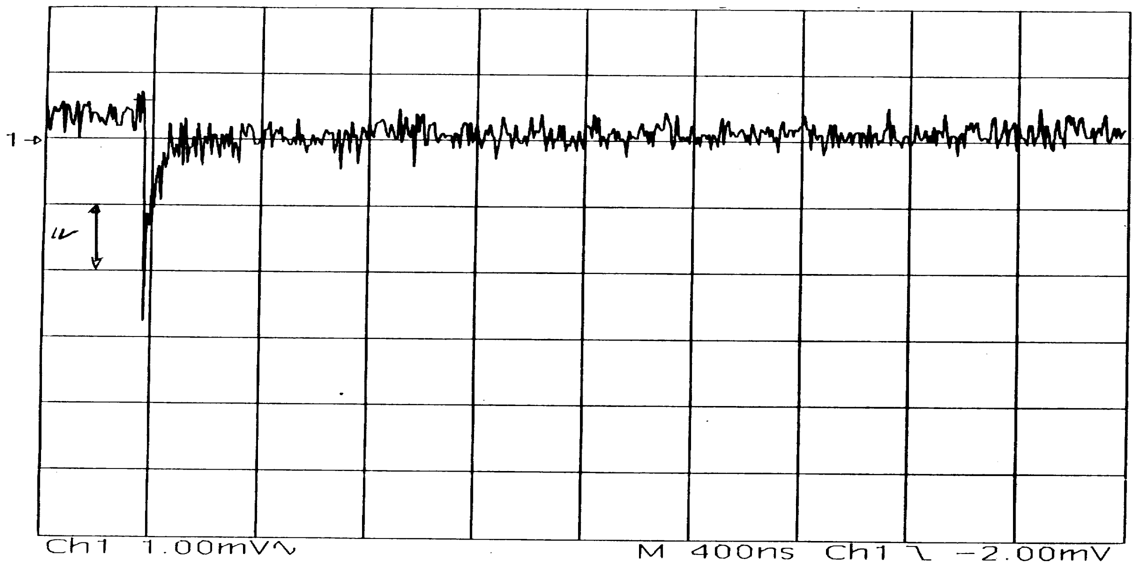

Figure 4: Response of a gap discharge due to a spark in case of an HRC electrode structure. The PA input signal has an amplitude of the order of 2 V. The time scale is 400 ns per unit.

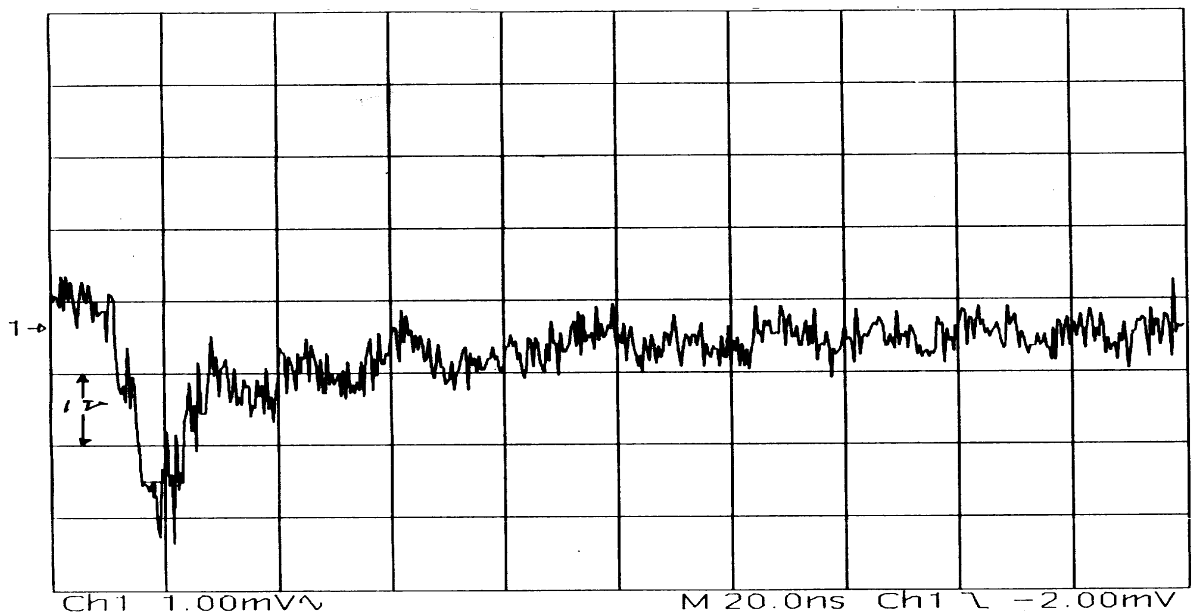

Figure 5: Response of a gap discharge due to a spark in case of an HRC electrode structure. The PA input signal has an amplitude of the order of 2 V. The time scale is 20 ns per unit.

