A Novel Method for Power Measurement of a Short Pulse Gyrotron Using Friis Transmission Formula at W-band

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***Abstract*— In this paper, we introduce a new measurement method for a W-band, high power short pulse gyrotron using Friis transmission equation. The proposed method is superior to other calorimetric measurements since it provides a real-time power measurement and without calibration. To apply to Friis transmission equation, we derive the directivity of Gaussian beam in detail. Also, to demonstrate the method, we measured the output power based on the proposed method and compared with conventional measurement. The results prove that the proposed new power measurement technique works very well without any limitation applying it to higher average and peak power and long pulse duration.**

I. Introduction

THE output power and frequency are important measure for analyzing the performance of the gyrotron. The accurate output power measurement of tens of kilowatts for short pulse (< 1 msec) might be difficult due to low average power. Alternatively, we used a surface calorimeter to measure the output power. However, it is also difficult to measure the power because the calorimeter is optimized for a laser power measurement. To increase the absorption factor, the surface of the calorimeter needs additional layers covered with carbon painting. The Friis transmission equation is defined in terms of the ratio of the received power to the transmitted power, distance, and antenna gains [2]. In this study, we derive the gain for a gyrotron output Gaussian beam as a transmitter in detail.

II. Results

From Friis transmission equation, we derive in detail that the maximum directivity of the Gaussian beam can be written as

$$D_t = D_0 = 8\frac{\pi^2 w_0^2}{\lambda^2} \tag{1}$$

where, w_0 is the beam waist radius. Using Eq. 1, Friis transmission equation for Gaussian output beam of the gyrotron can be express as,

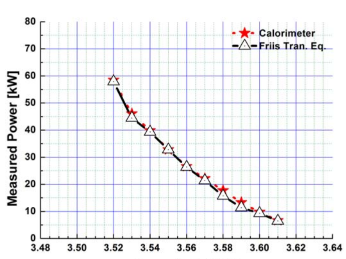

Fig. 1. The power measurement with respect to the magnetic field varying

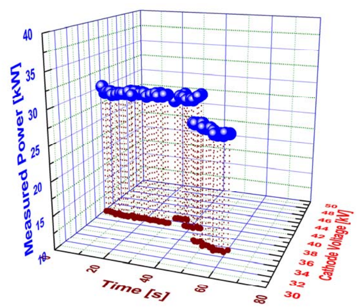

Fig. 2. Real-time output power measurement

$$\frac{P_r}{P_t} = \frac{\lambda^2}{(4\pi R)^2} D_t \cdot D_r \tag{2}$$

Figure 1 and 2 are results of the output power measurement using Eq. 2. Fig. 1 shows the output power measurement result as the main magnetic field varies. This result shows an excellent agreement between two methods. The new proposed Friis method and the conventional calorimetric method. Furthermore, great advantage of this technique is that it is capable of measuring the output power in real-time. Fig. 2 shows power measurement results obtained by the proposed method every second. In this test, we determined that proposed method is responsive immediately and exactly with respect to the cathode voltage varying.

III. Summary

In this study, we derive the directivity of Gaussian beam and Friis transmission equation for high power of the gyrotron in detail. As far as we know, power measurement using Friis transmission equation for a W-band, a high power of tens of kilowatts is the first time verifying. We carry out the power measurements depending on the B-field varying, cathode voltage varying and distance varying. All results show a good agreement. This study shows that the proposed method can be an alternative method to measure the output power of high power gyrotron sources.

References

[1]. M. Thumm, "State-of-the-art of high power gyro-devices and free electron masers update 2002," *FZK internal report,* 2003.
[2]. D. C. Hogg, " Fun with the Friis-space transmission formula," *IEEE Trans. Antennas. Propag.,* vol. 35, no. 4, Aug., 1993.