MEASUREMENT UNCERTAINTY ASSESSMENTS OF THE SPIRAL2 ACCT/DCCT

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Abstract

Four instrumentation chains with AC and DC Current Transformers (ACCT-DCCT) will equip the lines of SPIRAL2 facility to measure the beam intensity and line transmissions. These measures are essential to tune and supervise the beam, to assure the thermal protection of the accelerator and to control that the intensities and transmissions are below the authorized limits. As such, the uncertainties of measurement chains must be taken into account in the threshold values.

The electronic has been designed with high requirements of quality and dependability by following different steps; from prototyping, the qualification through an Analysis of Failure Modes and Effects Analysis (FMEA) [1] until final fabrication.

This paper presents the measurement uncertainty assessments of the ACCT/DCCT chains.

INTRODUCTION

The SPIRAL2 facility at GANIL in France is planned to accelerate deuteron, proton and heavy-ion beams with a RFQ and a superconducting linear accelerator. Table 1 recalls the main beam characteristics.

Table 1: Beam Specifications

Beam	P	D+	Ions (1/3)
Max. Intensity	5 mA	5mA	1 mA
Max. Energy	33 MeV	20 MeV/A	14.5 MeV/A
Max. Power	165 kW	200 kW	43.5 kW

A DCCT bloc is set up at the entrance of the Radio Frequency Quadrupole (RFQ) and three ACCT/DCCT blocs (Fig. 1) will be installed at the Linac entrance, the Linac exit and the Beam Dump entrance (Fig. 2). [2]

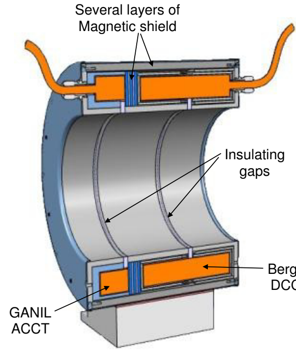

Figure 1: ACCT-DCCT bloc section.

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These non-destructive beam intensity diagnostics are required to:

- ✓ Control and monitor the beam intensity
- ✓ Control and monitor the transmissions (intensity differences between two blocs),
- ✓ Control the intensity quantity sent to the Beam Dump Linac over 24 hours.

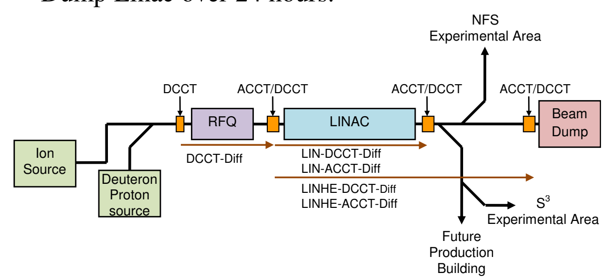

Figure 2: Beam Intensities and transmissions.

MEASURING CHAIN DESCRIPTION

DCCT Measuring Chain

The figure 3 shows a schematic overview of the DCCT chain. The transformer and the first electronic are commercial devices (Bergoz ref: NPCT-175-C030-HR). In order to decrease the offset fluctuation, the DCCT is maintained at a temperature of 40°C±1°C.

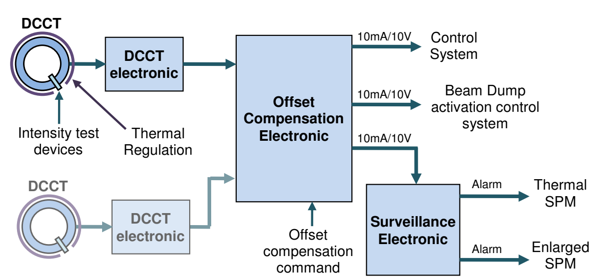

Figure 3: DCCT chain.

