Radiation testing of COTS-based safety infrastructure: from analogue acoustic chains to GaN and LED testing for signalling systems

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Abstract

Safety infrastructure in particle accelerators must remain operational under radiation levels exceeding 100 kGy, where conventional radiation-hardened solutions are often unavailable. This work evaluates the radiation tolerance of Commercial-Off-The-Shelf (COTS) components for use in emergency communication and signalling systems. Irradiation campaigns at CERN CHARM and CC60 facilities included analogue telephone microphones and speakers, SMD high-power LEDs, polycarbonate optical lenses, and GaN power transistors, were exposed to doses up to 150 kGy. The results identify key degradation mechanisms and provide guidance for qualifying COTS components and developing radiation-hardened safety systems for nuclear and accelerator infrastructure.

Irradiation Facilities and Test Methodology

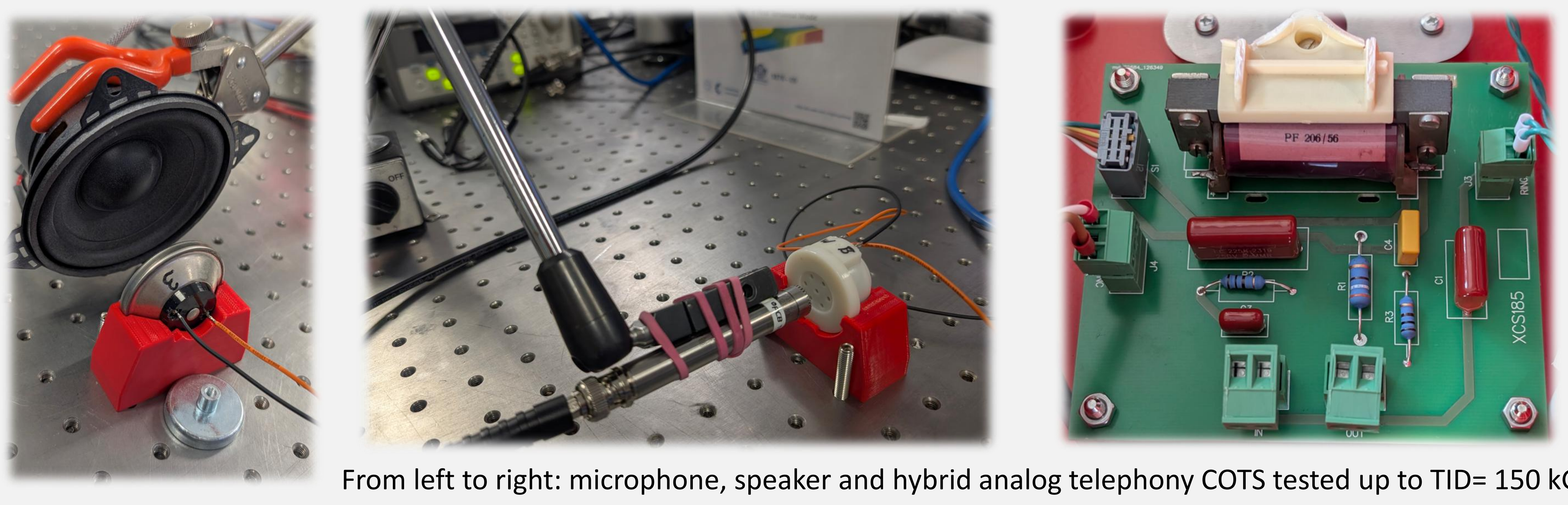
Irradiation campaigns at CERN CHARM and CC60 facilities used mixed-field and gamma environments representative of particle accelerator infrastructure areas.

Tested components include:

- OSRAM high-power LED (part number: Q9LR33)
- GaN Systems E-mode transistor (part number: GS-065-030-2-L)
- Polycarbonate optical lenses
- Analogue telephone microphone and speaker assemblies

All used for emergency telephones and evacuation flashing lights. They were exposed to accumulated doses between 80 and 150 kGy. Electrical, optical, and acoustic characteristics were monitored periodically during irradiation to evaluate performance evolution, degradation, and functional failure thresholds.

