CHARACTERISATION OF A SINIS PROGRAMMABLE BINARY JOSEPHSON JUNCTION ARRAY AS A REFERENCE FOR THE FRENCH WATT BALANCE EXPERIMENT.

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ABSTRACT:

The kilogram is presently the only unit of the Système International (SI) still defined with a single artefact. Among the research developed by national metrology laboratories in order to propose a new definition, one of the possible way is the watt balance experiment (WB). It consists in comparing a mechanical and an electromagnetic power in a two-phase measurement [1]. The first one (static measurement) consists in comparing the Laplace force rising on a coil driven by a direct current and immersed in a magnetic field to the weight of a standard mass. During the second one (dynamic measurement), the voltage induced at the terminals of the same coil moved in the same magnetic field at a known velocity is measured. Through the use of quantum effects, respectively the Josephson effect and the quantum Hall effect to measure voltage and resistance, a link between the mass and the Planck constant is established.
The $1x10^{-8}$ expected relative uncertainty for the whole determination implies that each individual quantity must be measured with a relative uncertainty at least one order of magnitude better.
For voltage measurements, a dedicated programmable Josephson array set-up has been developed. The main element is a SINIS binary array, provided by PTB and composed of 14 sections constituting a 14 bit frequency to voltage DAC. When driven with a 70 GHz microwave source, each segment being biased by a direct current, it delivers programmable voltages in the range of ± 1.18 V. The detector used in the set-up is a combination of a low noise preamplifier and a digital voltmeter.
The I-V characteristics of each segment with and without microwave irradiation were first determined, showing an homogenous behaviour of all the sub-arrays. All critical currents were equal to 1.4 mA while the first voltage plateaus were centred at 2mA, the adjustment of the microwave power leading to plateau widths of about 1 mA. Precise measurement of the plateau associated to the 1024 junctions segment showed flatness better than $1x10^{-10}$ V in a range of 0.8 mA Moreover, measurements during several weeks occurred without any flux trap.
Direct comparisons were performed against two different types of arrays available in the laboratory. The first one was a classical SIS array used for routine calibrations. The voltage difference between the 1.18 V delivered by each array and measured by the mean of an EM N11 nanovoltmeter showed differences of about $1x10^{-10}$ V with a standard deviation of the mean of the same value. During the second comparison, the SINIS WB array has been compared to a similar programmable array using an EM A20 preamplifier and an Agilent 3458A digital voltmeter, with same results.

Finally, a step-up procedure has been used to check the additivity of the voltages delivered by the different segments of the WB SINIS programmable array. The voltage delivered by each segment was compared to the voltage delivered by all the segments of lower weight connected in series. The deviations and standard deviation of the mean were always lower than $1x10^{-11}$ V.
These results clearly show that the performances of the programmable array are totally adequate for the needs of the watt balance experiment. More details on the set-up and the comparison results will be given at the time of the conference.

References

[1] B. P. Kibble, "A measurement of the gyromagnetic ratio of the proton by the strong field method,"*Atomic Masses and Fundamental Constants 5 (edited by J. H. Sanders and A. H. Wapstra), New York,Plenum Press*, pp. 545–551, 1976.
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