The electronic card “offset compensation”:

- ✓ sets the zero point, with a manual command before each start of new beam tuning
- ✓ generates the transmission signal (difference of two intensity signals)
- ✓ distributes the intensity and transmission signals at different systems

The surveillance cards carry out moving averages of their input signal. These averages are compared to thresholds and the cards generates alarms in case of overtake. The alarms (a cut-off request) are sending to the Machine Protection Systems (Thermal and Enlarged MPS) [3].

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ACCT Measuring Chain

The transformer and its electronics were developed by the Ganil's Electronic Group (Fig.4). The transformer is a nanocrystalline torus with winding turns ratio of 300:1.

The pre amplifier is a courant to tension convertor. It is placed as close as possible to the transformer for minimize the noise but outside the linac room to be protected of the radioactive effects.

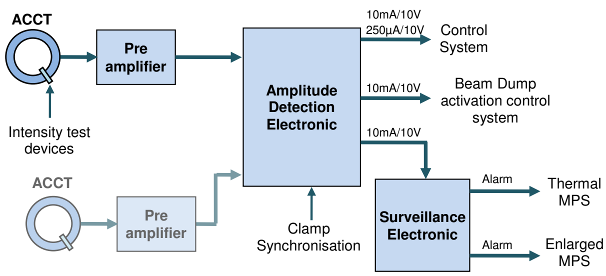

Figure 4: ACCT chain.

The amplitude detection electronics have a main function; regenerate the DC signal non-transmitted by the ACCT. This function is realized by an electronic clamping clocked on the "clamp synchronisation" signal. The slow chopper modulates the intensity and periodically "cut" the beam. The "clamp synchronisation" signal indicates when the beam is "off", at the middle of the beam absence.
Like the compensation offset electronic, the amplitude detection card generates beam intensity and transmission signals and distributes them at the different systems.

The surveillance of thresholds is the same as DCCT chain.

UNCERTAINTY EVALUATIONS

Study and Design Stage

The first uncertainty evaluations on the prototype electronics have guided the development of ACCT/DCCT chains [4]. The main influences were the subject of specific studies. Four of them are listed in the table 2.

Table 2: Example of Optimization Studies

Influence parameters	Results
Room temperature on DCCT sensor	Implementation of system to stabilize the transformers temperature.
External Electromagnetic Field	Three shielding layers protect the sensors. Definition of PCB EMC design rules for the electronic cards
Disturbances between AC and DC sensors.	A vertical shield plate is installed between the sensors to minimize the effect of DCCT magnetic modulator on the ACCT.
ACCT Low Drop	Choice of the nanocrystalline torus with winding of 300 turns. Implementation in preamplifier a function to decrease the resistance value of ACCT winding. Clamp function trigged in the middle of the time off.

The sums of uncertainties determine the measurement limits of both chains. These limits of the prototypes were accepted and validated in the design review meeting.

Validation and Qualification Stage

Now, the ACCT-DCCT chains are manufactured in the definitive version. Their validation and their qualification require new uncertainty evaluations more accurate and final. These evaluations were realized at first from measures in laboratory and will be completed by measures on site without and with beam.

These assessments are used to identify the dynamics of measures, to qualify the systems and to define compliance checking templates for the periodic tests.

Also, the goal is to take into account the total uncertainties in the threshold values. The applied thresholds are equal to the desired threshold minus the uncertainties. This ensures that the intensities and the transmissions don't exceed the operating ranges authorized.

For evaluate the total uncertainties, all the influence parameters should be identified and quantified [4].

Several test benches were set up to characterize these parameters. For example, the figure 5 presents the test bench used to evaluate the gain and linearity influences.

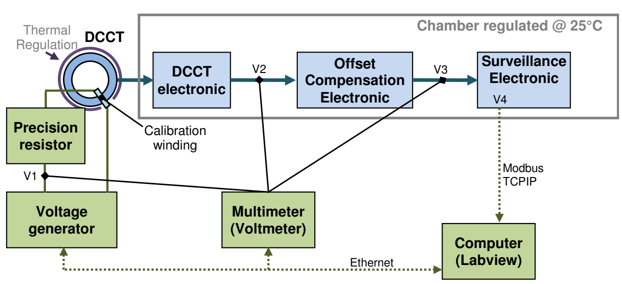

Figure 5: Gain & linearity test bench.

