# Truffaldino, a Tool for Simulating Rotating Coil Magnetometers

L. Bottura, M. Buzio, P. Schnizer, N. Smirnov

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**Abstract**

When investigating the quality of a magnetic measurement system, one observes difficulties to identify the "trouble maker" of such a system as different effects can yield similar influences on the measurement results. We describe a tool in this paper that allows to investigate numerically the effects produced by different imperfections of components of such a system, including, but not limited to: vibration and movements of the rotating coil, influence of electrical noise on the system, angular encoder imperfections. This system can simulate the deterministic and stochastic parts of those imperfections.

We outline the physical models used that are generally based on experience or first principles. Comparisons to analytical results are shown. The modular structure of the general design of this tool permits to include new modules for new devices and effects.

## 1 Introduction

Main dipoles and quadrupole being built in industry will be measured at CERN in cold condition. These measurements will mostly be performed using the rotating coil technique. While searching for the source of errors in rotating coil magnetometers one can see that different malfunctioning components can give different artifacts. The aim of this tool is to identify the weakest spots of the measurement system and to improve the quality of the LHC series magnet tests.

## 2 Approaches

Before implementing such a tool the first question to answer, is in which space the calculation should be performed. The multipole contribution of a coil's signal can be described as a frequency of $(n\omega)$ with $n$ the $n^{th}$ multipole. However desciribing a missing mark of the angular encoder would require a lot of frequencies. The second choise is the time domain. The advantages are that nearly all components of a rotating coil system can be modelled very simply.

A great part of this tool involves the modelling of the rotating coil and its artifacts. As the voltage is obtained as a differential of the flux, this has to be repeated in the tool. Here one can select between analytical and numerical modelling. For the numerical modelling typical the coil geometry is used. A vibrating coil would be modelled adding a vibration to the motion of each wire. The signal would then be differentiated. Using analytical formulae which discribe the imperfections allows the direct use of the sensitivity of the rotating coil to the magnetic multipoles.

## 3 Implementation

To mirror reality as close as possible an object oriented hierarchy was chosen. To each module the parts it depends on are registered. This allows a independent evaluation of each module in the chain to see the status of each part of the system.

# 4 Physical Model

The pysical models are based on first principles but still allow experimental accquired input to modell deficiencies of the system. This means e.g. instead of trying to find the eigenfrequencies of a mechanical coupling its vibration is modelled using a Fourier series.

# 5 Comparison to analytical results

If a torsional vibration of the type $p * \sin(\omega t)$ exists between the harmonic coil and the angular encoder fake harmonics are generated as described by formula:

$$C_{p+n} \approx \frac{nK_n}{2K_{p+n}} \zeta \bar{C}_n \tag{1}$$

$$C_{p-n} \approx - \frac{n\bar{K}_n}{2K_{p-n}} \bar{\zeta} C_n. \tag{2}$$

$C_n$ is the $n^{th}$ multipole of the magnet field, $K_n$ the coils sensitivity to the multipole, $\zeta$ the amplitude, $p$ the frequency index of the vibration and $\omega$ the nominal rotation speed. In the figure on page 17 the comparison between the analytical and the numerical calculation is shown.

# 6 Example Applications

As examples of applications te following examples are shown:

- *electromagnetic noise pickup:* In the cables the signal of electro magnetical noise of the environement was measured. This noise was modelled and its effect on the measurement system was calculated.
- *Explaining a fake quadrupole in a dipole:* A quadrupole component was measured in our dipoles which was much larger than the field calculations predicted. One source which could generate such a fake quadrupole is torsional vibration. Using the tool the vibration was found to have to be of the order of $\approx 10\, mrad$. We know that our system is performing far better.

# 7 Conclusion

A system, simulating a rotating coil magnetometer has been described. It allows to study the main components and imperfections of such a system. The basic structure is given and comparisons to analytical results were shown. Due to its modularity it is straightforward to add new components to study additional imperfections.