'91 KACC 1991. 10. 22~24

ONLINE OUTPUT POWER MEASUREMENT OF FULL-BRIDGED MOS-FET RF POWER INVERTER OPERATING AT SHORTWAVE FREQUENCY

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ABSTRACT

An online RF power measurement is needed for the full-bridged MOS-FET RF power inverter because the output current and/or voltage waveform is other than sinusoidal. In order to satisfy the requirement, the online measurement of the output power of this type of RF power inverter by the use of the PC-98 personal computer has been presented. The current and voltage waveforms are sensed by the digital oscilloscope probes so as to obtain the instantaeous power and they are entered into the PC-98 personal computer so as to average the instantaneous powers. The RF power of up to 1 kw at 1 MHz measured for the power inverter at the output transformer. This method was confirmed to be applied to evaluate the load resistance change with temperature.

1. INTRODUCTION

Although the full-bridged MOS-FET RF power inverter operating at shortwave frequency has been constructed so as to generate an output power of up to 1 kW (1)-(3), the output power has been measured by using an RF output power meter of rectifier type. This type of RF output power meter can measure only the root-mean-square value of the RF output power and it cannot precisely measure the output power unless the output voltage waveform is of accurate sinusoidal waveform.

The output current or voltage waveform is generally other than sinusoidal when measured across the output terminals of the full-bridged MOS-FET RF power inverter of voltage-fed type operating at 2.5 to 3.8 MHz, and the measured power contains some errors in the order of more than 10 % as well as errors which may occur generally in measuring the RF power at shortwave frequency unless the corrections for the waveform change have been done.

The errors can be reduced if the instantaneous current and voltage product is contiguously obtained after the current and voltage waveforms are acquired by measurement. Although the current and voltage product can be obtained from the calculation of the current and voltage waveforms on the oscilloscope, the calculation has to be carried out offline after the current and voltage waveforms are acquired on a graphic display printer connected to the GPIB terminal of the oscilloscope. Although the online output power measurement is required for the full-bridged MOS-FET RF power inverter, it can only be done by using the personal computer connected to the oscilloscope to measure the current and voltage waveforms.

2.FULL-BRIDGED MOS-FET RF POWER INVERTER

Figure 1 shows the circuit diagram of the full-bridged MOS-FET RF power inverter operating at shortwave frequency. In the power inverter shown in Figure 1, the output power can be measured by reading both the voltage waveform across the secondary winding on the output transformer and the current waveform flowing through the output lead wire leading from the secondary winding on the output transformer to the load resistor.

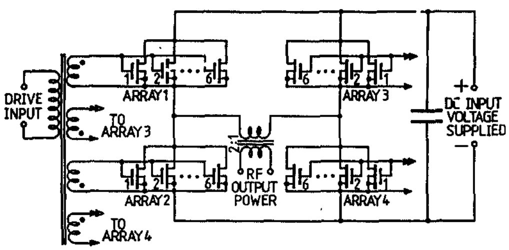

Fig.1 Circuit diagram of the full-bridged MOS-FET power inverter of voltage-fed type.

The output current and voltage waveforms are other than rectangular at shortwave frequency even though no resonant circuit is connected to the output transforner.

When the output current is sinusoidal although the output voltage is rectangular, output power P_O is given by

$$P_O=\frac{8E^2\eta_D}{\pi^2}\cdot\frac{1}{\frac{2R_{on}}{N}+R_L} \quad (1)$$

and peak load current I_m is given by

$$I_m=\frac{1}{\pi}\cdot\frac{4E}{\frac{2R_{on}}{N}+R_L} \quad (2)$$

When the output current and voltage are rectangular, output power P_O is given by

$$P_O=\frac{E^2\eta_D}{\frac{2R_{on}}{N}+R_L} \quad (3)$$

and peak load current I_m is given by

$$I_m=\frac{E}{\frac{2R_{on}}{N}+R_L} \quad (4)$$

From above expressions, the rectangular current is sensed in place of the sinusoidal current, errors in the order of approximately 20% are expected for measuring the RF output power.

Although this type of errors can be corrected from the theoretical expressions, the correction is troublesome in the online measurement and the correction errors may occur in many cases because the current and voltage waveforms are indefinitive depending on the parasitic circuit parameters.

3. MEASUREMENT SYSTEM

Figure 2 shows the schematic diagram of the measurement system, where the current and vcltage waveforms of the RF power output are respectively sensed by the current and voltage probes of the digital oscilloscope and the current and voltage probe outputs are fed from the GPIB terminals of the oscilloscope. The current and voltage probes cover the frequency range of up to 40 MHz.

The full-bridged MOS-FET RF power converter was operated at a frequency of 1 MHz, and the output power was in the experiment fed from the output transformer to the 50 ohm resistive load through a 50 ohm coaxial cable with a length of 1 meter. Since the current and voltage waveforms are respectively sampled and dissected into up to 1024 points to calculate the current and voltage product at the respective sampling points. Figure 3 summarizes the sampling procedures for obtaining the RF output power. In order to acquire the current and voltage values at the respective sampling point, digital oscilloscope outputs are sent to a PC-98 personal computer.

Current i and voltage v at the respective sampling point are multiplied and the obtained are averaged at the respective sampling points over the entire cycle times displayed on the oscilloscope CRT at a time. The output power is first calculated as a current and voltage product at a sample time and then the respective output powers at the respective sample times are averaged over the time of 2 to 4 cycles of the RF current and voltage. That is,

$$P_{out}=\frac{1}{T}\cdot\int_0^T iv\ dt \qquad (5)$$

$$=\frac{1}{N}\cdot\sum_{N=1}^{N} iv \qquad (6)$$

Where T is the time of averaging and N is the number of sampling points.

