SPIRAL2 BEAM ENERGY MEASUREMENT

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Abstract

In order to produce high intensity exotic beams in the existing experimental rooms of the GANIL facility, the SPIRAL2 project is under development and under construction at GANIL.

The first phase of the SPIRAL2 project consists to build a new accelerator composed of two sources, an ion source and a proton/neutron source, a RFQ and a superconducting Linac. The linac is designed to accelerate 5 mA deuterons up to 40 MeV and 1 mA heavy ions up to 14.5 MeV/u. A new electronic device has been developed at GANIL to measure phase and amplitude of pick-up signals and calculate the beam energy. The principle consists of directly digitizing the pick-up pulses by under-sampling. The Phase and amplitude of different harmonics are then calculated with a FPGA by an I/Q method before the beam energy calculation.

This paper gives results of the pick-up tests in laboratory and the comparisons with simulations.

The tests in laboratory and on the GANIL accelerator of an electronic prototype are shown and presented.

TEST BENCH CARACTERIZATION

The measures have been made on three phase probes, which will be used for the energy measurement at the RFQ exit of the SPIRAL2 accelerator [1]. Measurements were done as well in frequency domain as in time domain test bench in laboratory (Fig. 1) at the SPIRAL2 frequency (88,05MHz).

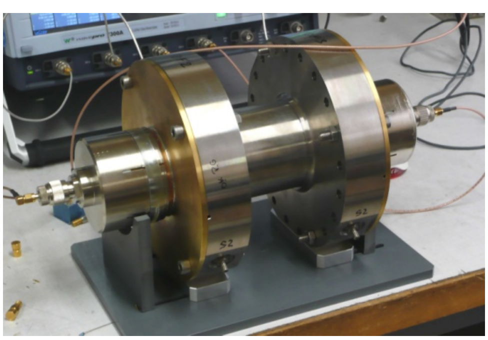

Figure 1: Test bench for the probe characterization.

The Model Design

The test bench is a transmission line with a characteristic impedance of 50 ohms. All ports are terminated with a 50 Ohm load, which absorbs the incident power. The input signal is applied on the coaxial line. The output signal is read on the pickup equipped with a SMA connector.

SIMULATION

The simulation results were obtained with CST Studio Suite. The geometrical model (Fig. 2) and mesh used for the frequency domain and time domain simulations is the same. All metallic parts of the simulated pickup were assumed to be made of perfect conductors (PEC) and all other boundaries are PEC.

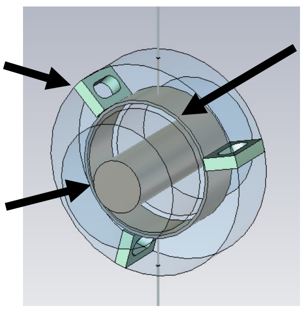

Figure 2: Model of the pickup in CST.

Frequency Domain Studies

For the simulation in the frequency domain, tetrahedral mesh was chosen. A Vector Network Analyser is used to measure S_{11}, S_{22} and S_{21} at the pickup ports. The transmission S_{21} simulation and measurements are reported in Fig. 3.

Microwave Studio simulations and RF bench measurements of the scattering parameter S_{21} for the probes are similar for frequency up to 1 GHz.

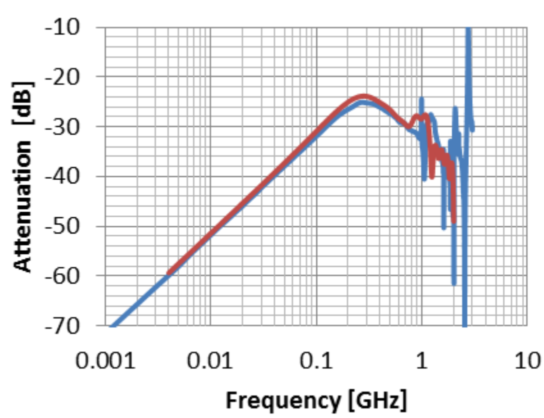

Figure 3: Comparison of Microwave Studio simulations (Red) and RF bench measurements (blue).

Time Domain Studies

For the time domain simulation, the pulse form from the bench generator was used as stimuli (Fig. 4). The pulse was recorded and injected as a bunch source through the TOF pick-up to perform analysis.