Analogue Acoustic Chain Qualification

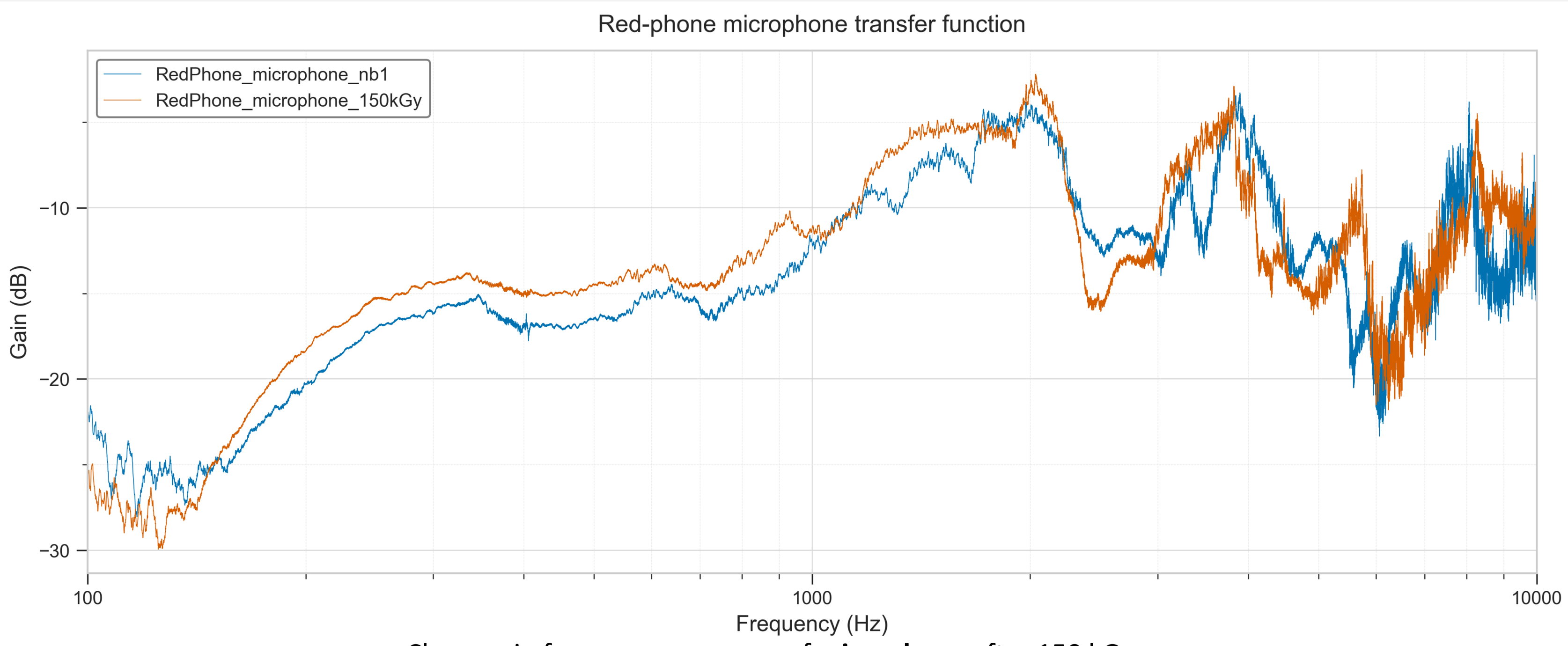


From left to right: microphone, speaker and hybrid analog telephony COTS tested up to TID= 150 kGy