4. MEASUREMENT AND APPLICATIONS

Figure 4(A) through 4(D) show examples of the measured output power when the current and voltage are sampled over i through 4 cycle times of the RF power, respectively. Data indicates that 4 cycle periods are required to reduce the variations of data in the RF output power although one cycle time of period is allowed for the practical measurement.

An experiment was carried out to test the capability of the measurement system when the load resistance changes with the temperature as the time goes on after the power is applied to the load. Figure 5 shows the load resistance change measured from the output power change with time when the temperature of the load resistor rose.

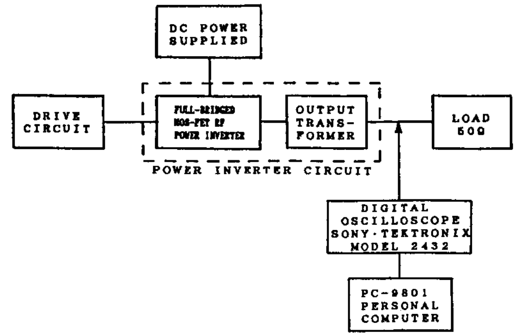

Fig.2 The structure of the measurement system.

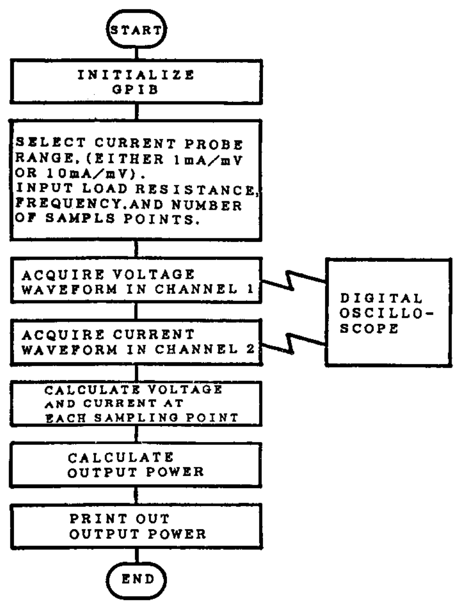

Fig.3 Flowchart of the measurement.

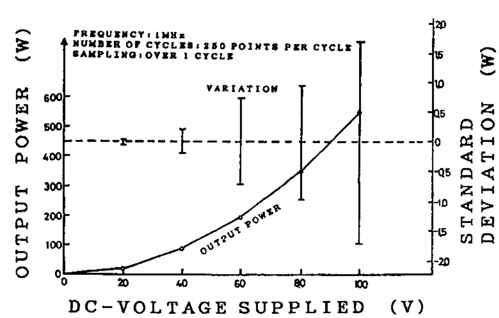

Fig.4-(A) Measured output power and standard deviation in terms of the DC voltage supplied. (Sampling of over 1 cycle)

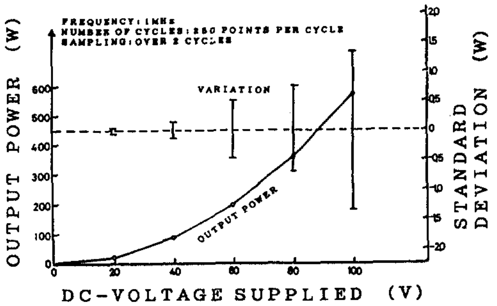

Fig.4-(B) Measured output power and standard deviation in terms of the DC voltage supplied. (Sampling of over 2 cycles)

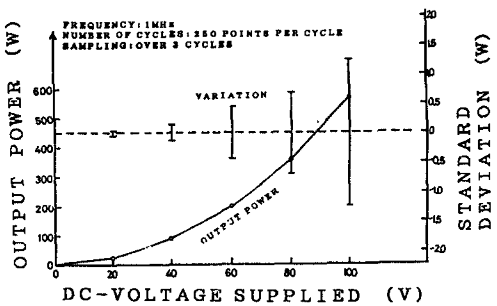

Fig.4-(C) Measured output power and standard deviation in terms of the DC voltage supplied. (Sampling of over 3 cycles)

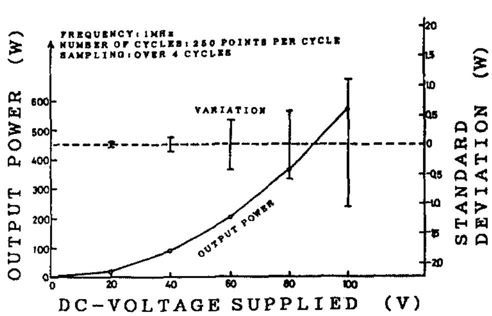

Fig.4-(D) Measured output power and standard deviation in terms of the DC voltage supplied. (Sampling of over 4 cycles)

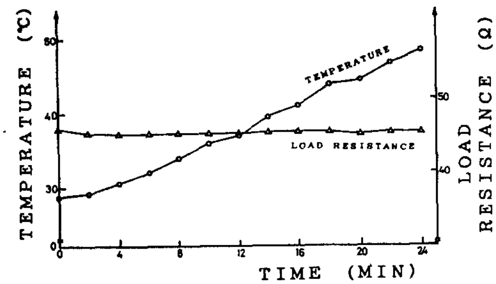

Fig.5 Measured temperature and load resistance in terms of elapsing time.

5. CONCLUSION

The instantaneous values of the RF current and voltage which are generated from the full-bridged MOS-FET RF inverter are directly fed from the digital oscilloscope to the PC-98 personal computer so as to calculate the instantaneous power online. This system can be used for the online measurement of the RF power generated from the RF power inverter even if the output current and voltage waveforms are other than sinusoidal.

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