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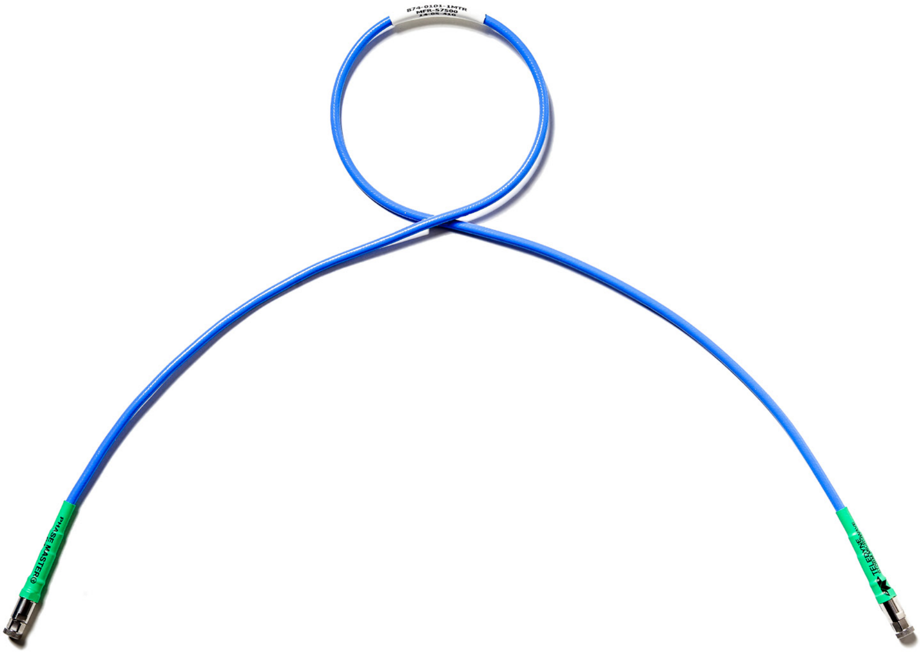
elspec group GmbH



Degradation of electrical properties of coaxial cables exposed to ionizing radiation

Dipl. Ing. (FH) Stefan Burger | DeltaGamma RF-Expert
Dr. Michael Kuntzsch, Helmholtz-Zentrum Dresden-Rossendorf

Zum Autor Dr. Michael Kuntzsch

is working at the Institute of radiation physics at the Helmholtz Institute in Dresden. He is co-laureate of the Technology- and Innovation-Prize 2015 for his work on synchronization and timing of the ELBE radiation source, his investigations of dynamic processes using IR- and THz-radiation, and his work on synchronization of electron-ray- and high-performance-laser-pulses connected to the generation of X-rays via Thomson scattering.

In this framework, Dr. Michael Kuntzsch and Andreas Schwarz designed and realized a system enabling them to measure the arrival time of electron pulses with an accuracy of a few femto-seconds. This arrival-time monitor captures the fluctuations in time of the generated electron pulses and forwards this information to subsequent instrumentation and experiments..

The author Stefan Burger

graduated in 1986, receiving his diploma as engineer (FH) (similar to a masters degree) from the University of Applied Science in Offenburg. He remained at the university as research associate until 1990 when he started working in the R&D-department at Endress + Hauser in Maulburg. Here he was involved in RADAR-based level measurement devices until 2001, his particular responsibilities being the development of antennas and pressure-resistant RF-connectors, among others.

From 2001 to 2011 he designed filters and duplexers for base stations at Panasonic Electronic Devices in Lüneburg, being entrusted with life-time and power-durability simulations.

In 2012 he founded his own enterprise Delta Gamma Consultant (www.delta-gamma.com) in Hampton, Australia. Since 2014 he has been working as exclusive consultant in the area of high-frequency and instrumentation for the el-spec GmbH company in Geretsried, Germany.