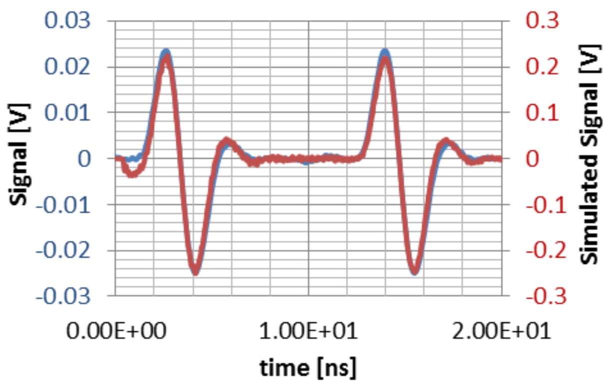

Figure 4: Measure of the derivative pulse signal on the probe: the results of simulation (red), the measure on oscilloscope (blue).

Laboratory Results

The simulations on CST show results very close to measurement signals.

The S parameters are similar except in high frequency. This difference can be due to the simplified mechanical drawing of the probes used in CST. Connectors and coaxial cables can produce insert losses and mismatches, but the difference is too small to be integrated in the simulation parameter.

The injection of the temporal stimulus used for the measure, have also close similarities with simulation.

The CST software allows modifying the mechanical forms to see the incidence on every parameter and also optimizing the sensors before or after realization. CST is a successful tool to understand the electric functioning of an electromagnetic diagnostic.

PHASE ELECTRONIC INSTRUMENTATION

A new electronic instrumentation has been developed at GANIL to measure the beam phase of each pickup. The choice was done to digitalize directly pulses from pickups. The main reason of this choice is the possibility to calculate the phase of the harmonic 1 and 2 of the signals with the same electronic.

Electronic Description

The FPGA board prototype is composed of analog to digital converters AD9246 Analog Devices (14 bits), a FPGA Spartan3 Xilinx, a PLL synthesiser ADF4360-9, a serial interface with a touch screen.

The Phase and amplitude of different harmonics are calculated with a FPGA by an I/Q method [2].

Phase Measurements in Laboratory

On a wide dynamic (60dB), FPGA phasemeter allows measuring precisely sinusoidal signal phase (+/-0.1°) on the three inputs (Fig. 5).

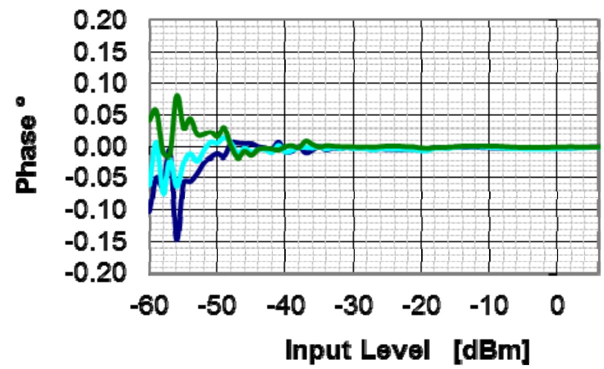

Figure 5: Accuracy in function of the signal level.

The board prototype is based on a development board called NanoBoard from ALTIUM. The NanoBoard is used as a complete test bed for FPGA-based embedded system design. Its flexibility and tight integration with the Altium Designer software improve our ability to design, implement and debug an entire FPGA-based system design. We conceived a peripheral ADC board (Fig. 6), which digitizes the inputs signals and generates the sampling frequency. The line adaptation was verified and the sampling clock jitter was minimized by using the Altium Software.

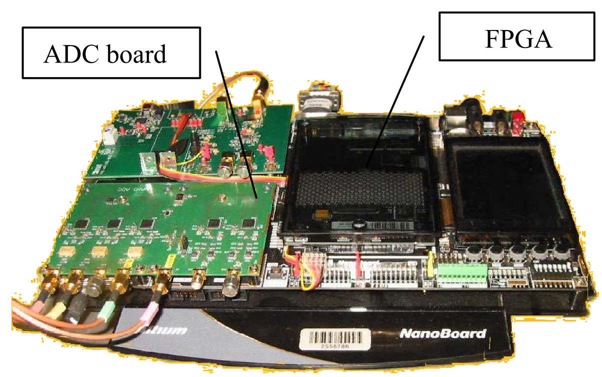

Figure 6: The NanoBoard from ALTIUM with the peripheral ADC Board.

