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# REDUCTION OF ELECTROMAGNETIC INTERFERENCE FROM PULSED RADIATION SOURCES

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**Abstract**—Practical measures required to reduce the sources and effects of electromagnetic interference associated with the irradiation of samples with short, high current pulses of high-energy electrons are described. This note primarily describes experience with a pulse radiolysis installation using a Van de Graaff accelerator as the radiation source, but similar methods could be implemented with other experimental systems and radiation sources.

## 1. INTRODUCTION

The production of high-energy electron pulses is often accompanied by the generation of high levels of electromagnetic interference (EMI). In this note, a simple method of reducing the interference effects of the accelerated pulse charge is described. It is primarily the result of the practical experience gained in our laboratory to improve the performance of a pulse radiolysis installation, but the same technique could equally well be applied to other accelerators and experimental situations.

In this instance, pulses of electrons (1.5 ns–5 μs) at an energy of up to 4 MeV and peak currents of several amperes are produced by a vertical Van de Graaff accelerator (High Voltage Engineering Corporation), deflected through 90° and enter an irradiation room through a ~1 m long section of beam line, as shown in Fig. 1. In pulse radiolysis installations,[1] the radiation pulse is used to initiate a chemical change in (usually) liquids contained in a small irradiation cell. The time-course of this change is monitored by following changes in some physical property of the sample; most often changes in optical absorption are measured. In order to maximise the probing light intensity (and hence maximise the signal-to-noise ratio), a short optical path length is desirable. Historically, however, most installations have used a relatively long optical path length in order to place the detection electronics well away from the irradiation vessel and thus eliminate the effects of EMI produced by the moving pulse charge. For an efficient optical system, it is preferable to keep the detection system within the radiation area[2] and this approach most often requires the use of a Faraday cage within the radiation area, depending on bandwidth, signal and EMI levels. In our case, we required a short optical path length but nevertheless considered that a Faraday cage was a rather inflexible solution in view of future expansion of the equipment. Instead, we considered the whole irradiation room as a kind of Faraday cage which is penetrated by the beam line and associated charge beam.

## 2. METHOD

The radiation pulse emerging from the beam line can be considered from the electromagnetic point of view as being equivalent to a conductor excited by a short duration current pulse, and hence behaving as a non-resonant radiator. The radiation pulse is usually collimated before striking the cell and the charge deposited both in the collimator and the cell must eventually find its way back to the accelerator.

This discharge path is usually ill-defined and long; the resulting flow of charge through this is one of the avoidable causes of EMI which is radiated into the associated experimental electronics. The EMI radiation losses can be minimised using a short, low-inductance return path, preferably coaxial with the beam line. If the radiation cell is enclosed in a metal container which is connected through a short, low inductance path to the beam line, most of the pulse charge will return to the accelerator through the beam line and there will be negligible flow of charge from the cell through other paths, limited by the non-zero impedance of the beam line. This container or screen must of course be thick enough to stop and contain all the direct and scattered electron beam; in practice, the collimator forms one face of the screen (Fig. 2) which is connected to the beam line through a flexible wire mesh used to decouple mechanically the cell from vibrations of the beam line.

The remaining problem to be dealt with is the flow of charge (and hence source of EMI) along the beam line back to the accelerator base-plate (ground). Any impedance along the line is undesirable and it is important to bond the beam line sections so that a good path is formed; if the beam line is broken electrically by insulated sections for charge measure-