3

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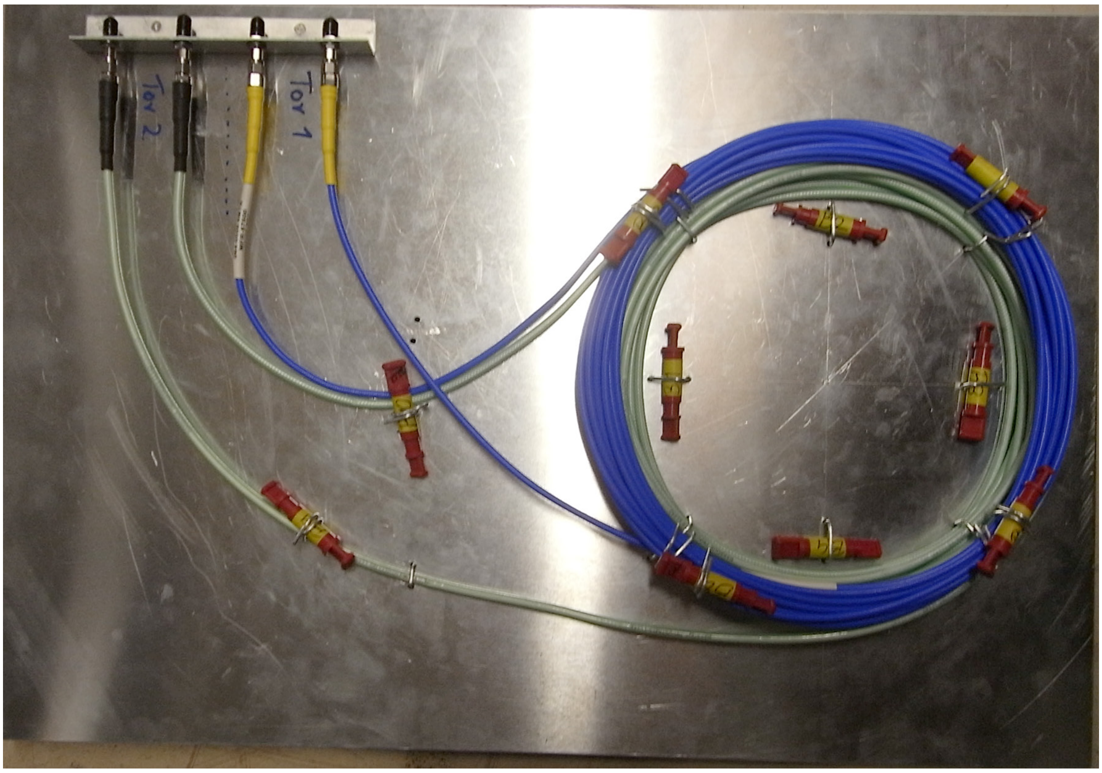
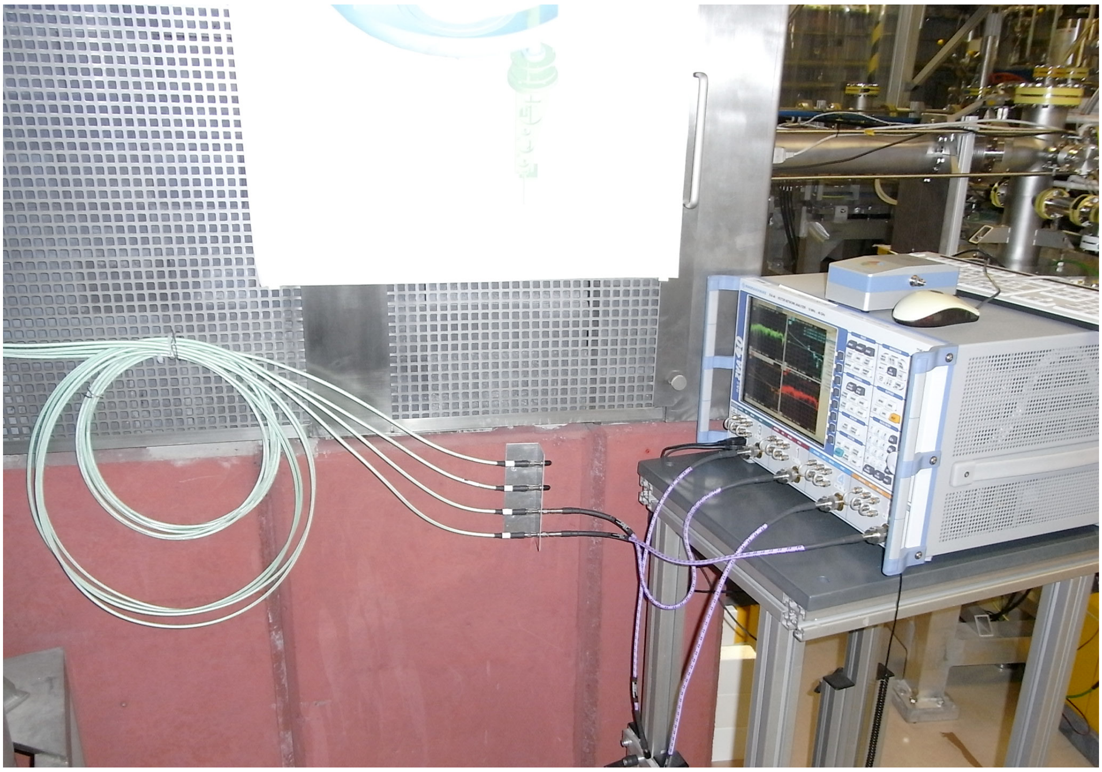
Content