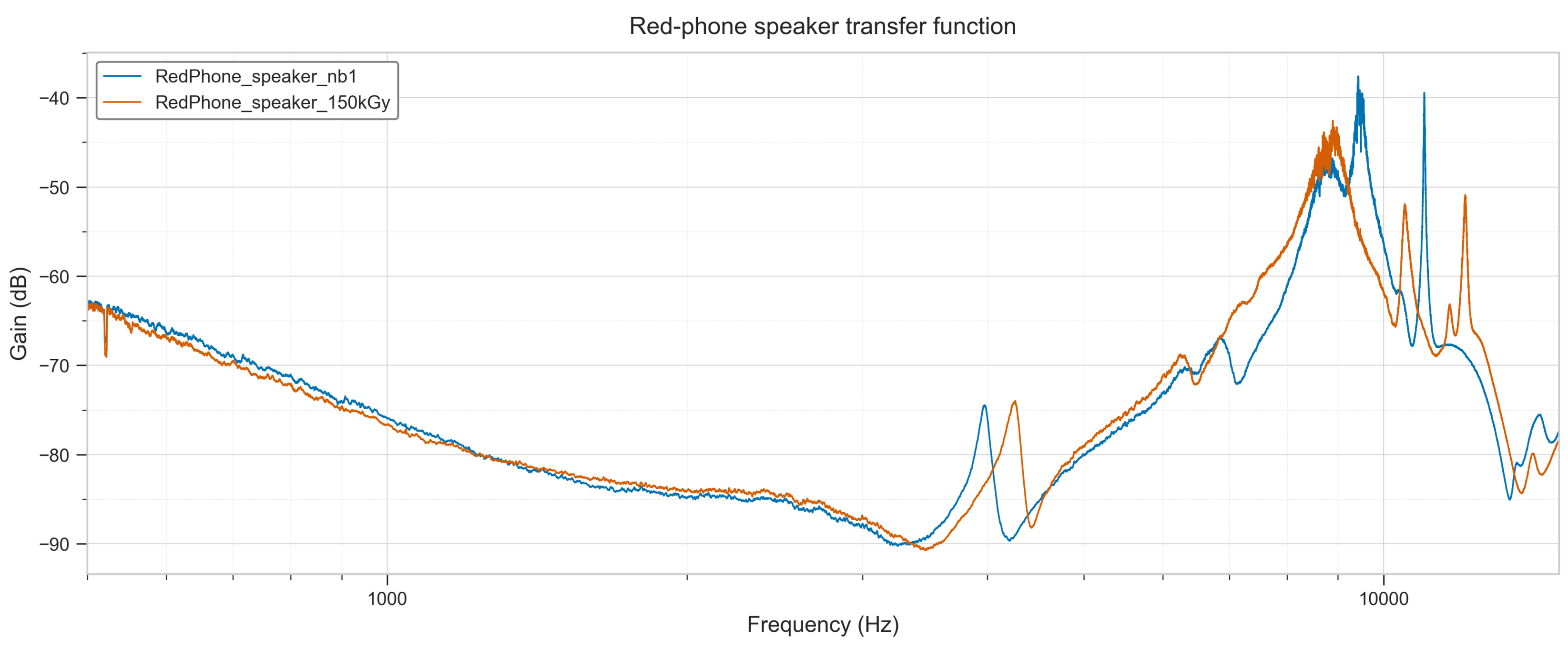
Emergency communication systems rely on analogue acoustic components whose radiation behaviour differs significantly from standard digital electronics. Microphones and loudspeakers used in emergency telephones were irradiated and characterized through:

- Frequency response measurements,
- Signal distortion analysis,
- Voice intelligibility evaluation.

Results showed that COTS components maintained acceptable operational performance well beyond 100 kGy. These observations support the feasibility of using COTS for emergency communication in radiation-exposed infrastructure.