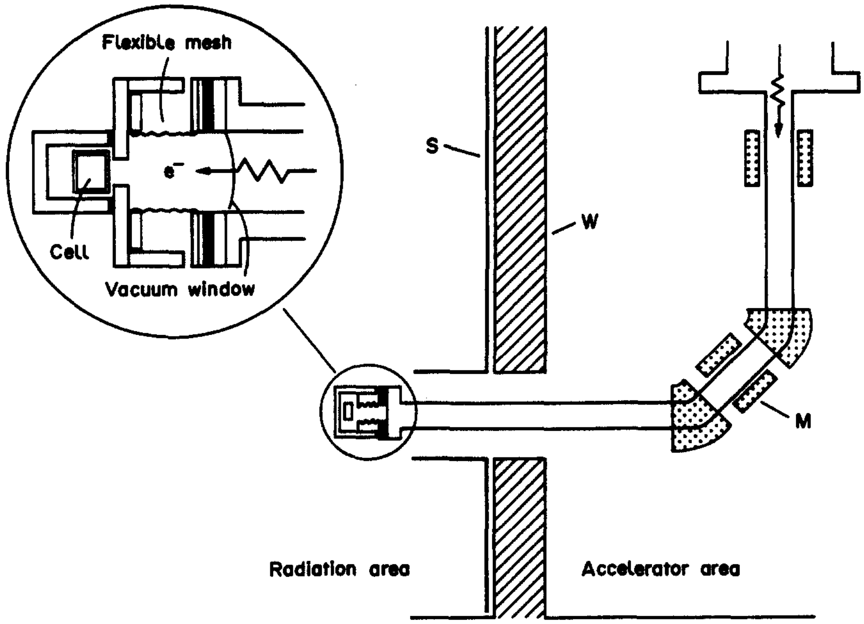


Fig. 1. Simplified layout of the accelerator and experimental areas. The target (cell) is enclosed by a thick container and electrically connected to the beam line (inset) so that the charge deposited therein is conducted away to machine ground. An additional screen (S) is useful in preventing currents flowing in the beam line from radiating EMI into the room.

ment, then these should be decoupled capacitively (several 5–10 nF ceramic capacitors have been found adequate).

We are fortunate in our laboratory that a thick (1.2 m) concrete wall separates the experimental area from the magnet and accelerator rooms. Any potential sources of interference from the latter areas are thus largely eliminated and only the section of beam line which enters the experimental area needs to be considered. This can be readily surrounded by a rather imperfect Faraday cage (Fig. 1) which is maintained at high-frequency ground by connecting it to a large metal sheet in contact with one of the walls (W) of the room. Although this beam line screen (S in Fig. 1) is far from ideal, it does provide adequate reduction of interference in the 5–100 MHz frequency range which is generally the most troublesome. The design of the screen allowed for the cell to be completely enveloped, but for most purposes limited shielding, as shown, of the beam line only proved adequate.

The practical effect of these rather simple measures is shown in Fig. 3. We did not have access to equipment to determine electric and magnetic field intensities accurately, but performed the measurements with a simple aperiodic aerial and loop. The interference levels can be readily reduced to the millivolt range (in a 50 Ω circuit) and in practical terms this implies that the vast majority of experimental electronic equipment only needs to be housed in "conventional" metallic enclosures rather than in any additional Faraday cages with consequent signal and power line feedthroughs. However, it should be pointed out that, when very short, intense pulses are used (< 5 ns), appropriate radiation shielding of the detector may have to be installed. The electron pulse results in an X-ray flash which can produce an EMI-like effect in the detector and its electronics; a similar effect may occur due to displacement of

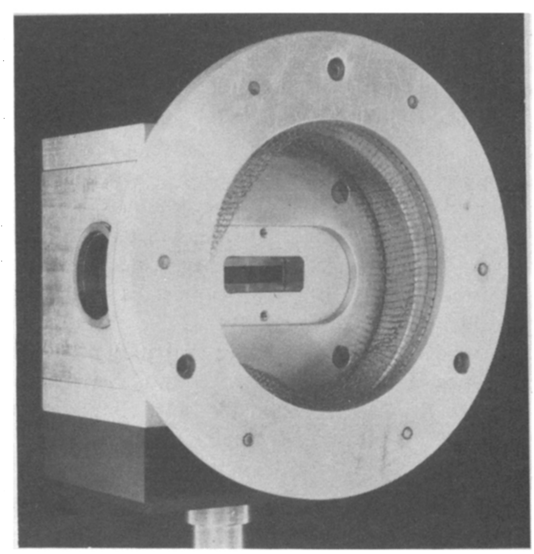

Fig. 2. The cell holder and associated collimator. The ring at the front is connected to the beam line and a flexible, woven mesh connection is used to couple the cell holder to the line. One of the optical lenses can be seen to the left of the picture.