(a) Cable under test (CUT)



(b) Measurment setup

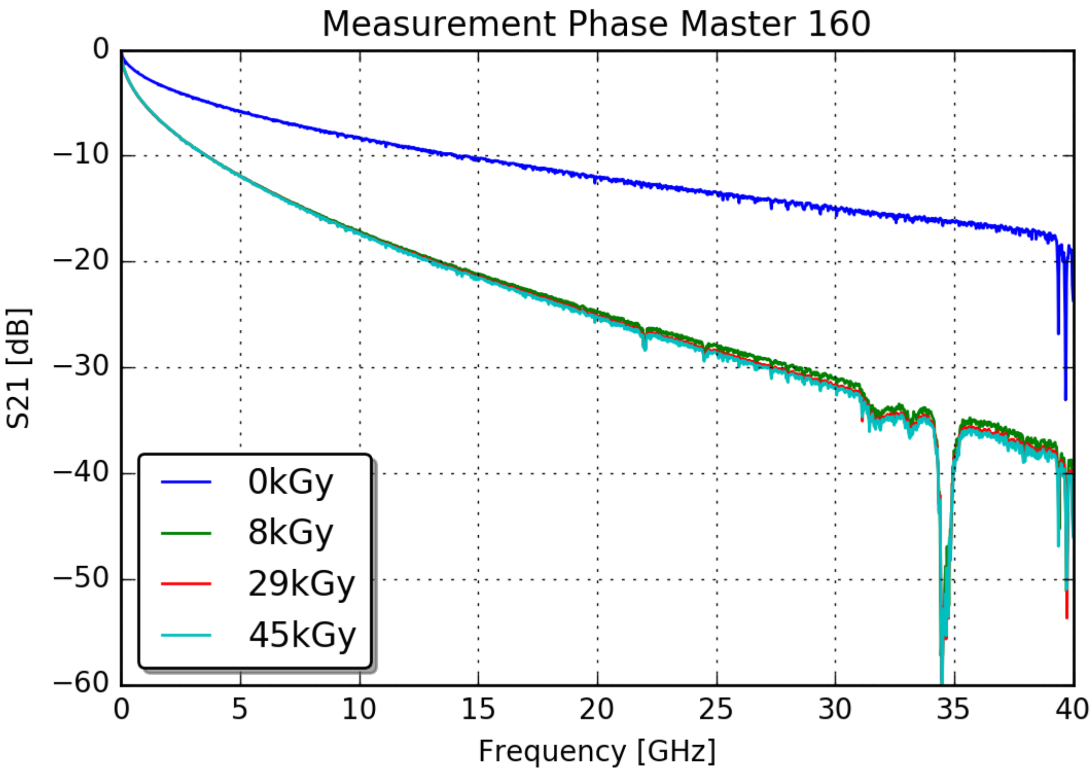
Figure 1: Test setup

Introduction

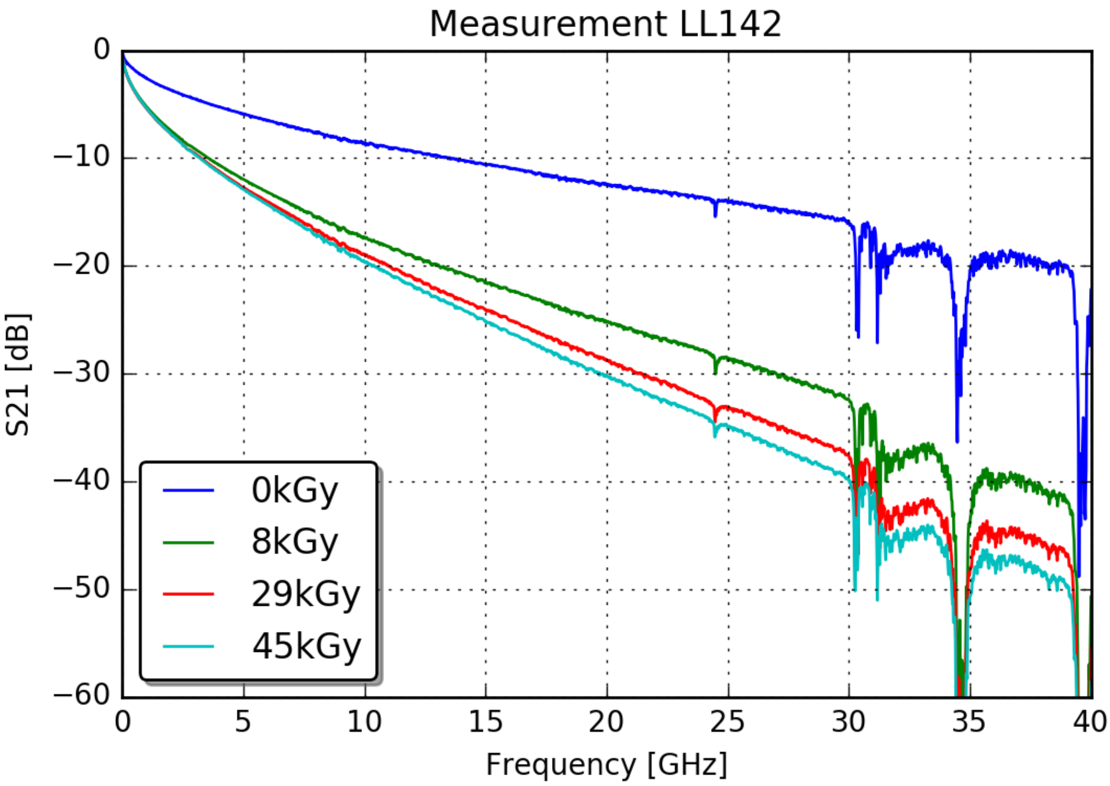
At Helmholtz-Zentrum Dresden-Rossendorf (HZDR) two types of coaxial cable have been exposed to ionizing radiation from October 2015 to October 2016. The first sample was a 8 meter piece of Teledyne Storm Microwave Phase Master® 160 and the second sample a 10 meter piece of Harbour Industries LL142. They were installed on the back of a beam dump at the ELBE FEL (U100) and connected with two times 5 meter long patch cable LL142. In this location the samples experienced a gamma radiation shower generated by the decelerated electrons in the beam dump - so called „Bremsstrahlung". Since both samples have been installed in this location at same time they experienced the same radiative field.

Set Up

The test cables have been installed on the back of the beam dump at the ELBE FEL (U100). Two types of cables have been mounted on a metal plate. Harbour Industries - LL142 (green) and Teledyne Storm Microwave - Phase Master® 160 (blue). The samples are connected to a patch panel outside the dump shield with 5 meters of Harbour Industries LL142 on each side (Fig.1). The radiation level is measured online with a Multidos dosimeter and for a more accurate measurement 10 Alanine probes have been attached to the cables. The readout of the probes can only be done off-line and will be done after removing the cables from the beam. The electrical properties of the test samples were recorded periodically using a Vector Network Analyser (Rohde &Schwarz ZVA40).