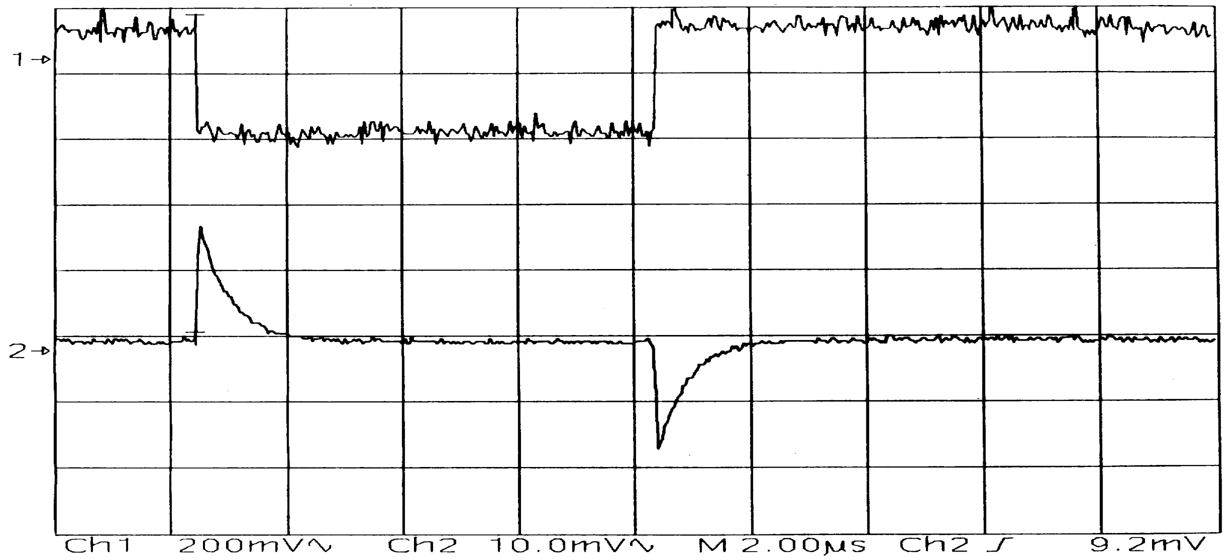

Figure 6: The calibration pulse at the PA input before the spark tests (time scale $2\mu s$). The upper curve shows the rectangular pulse at the pulse generator output, the lower curve shows the triangular calibration pulse after the shaping network.

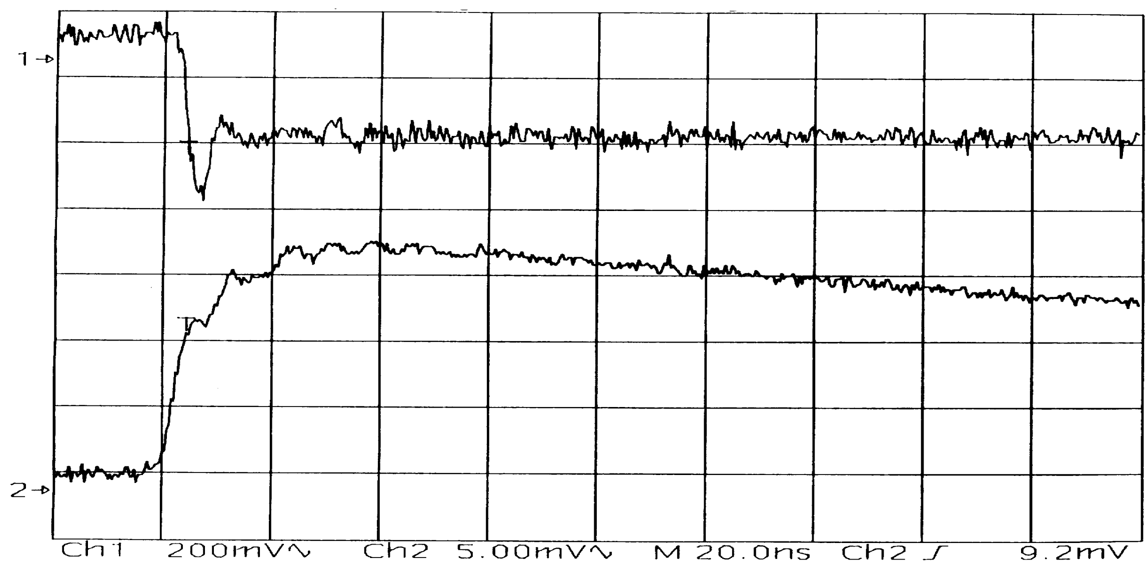

Figure 7: The calibration pulse at the pulse generator output (time scale 20 ns) and at the PA output before the spark tests.

