Study on a 5.8GHz Injection-locked Magnetron for Transferring Data

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***Abstract*— It is shown that a 5.8 GHz injection-locked magnetron can transmit a digital data. We modulated a motor control signal on a 5.8 GHz signal by frequency shift keying. Utilizing injection locking method, we injected this modulated signal to a 5.8 GHz magnetron and the magnetron amplified this modulation signal as a transmitter. At the receiver, we demodulated this signal and controlled the motors. The transmitted data rate worked at 9600 bps with no bit errors. In the future, we will build this system for a wireless power and data transfer system in the same microwave bands.**

Keywords—5.8GHz Magnetron; injection-locked; frequency-shift keying;

I. INTRODUCTION

With develop of industrial production, the factory automation has been continuously improved. Electric trolleys or transport robots that carry parts are widely used in the automated factory [1]. However, the electric trolleys need people to charge the battery. We propose to use a wireless power transfer system to charge the power to the trolley. At the same time, the system using the same microwave to control the trolley. Since the electric trolley needs a large amount of power for charging, we suggest a magnetron to as the microwave transmitter as shown in Fig.1.

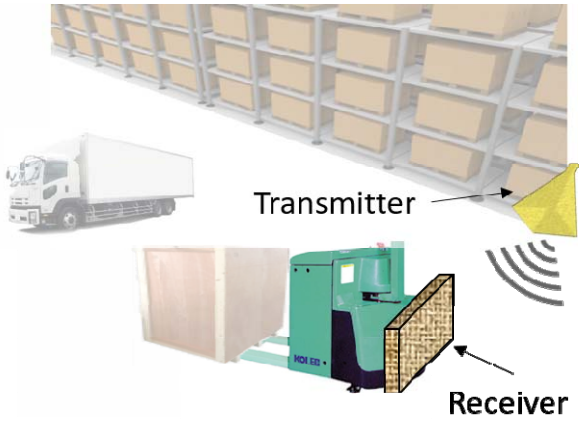

Fig.1 A wireless power transfer system for electric trolley

Magnetrons as low cost and high efficiency microwave sources, are widely applied in heating areas such as microwave ovens. However, the magnetrons have poorly stable output frequency and high noise. According to Alder's equation [2], an injection signal stabilizes the magnetron oscillation frequency. A phase locked loop (PLL) method controlled the magnetron phase and the magnetrons worked in a low noise level [3]-[6]. The injection-locked magnetron was applied in a wide area, like wireless power transfer [3]-[4], power combining [5], and communication [6].

Regarding frequency and phase modulations by a 2.45GHz injection-locked magnetron as a transmitter for communication, the transmission of phase-shift keying (PSK) data at 2 Mbps has been achieved by Tahir *et al*. [6]. However, his developed system had few discussions on frequency-shift keying (FSK) which was much lower cost than PSK system. As the system transmitted a square wave signal without information, it could not evaluate the quality of communications well.

In this study, we utilize a 5.8 GHz injection-locked magnetron for a wireless power and data transfer system whose antenna size can be smaller than 2.45 GHz. The magnetron outputs can follow the injection signal in the frequency locking range [2]. A data signal was modulated by frequency shift keying (FSK) on the injection signal, then this modulated signal was injected to the magnetron. The magnetron output the high-power level microwaves carrying the data information, at the receiver, then we can rectify the microwave power and demodulate this data signal. In this paper, we present how to utilize the injection-locked magnetron to transmit data.

II. FSK BY INJECTION-LOCKED MAGNETRON

A. Experimental Arrangement

Figure 2 shows a block diagram of the injection-locked magnetron for the FSK modulation system. A LabVIEW program was designed and output the motor control signal to the modulator (Pakite PAT-630 transmitter) through the RS-232 TxD port. The modulator modulated the control signal on the microwave by FSK. This FSK modulated signal was amplified to 10 W and via a circulator, injected to the magnetron (Panasonic M5802). Here, the modulation frequency was nearly at the magnetron oscillation frequency. Then, the magnetron followed the modulated signal and amplified it. Then the high-power modulated microwaves were transmitted through the antenna. At the receiver, the transmitted microwaves were received and demodulated by a frequency demodulator (Pakite PAT-630 receiver). Then a

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driver circuit was designed that transferred the demodulated data to control the motors.