(a) PM160



(b) LL142

Figure 2: Transmission measurement up to 40 GHz

Measurement

The provided measurement data showed attenuation peaks above 30 GHz of the LL142 cable (Fig. 2). The analysis was done with the data up to 30 GHz to prevent misinterpretation. The Phase Master® 160 by itself shows attenuation peaks around 39 GHz and could be analysed up to this frequency. Using LL142 as patch cables introduced similar attenuation peaks for the Phase Master® 160 setup. Therefore a final evaluation of the data can only be made after the final test run, measuring the samples without patches. The first measurement of the cables, without any radiation exposer in Fig. 2 (0kGy), was done without the patch cables. Therefore the attenuation is less of the attenuation of the patch cables.

Attenuation Model

From the cable dimension, metallisation and used dielectric it is possible to calculate the cable performance. The dimension of the Phase Master® 160 was not available and the common fit function was used to extract the cable performance.

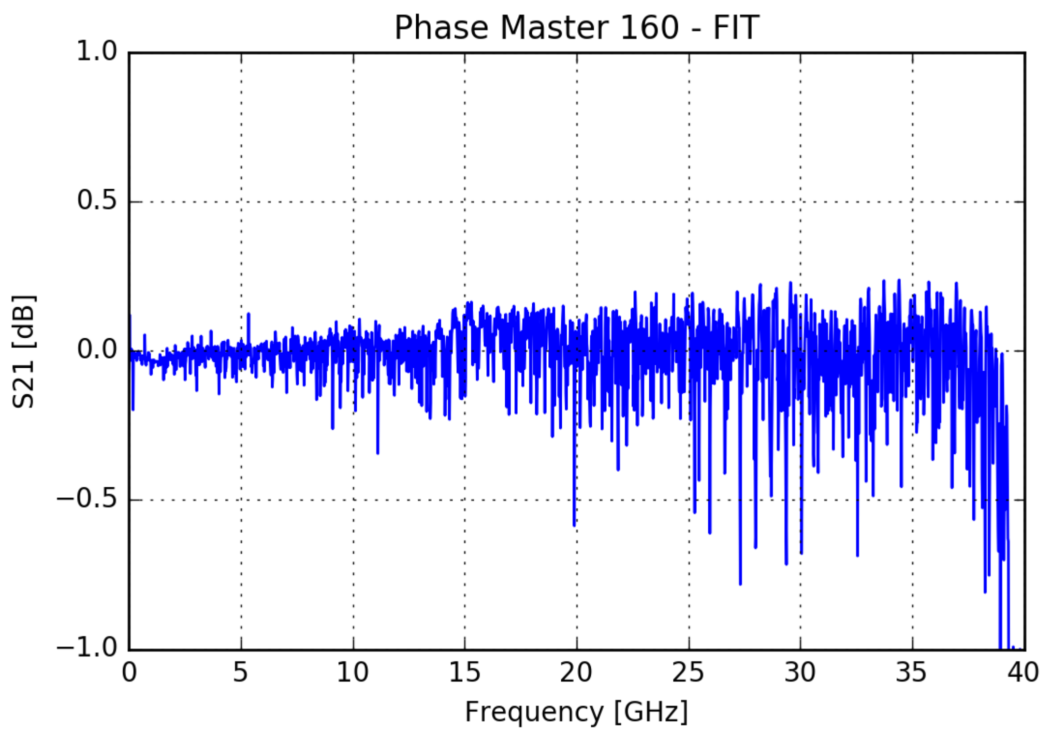
$$IL = l \cdot (K1 + \sqrt{f} + K2 \cdot f) \quad (1)$$

IL : Insert Loss [dB]
f : Frequency [GHz]
K1 : Factor for resistive loss
K2 : Factor for dielectric loss