Beam Energy Measurement at GANIL

A FPGA phasemeter prototype has been installed on the GANIL accelerator, measuring the time of flight with two pick-ups. The principle consists to compare two energy measurements with two different methods. The first method, which uses the spectrometer, gives an energy reference value. The second method consists to calculate the beam energy from the phase difference. The goal is to compare results, validate the phase measurement and measure the accuracy.

For the second method, two capacitive probes are used along the GANIL beam line at a known distance.

The FPGA phasemeter measure the phase difference between the pickup signals (Fig. 7). We use the same type of system of measurement for both probes.

To define the measurement accuracy, we need to qualify the phase difference between both channels. The connection cables must be mated.

To calibrate the channel, we also have to know the length of the cables of tests. All these measures have been done with a vector network analyzer.

A test signal can be send to calibrate each channel in phase.

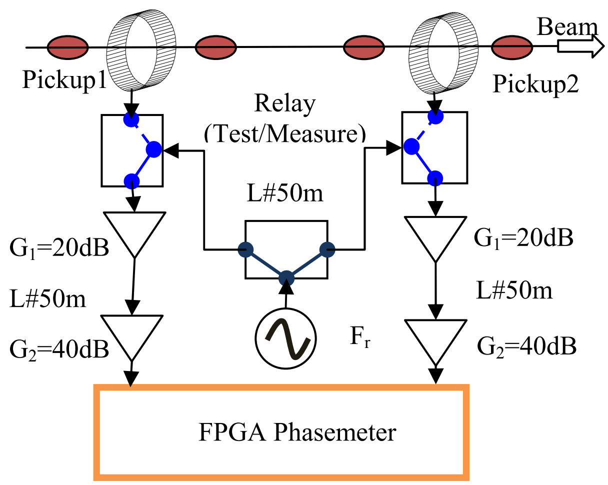

Figure 7: Block diagram of the phase measure at GANIL.

Beam Energy Results

An offset compensation is necessary to reach the accuracy of the measures. The offset is set when the beam is stopped with a faraday cup situated upstream on the GANIL accelerator.

By taking into account the difference of phase between both ways of measure (difference of probe capacities, gap of phase amplifiers and cables), we obtain close measures of energy up to 2°/°° (Fig. 8).

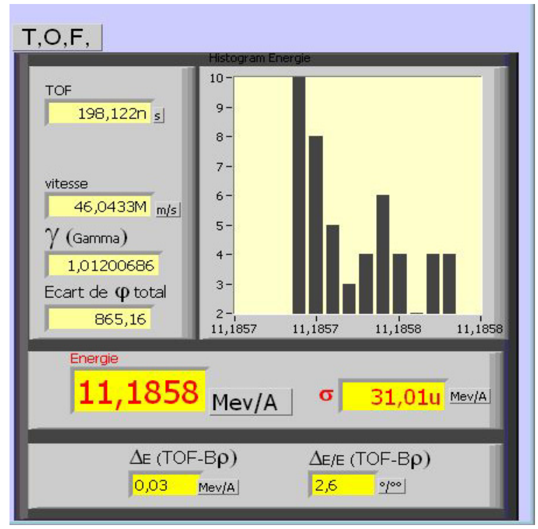

Figure 8: Beam Energy measurement on a carbon beam at GANIL. The difference with the spectrometer measure is under 3ppm (without correction).

CONCLUSIONS

The CST software is a useful tool for the 3D EM simulation and optimizing devices.

The tests in laboratory and with the beam confirm that the chosen method with a direct digitalization and a digital signal processing give good results. The comparison between the energy measurements with the spectrometer and the probe phase measurement shows a difference up to 2°/°° in energy and 1° in phase. New ADC boards and communication boards are under fabrication to get definitive electronic devices.

REFERENCES

[1] C. Jamet et al., "Injector Diagnostic Overview of SPIRAL2 Accelerator", DIPAC07, Venice, Italy.

[2] C. Jamet et al., "Phase and amplitude measurement for the SPIRAL2 Accelerator", DIPAC09, Basel, Switzerland.