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Michaud, Alain

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Accurate Measurement of Microwave Power in the IEC: R-70 (WR-138) Waveguide Transmission Line

Alain Michaud

Measurement Science and Standards,
National Research Council, Canada,
Ottawa, ON, Canada K1A-0R6
(Email: Alain.Michaud@nrc-cnrc.gc.ca)

Abstract—We compare the accuracy of different techniques to measure guided RF power at 6.83 GHz. The transmission line is a standard rectangular metallic waveguide IEC: R-70 (WR-138). We used three calculable standards including a waveguide calorimeter, a coaxial calorimeter, and an atomic (quantum based) power meter based on laser cooled rubidium atoms.

Index Terms—Microcalorimeter, radio-frequency (RF) power traceability, laser cooling, Rabi oscillations.

I. INTRODUCTION

The calorimetric power sensor is the most accurate way to evaluate the amount of incident power in transmission lines. However, one can imagine a different technique based on the interaction with an atomic vapour in order to probe the amplitude of RF field [1][2][3].

In order to show the merits of this new type of standard, one needs to compare the two systems in such a way that it would include the best results from both methods. In [2] we could compare our “atomic” system to a coaxial type transfer standard by using coaxial to waveguide adapter. Although this was not the limiting factor in our study, it did not represent a typical uncertainty for this kind of measurement. We then decided to build a waveguide calorimeter that would be used for direct comparison with the atomic (quantum) system.

The objective is to study the aspects of the comparison between the (new) atomic standard and the calorimetric standard.

II. “ATOMIC” POWERMETER [2]

As amazing as it sounds, the “laser cooled” atoms simply fall through a rectangular metallic waveguide, due to the effect of the gravity. At the exit port, the phase of the internal (coherent) atomic state is shifted by an amount proportional to the field amplitude and the interaction time ie. the time spent inside the guide.

This “interaction” is linear (periodic oscillation), sensitive (long interaction time to the small effect of gravity), and does not absorb the radiation. This system has a potential for being very accurate, or at least the design is based on a very different concept than the “temperature” based standards.

The system is passive, requires a continuous (CW) unmodulated signal, and is therefore compatible with any direct substitution (comparison) method.

III. J-BAND CALORIMETER

Our system is designed around the use of rubidium, which dictates the measurement be performed at 3.035 or 6.834 GHz. We adopted the standard rectangular R-70 (34.8×15.8 mm) guide corresponding to the higher frequency. The thin walled waveguide calorimeter presented in [4] has been rebuilt. We will show its design and characteristics.

IV. NRC ATOMIC POWERMETER

Although our atomic powermeter [2] had an excellent sensitivity ($\sim 50 \mu\text{W}$), linearity ($\sim 0.05\%$) and dynamic range ($\sim 20\text{dB}$), its accuracy has to be improved:

RF field distribution

A small cylindrical tube is attached to both sides of the waveguide. Although the leakage of the field outside of the guide is limited, there is a small distortion in the field distribution. This could result in an apparently wider guide than the actual one. This effect had to be studied.

V. OUTLINE OF THE PRESENTATION

The presentation is a progress report of our project that will focus on our most recent work. Questions and comments are welcome.

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