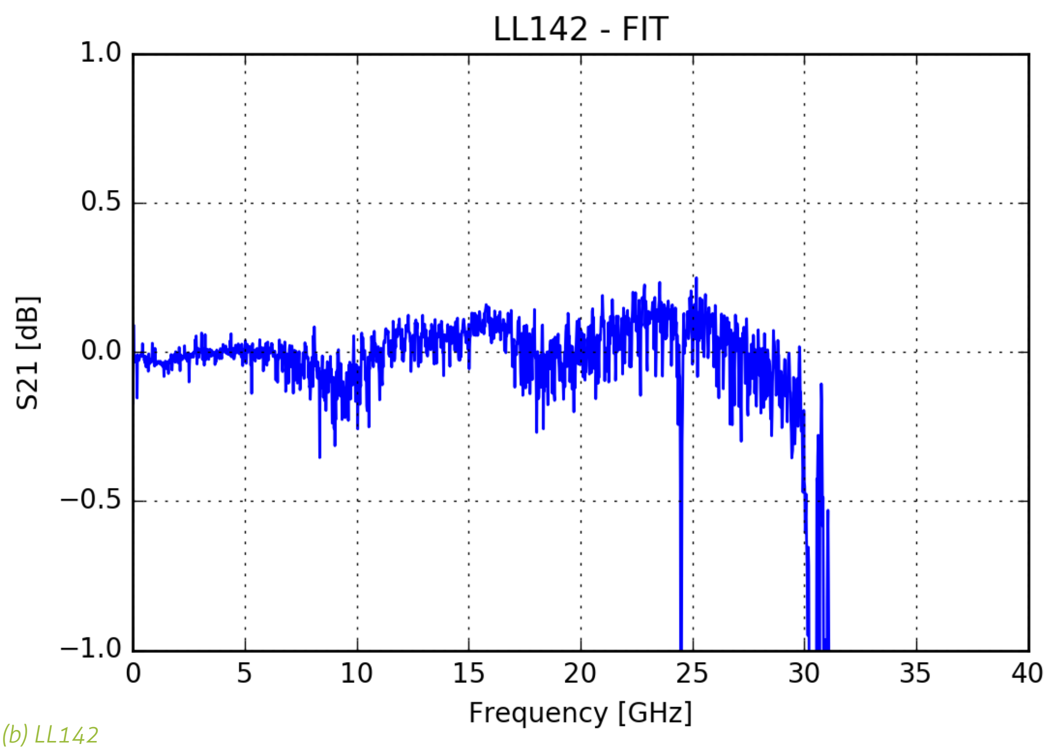
K1 and K2 for the patch cables were extracted from the first measurement of the LL142 cable without the patch cables and used for the analysis. It has been assumed that the patch cables were outside of the radiation beam and they didn't degenerate. The final measurement of the cables after removing from the beam will show if this assumption is valid. A Python program was written which uses the non-linear least squares curve_fit method to fit the parameters K1 and K2.

Curve Fit

The fit was done with the measurement data for the Phase Master® 160 and LL142 in the frequency range from 0 to 30 GHz. The function matches the data within 0.1 dB of the average value for the measurements without any radiation exposer. The Phase Master® 160 has a higher noise level whereby the LL142 has some attenuation ripple (Fig. 3)