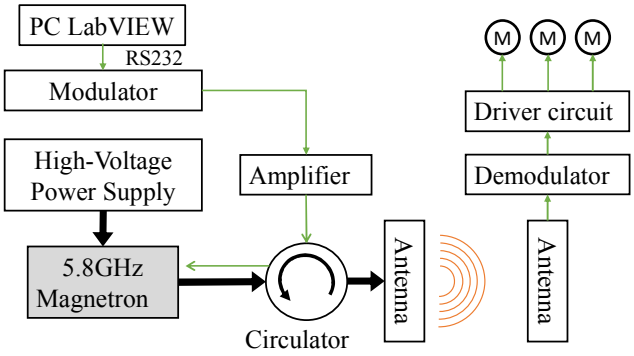

Fig.1 Schematic of data transfer system by FSK modulation

B. *FSK MODULATION*

The parameters of the FSK modulation experiments are shown in Table. 1. Figure 3 shows the transmitted the control data and demodulated data. The demodulation data controlled the motors successfully. Figure 4 shows the photos of data transfer system. Through the driver circuit, the motors were controlled.

Here, the magnetron that must be worked in the locking state can transmit the data. According to Alder's equation, the locking range Δf was related to the injection power level [2]. In this experiment, the locking range Δf was 5 MHz when the injection power was 10 W. The FSK bandwidth should be narrower than the locking range of the magnetron, otherwise the magnetron will lose its locking status.

TABLE I. PARAMETER OF THE FSK MODULATION EXPERIMENTS

Anode Current	250 mA
Anode Voltage	-4.48 kV(DC)
Filament Current	7.4 A
Filament Voltage	3.35 V(AC)
Injected Power	10 W
Output Frequency	5.774 GHz-5.776 GHz
Output Power	655.3 W
Modulation	FSK@9600 bps

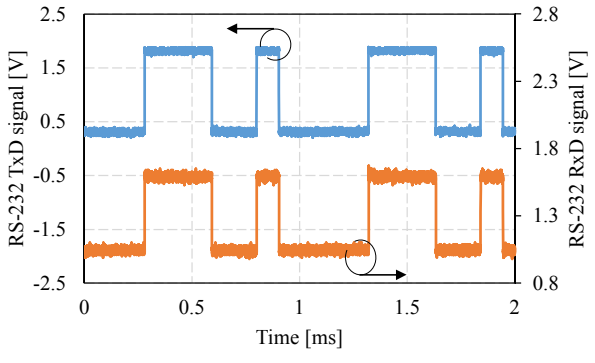

Fig.3 Transmitted data vs. received data

Increasing the injection power, the transmission data rate can be faster. We also confirmed this data transfer system provided much higher rate such as 115200bps and worked well. We set the demodulated data as the RS-232 RxD data, and fed back to the PC to check the data error. The transmitted data file was larger than 1 MB, and the received data had no bit error. We demonstrated a 5.8 GHz injection-locked magnetron could transmit the FSK data.

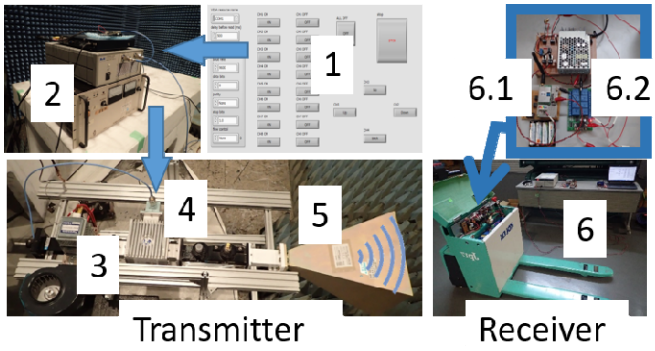

Fig.4 Photos of data transfer system (1: LabVIEW panel, 2: High-Voltage Power Supply and Amplifier, 3: Magnetron, 4: Circulator, 5: Transmitting antenna, 6: Electric trolley, 6.1: Demodulator, 6.2: Driver circuit)

III. CONCLUSIONS

We demonstrated a 5.8 GHz injection-locked magnetron could transmit the motor control data by FSK modulation. Through the transmitted data, we successfully controlled the electric trolley. In the future, we will build a wireless power and data transfer system for the electric trolley.

ACKNOWLEDGMENT

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