Frequency and Phase Locking Experiments on a 2.45 GHz magnetron.

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***Abstract* — This paper describes a study and experimental demonstration on a magnetron operating at 2.45 GHz. We checked the characteristics of the 1 kW magnetron. There were two noise sources of magnetron at frequencies of 0.5 Hz and 75 kHz. In order to suppress these noises, we used an external injection locking method. Measurement results showed that the frequency noise suppression was down up to 30 dBc and the phase fluctuation is reduced to 4 degrees when injection input power was 7 W. Power combining experiments were performed using two identical magnetrons. An initial result showed an output power of 2 kW, corresponding to combining efficiency > 93%.**

Index Terms — magnetron, 2.45 GHz, noise suppression, magic-tee

I. Introduction

A 2.45 GHz high power (> kW) microwave source, magnetron is used for many applications including industrial heating applicators, wireless power transmission, and plasma lighting. A primary interest is due to a very economical advantage. However, the magnetron oscillation frequency and phase are sensitive to the voltage and current variation of the DC power source applied between the cathode and anode. For the case of phase arrayed wireless power transmission, high-efficiency power coupling is required using a phased array antenna with a large number of magnetrons operating under good frequency and phase stabilities [1].

Here, it is important to fix the oscillation frequency and phase of each magnetron. There is one of technique to lock frequency and phase, or the external injection locking method [2] [3]. In this paper, we analyzed the frequency and phase noise characteristics of a 2.45 GHz magnetron and suppressed noises of magnetron frequency and phase using the external injection locking method.

II. Meaurement result

For this reaserch, we used a Panasonic magnetron (TMx 12-TI012) which generates a maximum power of 1.2 kW CW power at 2.45 GHz. We checked the characteristics of the magnetron in the free-funning state at output power 1 kW and found two noise sources originating from two frequencies of 0.5 Hz and 75 kHz. The heater was turned off during all measurements. Noise spectral peaks were confirmed using a Agilent PSA (Performance Spectrum Analyzer, E4440A). Phse fluctuations were measured by three methods: VNA (Vector Network Analyzer), phase detector (Analog Device, AD8302-EVALZ) and oscilloscope using a mixer. The noise sources at 75 kHz and 0.5 Hz were found to be from the magnetron power supply. For noise suppression of magnetron, we used the external injection locking method. Fig. 1. Is a photo of the magnetron injection locking measurement setting. The external injection source is an Ampleon LDMOS solid state power amplifier.

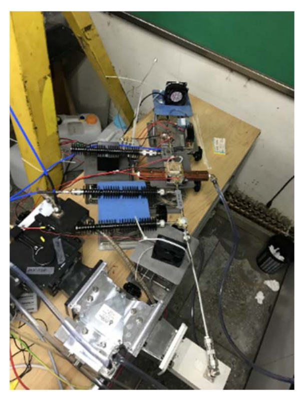

Fig.1 : A Photo of the magnetron measurement using injeciton locking source

Fig. 2. shows the spectrum analyzer results of an injection locked magnetron where the injection powers are 0.3W, 3 W, and 7.5 W. The higher the injection power is the better the noise suppression performance as expected. Figure 2(a) is injeciton power level of 0.3 W. The siganl level difference between the oscillation frequency and the sideband noise was measured to be 20 dBc at 0.3 W and 35 dBc at 7 W injection power, respectively.

(a) (b) (c)

Fig. 2. Spectral peaks from a frequency locking magnetron with the injection powers of 0.3 W, 3 W, and 7.5 W.

The phase difference between the reference signal and the injection locked magnetron output was measured through the osciloscope using phase detector as shown in Fig. 3. The green trace indicated phase flunctuation. When injecion power is 7 W, the 0.5 Hz and 75 kHz noises nearly disappeared and the output power was in a stable state.

(a) (b) (c)

Fig. 3. Osciloscope signals on phase locking magnetron with the injection power.

In the table below, measured results on the signal-to-noise level and phase fluctuation are summarized.

Table 1. Results on signal-to-noise level and phase fluctuation.

	(a) 0.3 W	(b) 3 W	(c) 7 W
Sideband level difference (dBc)	20	30	35
Delta phase (deg)	unlocked	9	4

We combined two identical 1kW magnetrons using Magic-Tee An initial result of power combiner test showed a maximum output poewr of ~ 2 kW at 2.45 GHz. This corresponds to a combining efficiency of more than 93 %. More detailed results will be presented at the conference.

VII. Conclusion

A 2.45 GHz 1 kW magnetron using external injection locking method was experimentally characterized for suppressing both freuqncy and phase noises. For the case of injection input power of 7 W, the sideband frequency was suppressed to 30 dBc and the phase flunctuation was reduced to 4 degrees, which was good enough to combine magnetron powers through a Magic-Tee.

Acknowledgement

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