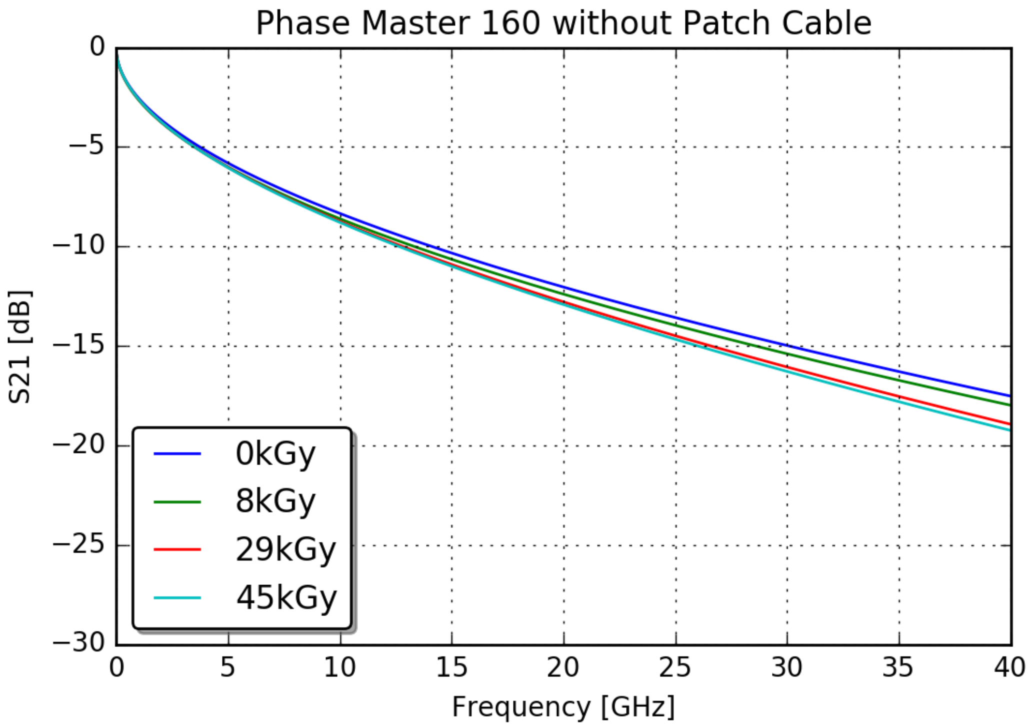
(a) PM160



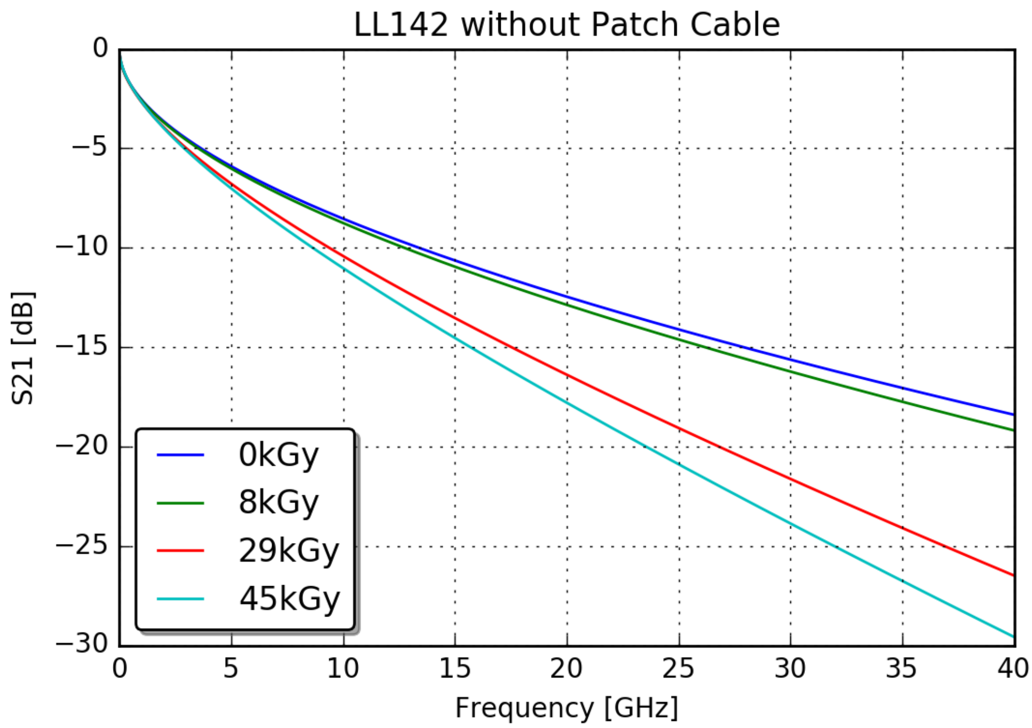
(b) LL142

Figure 3: Difference to measurement up to 40 GHz

In Figure 4 the fit-function up to 40 GHz without consideration of the patch cables are shown. The attenuation of the Phase Master® 160 increased slightly while the LL142 increased around 10 dB after the irradiation run. The difference can be explained by the K1 and K2 value for both cables (Fig 5). K1 for the restive loss is nearly constant but K2 for the dielectric loss increases with the accumulated dose. K2 doubles for the Phase Master® 160 while K2 for the LL142 is nearly 8 times higher for the same dose level.