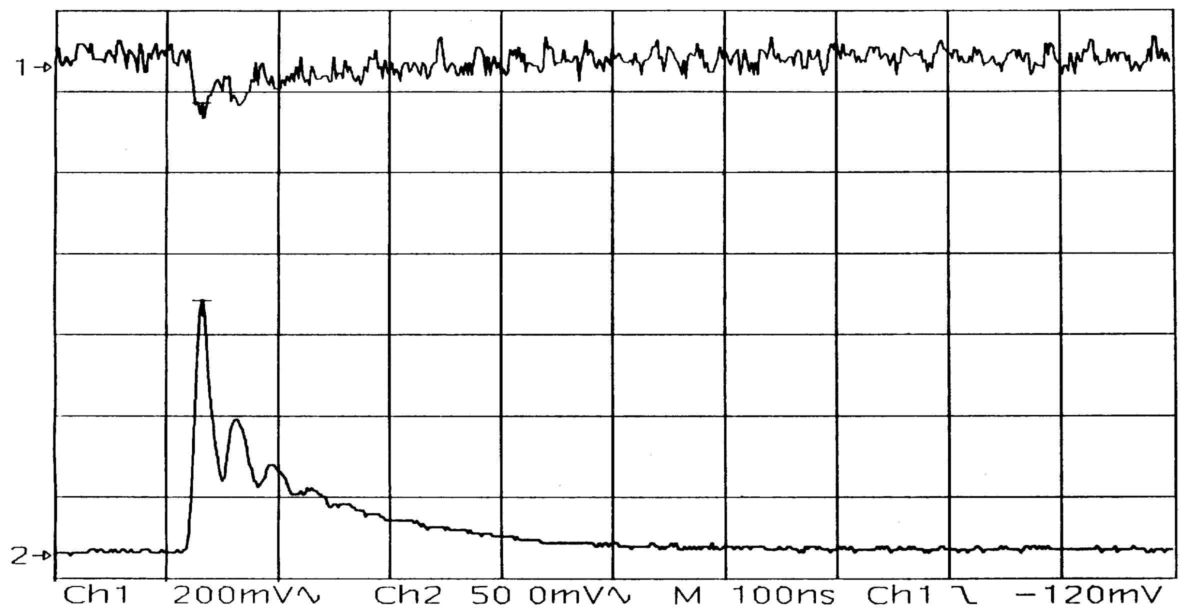

Figure 8: The direct response of a gap discharge due to a spark, observed at the PA input (upper curve) and at the PA output (lower curve). The time scale is 100 ns per unit.

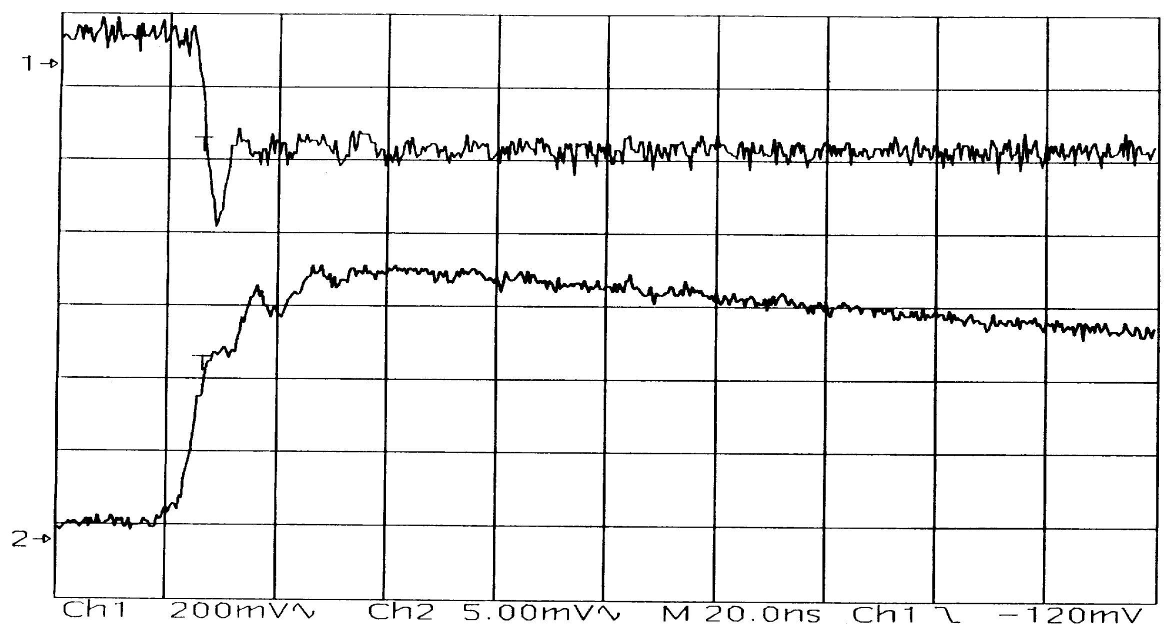

Figure 9: The calibration pulse at the pulse generator output (upper curve) and at the PA output (lower curve) after the spark tests. The time scale is 20 ns per unit.