Changes in frequency response of **microphone** after 150 kGy



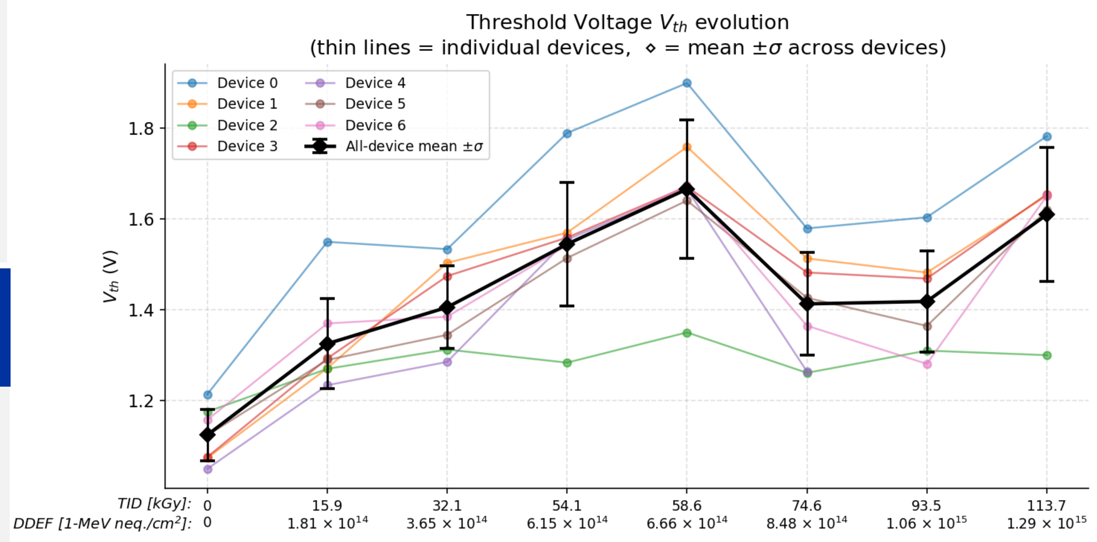
Changes in frequency response of **speaker** after 150 kGy

GaN Transistor Evaluation

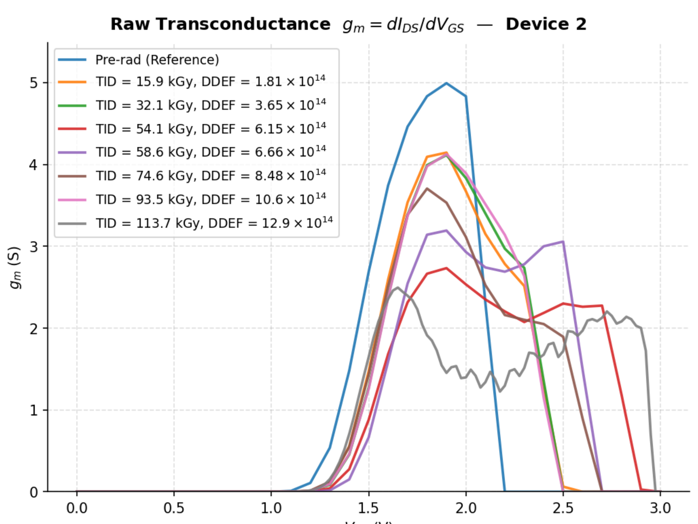
GaN power transistors were investigated as candidates for next-generation radiation-tolerant flashing lights.

Transistors were exposed up to 110 kGy while monitoring threshold voltage, leakage current and switching characteristics.

Compared to conventional silicon technologies, GaN devices exhibited strong tolerance to ionizing radiation as well as displacement damage with limited parametric drift. Such results confirm the potential of GaN technology for compact and efficient Rad-Hard signalling electronics.