(a) PM160



(b) LL142

Figure 4: Interpolation of CUT without patch cable up to 40 GHz


TELEDYNE
STORM MICROWAVE
TELEDYNE
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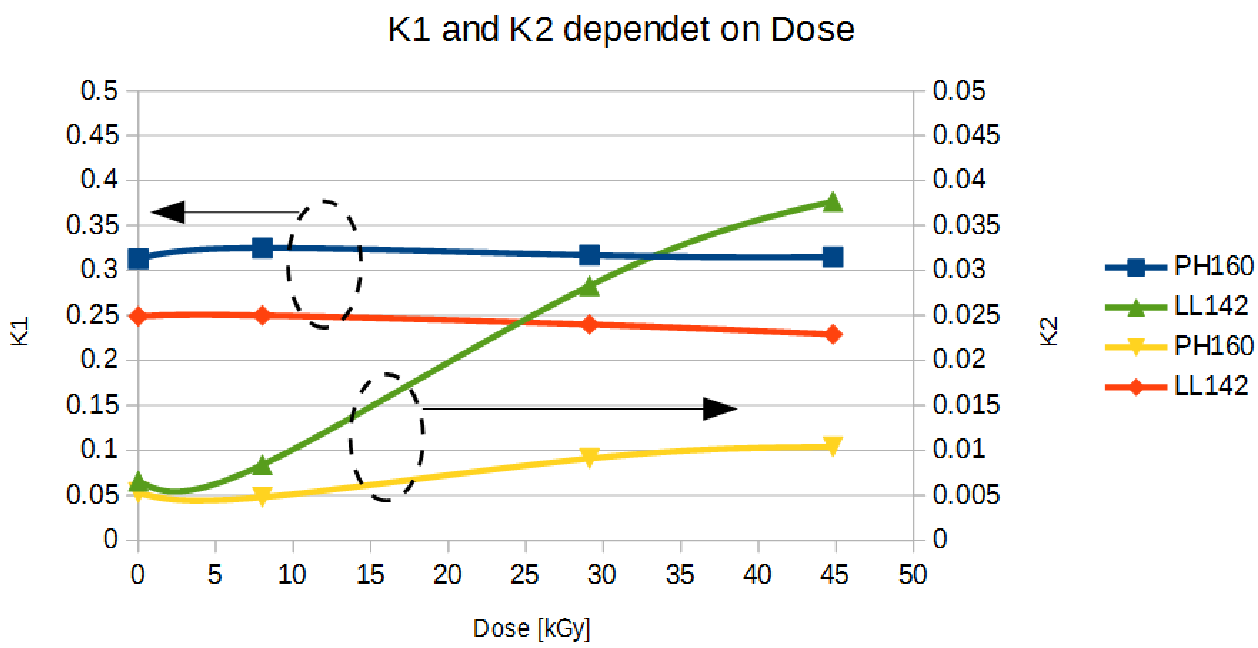

Figure 5: Coaxial-Cable parameters dependent on irratiation dose

Imprint

Concept, text & drawings: Stefan Burger, DeltaGamma RF-Expert, Melbourne Australien and
Dr. Michael Kuntzsch, Helmholtz-Zentrum Dresden-Rossendorf
Layout & design: Udo Klünsch | kpr kommunikation, Geretsried
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el-spec GmbH
Lauterbachstr. 23c
82538 Geretsried-Gelting
T.: +49 81 71 43 57-21/-22
F.: +49 81 71 43 57-99
info@elspecgroup.de
Geschäftsführer: Thomas Weber
www.elspecgroup.com

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el-spec GmbH
Lauterbachstr. 23c
D-82538 Geretsried-Gelting, Germany
Tel. +49 8171-4357-21/-22
Fax +49 8171-4357-99
info@elspecgroup.de
www.elspecgroup.com