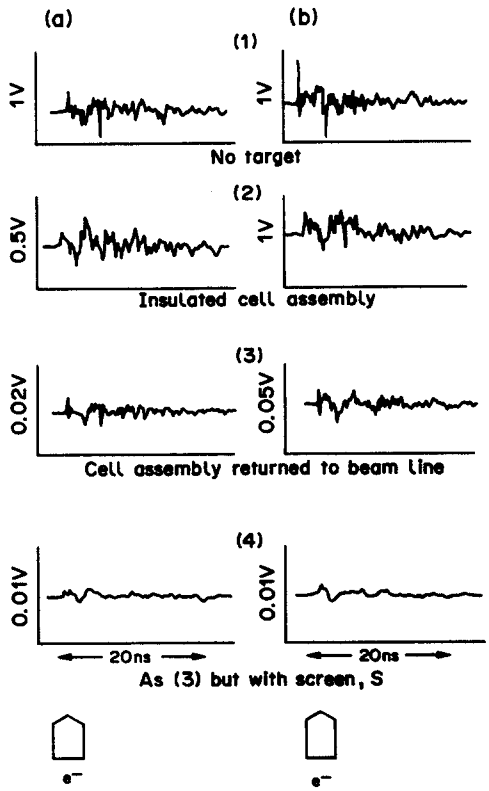


Fig. 3. Electromagnetic interference as sensed by (a) a 10 cm radius loop and (b) short (20 cm) aerial both loaded by 50 Ω, 10 cm from the exit window; 30 ns, 30 nC, electron pulse, 3.5 MeV. 1, Beam fired into radiation room (no target); 2, Beam fired into insulated cell assembly; 3, Beam fired into cell assembly connected to exit window through flexible mesh (Fig. 1); 4, As (3) but with the addition of screen S (Fig. 1).

Compton electrons in signal cables. The magnitude of this "interference" is dependent on the geometry of the set-up but since the X-ray flash will tend to peak in the direction of the beam, the detector should be placed as far away as possible to the side or behind the vacuum window. In some instances it may not be possible to make a direct connection between the cell holder and the accelerator beam line. The beam line is usually not a good low frequency (< 100 Hz) earth and the connection of other associated electronic equipment to the cell may cause the formation of an earth loop; this may occur with cells designed to measure changes in conductivity or with temperature-regulated cells with thermocouple or resistance temperature sensors. Since the cell holder must be coupled to the beam line primarily at high frequencies, capacitive cell-beam line coupling can be used and the reactance of the capacitor can be made high enough at power line frequencies to effectively break the earth loop. A suitable solution is to insert a distributed capacitor between the cell holder and the beam line, made up from double-sided printed circuit board, such as high dielectric constant ($\epsilon_r \sim 10.5$) ceramic Teflon board (Rogers type RT 6010.6), bridged by a number of 10 nF ceramic plate capacitors.

## 3. CONCLUSION

The practical measures described in this note can readily be applied to the majority of accelerators used in pulse radiolysis installations and result in the reduction of electromagnetic interference generated by the pulse charge to the extent that it is generally unnecessary to use any other form of screening of electronic equipment. The accelerator circuits generally operate at peak power levels of several megawatts, while the detector signals may only be in the nanowatt region; the coupling factors thus have to be less than $10^{-15}$. It is important to distinguish between EMI generated by the accelerator and EMI caused by the accelerated pulse charge. Van de Graaff machines are generally "quieter" than linear accelerators and the latter type of machine may require additional screening; it is obviously preferable if the accelerator and experimental areas are situated in separate rooms since concrete walls provide a desirable attenuation of machine EMI. Nevertheless, considerable interference can be generated by the electron pulse itself but this is avoidable if careful attention is paid to the pulse current paths as shown in this note.

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