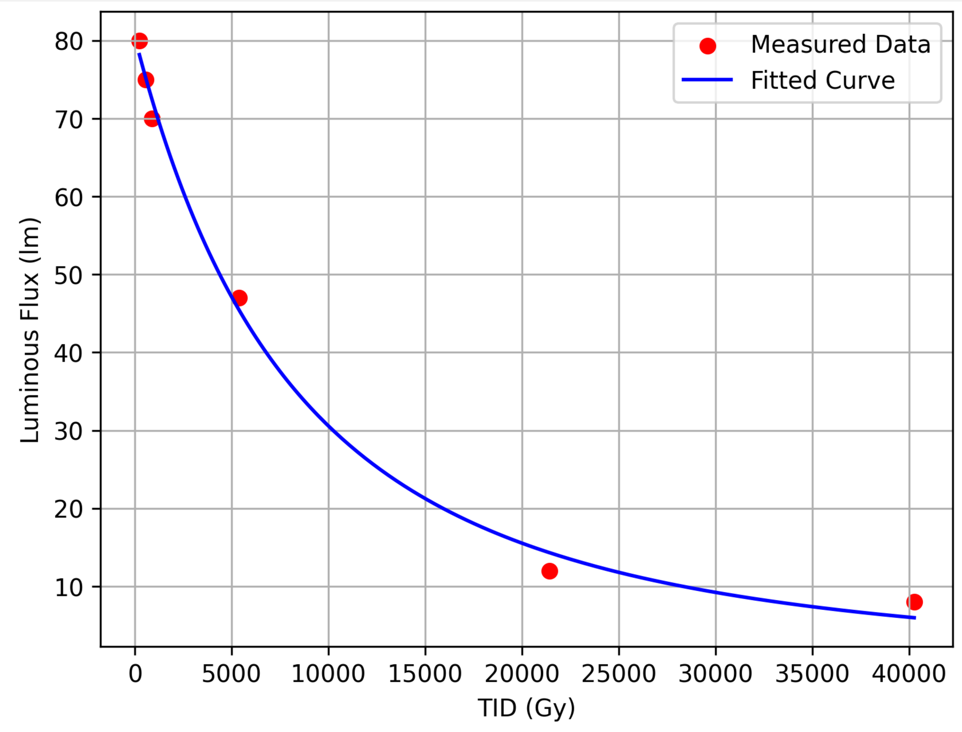
Transistor threshold voltage changes function of accumulated dose



Changes observed in GaN transconductance

High-Power LED Characterization

OSRAM SMD LEDs were irradiated up to 40 kGy to evaluate their suitability for visual emergency lights. The measured luminous flux degradation confirmed the degradation model given in [1] and allows us to predict LED lifetime as a function of its position in the particle accelerator.



Luminous flux degradation model

$$L = L_0(1 + \tau_0 \kappa \phi)^{-\frac{1}{n}}$$

where:

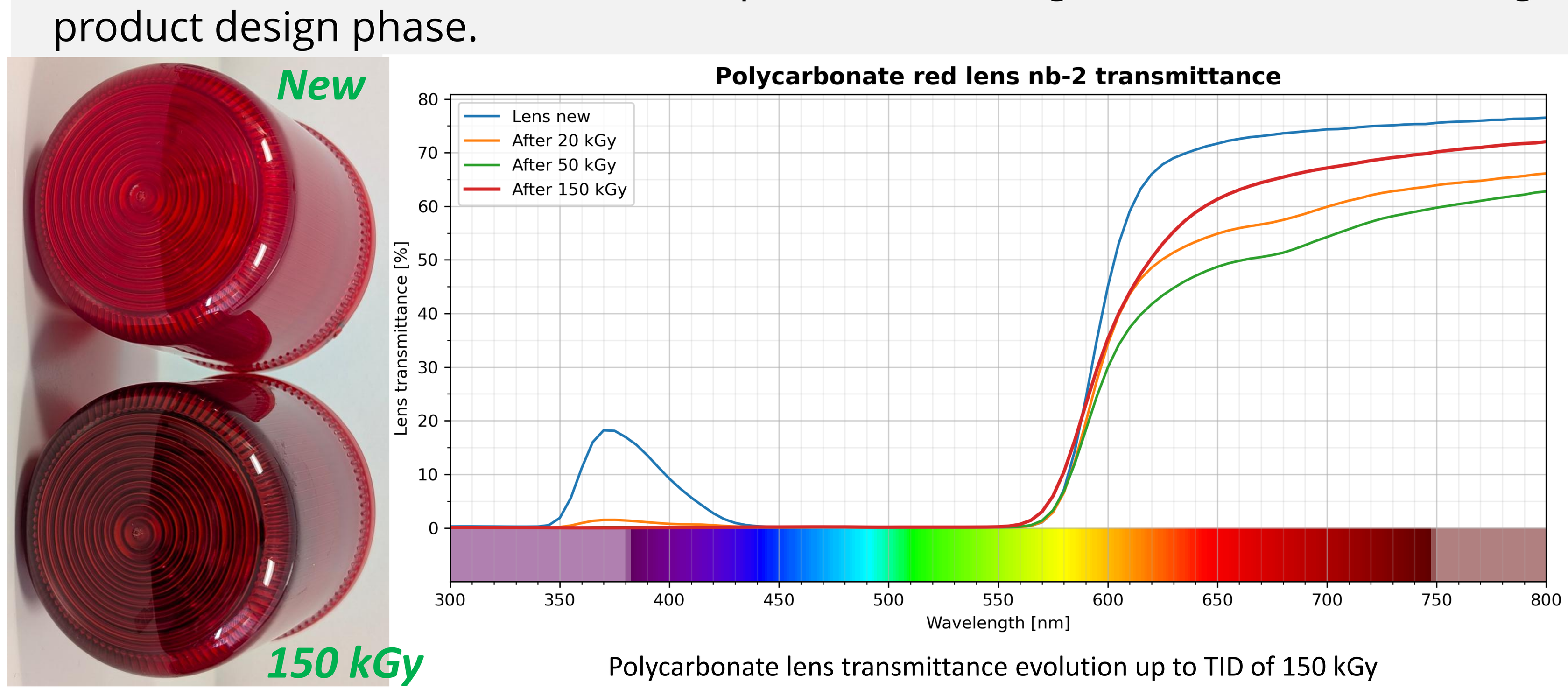
- L_0 is the luminous flux before irradiation.
- n an exponent typically comprised between 0.3 and 1.
- τ_0 the initial carrier minority lifetime.
- κ the damage constant.
- Φ the particle fluence.

[1] A. H. Johnston and T. F. Miyahira,"Characterization of Proton Damage in Light-Emitting Diodes", *IEEE Transactions on Nuclear Science*, vol. 47, no. 6, pp. 2500–2507, Dec. 2000, DOI:10.1109/23.903799

Measured drop in luminous flux and predicted model

Optical Polycarbonate Irradiation

Polycarbonate lenses used in signalling beacons were irradiated to evaluate radiation-induced attenuation. Despite showing noticeable losses and darkening during the first irradiation dose steps, the material started improving back above 50 kGy to establish to less than 17 % transmittance loss compared to a new lens. Here again, standard COTS confirms to fulfil the need of radiation-hardness if these parameter changes are accounted during product design phase.



Polycarbonate lens transmittance evolution up to TID of 150 kGy

Conclusion

This paper demonstrates that selected **COTS components can survive radiation** levels relevant for CERN's safety infrastructure.

Analogue acoustic components showed high resilience, even **above 150 kGy**, allowing a design of **emergency communication system** for radiation environment.

Optical polycarbonate lenses showed an acceptable **radiation induced attenuation** during the test with transmittance even improving at higher doses.

GaN transistors exhibit a very limited **$V_{GS\ Threshold}$ shift** while **transconductance** remains sufficient for the application.

Finally, characterization of **high-power LEDs** allowed the identification of ageing behaviour so that preventive maintenance can be planned accordingly.