The electronic cards is stabilized in a chamber at 25°C and the sensor maintained at 40°C, to suppress the temperature influence. The calibration winding of 1 turn, resistor and voltage generator simulate the beam intensity.

A multichannel multimeter measures the output voltages of the generator. Only, the multichannel voltmeter must be calibrated. Furthermore, the measurement uncertainty associated with voltmeter and precision resistor is lower than the generator.

A Labview program drives the voltage generator and the voltmeter to automate measurements.

The measurements were performed on a complete chain. However, the uncertainties are evaluated on each following parts:

- ✓ sensor & electronic card of DCCT
- ✓ offset compensation electronic card
- ✓ surveillance electronic card

A requirement is to avoid redefining the total uncertainty values, when an electronic card is replaced for

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maintenance reasons. That means the uncertainties of each parts should take into account the maximum parameters of all the cards. So, typical gain, gain dispersion and highest non-linearity were determined for each part.

Uncertainty Results

The table 3 and 4 list the main uncertainties. All the values were calculated from laboratory measurements.

Table 3: Main Uncertainties of Average Intensities

Sources of uncertainty	ACCT	DCCT
Gain & Linearity	0.04%	0.45%
Sensor Temperature	-	13µA (1)
Electronic Temperature	-	23µA (2)
Noise (3)	10nA	2µA
Clamp	2.5µA	-
Initialization Offset with surveillance cards	50nA	5µA
Gain & Linearity of surveillance cards	0.35%	0.35%

(1) DCCT range 20mA -Thermal regulation at 40°C ±0.5°C
(2) Ambient temperature range: 18° - 31°C
(3) Noise measured in laboratory

Table 4: Main Uncertainties of Average Transmissions

Sources of uncertainty	ACCT	DCCT
Gain & Linearity on the intensity	0.035%	0.12%
Gain & Linearity on the loss	0.04%	0.45%
Sensors Temperature	-	26µA
Electronic Temperature	-	9µA (1)
Noise	15nA	3µA
Clamp	4µA	-
Initialization Offset with surveillance cards	75nA	7µA
Gain & Linearity of surveillance cards	0.35%	0.35%

(1) Temperature difference of electronics: 5°C max.

For DCCT chain, the temperature and the noise (external magnetic fields) are the two predominant sources of uncertainty.

For ACCT chain, it's the "clamping" function. The frequency of 1Hz is very restrictive because the signal can't be average in a short time. To decrease "clamping" uncertainty, a solution is to multiply the frequency by 100 to reduce it by a 10 factor.

The table 5 and 6 presents the total uncertainty values for few values the intensities and transmissions.

Table 5: Examples of Intensity Uncertainty

Beam Intensity	Uncertainty	
	I ACCT	I DCCT
5mA	±23µA	±82µA
1mA	±7µA	±51µA
50µA	±3µA	±43µA

Table 6: Examples of Transmission Uncertainty

Beam Intensity	Transmission Loss	Uncertainty	
		ΔI ACCT	ΔI DCCT
5mA	250 µA	±7µA	±52µA
1mA	250 µA	±7µA	±48µA
50µA	50 µA	±5µA	±45µA

ACCT uncertainties are lower than those of DCCT. More particularly, the ratio for intensities of few 100µA is about 10.

CONCLUSIONS

The overall chain ACCT-DCCT is manufactured validated and will be installed on the accelerator before the end of the year 2016. The characterization and the qualification should continue on site without and with beam. For example, the influence of the extern magnetic fields should be quantified with SPIRAL2 in operating. The qualification will finish by tests with the other interfaced systems. Mainly, the response times between beam overrun and its cut off must be verified.

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