TUNING MEASUREMENT OF MULTI-CAVITY KLYSTRONS IN DIODE MODE OPERATION

Shigeru Isagawa, Masato Yoshida
KEK, National Laboratory for High Energy Physics, 1-1 Oho, Tsukuba-shi, Ibaraki-ken, 305 Japan

Yoshihisa Ohkubo, Hiroshi Yonezawa
Electron Tube Div., Toshiba Corp., 1385 Shimoishigami, Ohtawara-shi, Tochigi-ken, 324 Japan

Abstract

The white noise method has been successfully used to measure resonant frequencies of intermediate cavities of multi-cavity triode klystrons in diode mode operation. Comparison has been made with the results in normal triode operation and has shown a good agreement. The same method has been applied to tuning measurement of a diode pulsed klystron, E3712. Although a small deviation has been found in tuning of one cavity, comparison with test results at the stage of cavity subassembly has shown a good agreement, too. A proposal is made to apply this method to *in situ* adjustment of cavity tuning in production line. If a modification were made in a klystron modulator circuit, the similar setup could be also used to suppress barium evaporation on to gun electrodes and protect pulsed klystrons from degrading in electrical insulation.

Introduction

To get the ideal behavior of a multi-cavity klystron, tuning of each cavity is very important. Even if the resonant frequencies are finely adjusted at the stage of cavity subassemblies, they can shift from desired values during assembling and heat treating processes. Cases not infrequently occur in which it becomes required to recheck the cavity resonant frequencies during operation. In the white noise method a weak beam is used as a probe to measure the tuning of such klystrons[1]. This method is very useful because resonant frequencies of input and intermediate cavities can be obtained *in situ* without using any additional coupling probes. It proved, for example, to be a powerful tool for recognizing the correlation between the cavity tuning and the dynamic performance of TRISTAN high power klystrons E3786[2]. Although it was invented for triode tubes equipped with a modulation anode[1], it can also be applied to tuning measurement of diode type pulsed klystrons such as E3712 for linear accelerators[3]. In this paper a method is described of observing cavity resonances of multi-stage klystrons in diode mode operation, in which a white noise is used in combination with signal processing techniques of a high resolution spectrum analyzer (e.g., SONY/Tektronix 2784).

Triode Klystrons in Diode Mode Operation

As the first step, the applicability has been tested by putting a couple of TRISTAN high power klystrons (YK1303 and E3732) each in diode mode operation. The modulation anode has been short-circuited to the body situated in earth potential. The beam current and the beam voltage up to 0.9A and 8kV, respectively, have been supplied from a portable high voltage power supply (Glassman PK8R900). No drive signals were fed to the klystron, as the input coupler was terminated with 50Ω or short circuited (see Fig.1). The signal source in this case is therefore an electron shot noise and/or a thermal noise that is randomly excited and injected into the input cavity, and can be practically treated as a white noise. By averaging out the small klystron output signals we could get the frequency spectrum informing about each cavity resonances as shown below.

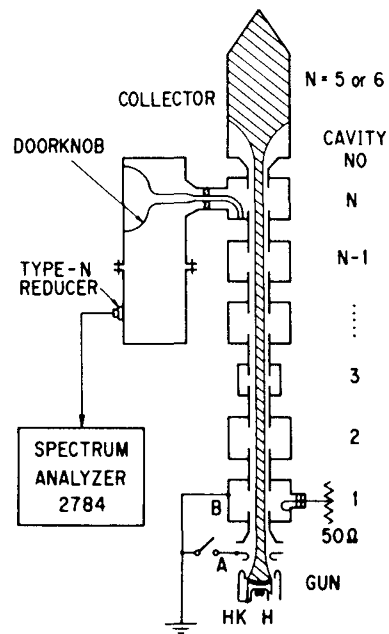

Fig. 1 Setup of the white noise method applied to triode klystrons in diode mode operation (A is connected to B in earth potential.)

TABLE 1
Results of Tuning Measurements of YK1303 (V28)

Cavity.	Measured values in triode mode operation (MHz)	Measured values in diode mode operation (MHz)	Factory tuning values (MHz)
Input	508.8	-----	509.0
Intermediate	[510.5]	[510.4]	510.58
"	(1,038) (1,042)	----- (1,042)	1,014.9
Penultimate	520.7	521.1	522.0
Output	[510.5]	[510.8]	510.7

Input is terminated with 50Ω.
( ) probably shows the ghost resonance.
[ ] means that resonances are overlapped.

The shape of the frequency spectrum was a little bit different between triode and diode mode operations. Detailed observation, however, showed that resonant frequencies of each cavity were consistent between both modes as summarized in Table 1 and Table 2. The second harmonic resonance of YK1303 could not be observed again just as shown before[1].

TABLE 2
Results of Tuning Measurements of E3732 (T61)

Cavity	Measured values in **triode** mode operation (MHz)	Measured values in **diode** mode operation (MHz)	Factory designed values (MHz)
Input	~ 507.5 507.4	----- 507.8	507
Intermediate	509.5 509.5	509.7 509.7	509.5
"	529.4 529.4	529.4 529.5	530
Penultimate	529.7 529.7	530.4 530.4	530
Output	-----	-----	508.6

Input is terminated with 50Ω (upper) and short circuited (lower).

(a)

(b)

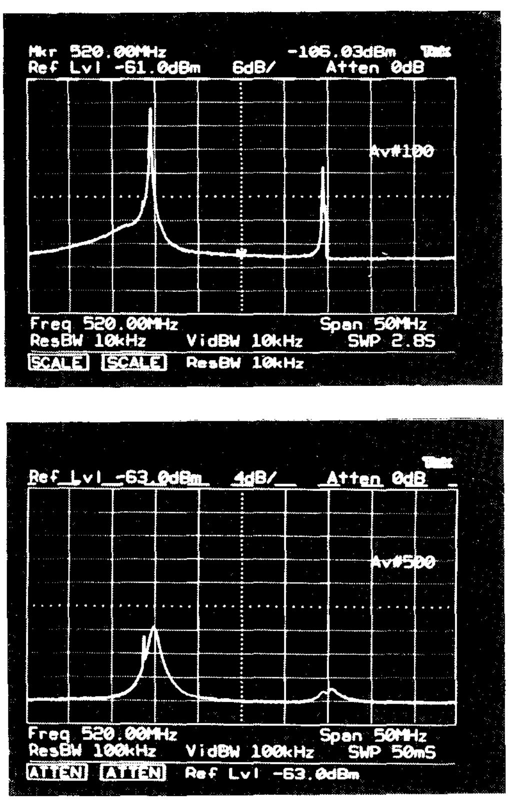

Fig. 2 Spectrum of the rf output of E3732 (T61) as seen on a spectrum analyzer 2784. (a) Triode mode operation. V_k 47.5kV, V_a 1.8kV, I_f 8.0A and I_b 0.2A. (b) Diode mode operation. V_k 7.98kV, I_f 8.0A and I_b 0.9A. The signal peak level is about -87dBm.

Tuning Measurement of Diode Tube E3712

The same measurement technique can be applied to a diode tube such as a high power pulsed klystron, E3712. In this case, however, as the coupling between beam and cavities were very small, it was necessary to artificially make the white noise and feed it intentionally to the klystron input. The noise was made by sweeping a signal generator and amplified with a wide-band signal amplifier. S/N was increased by use of the maximum-hold processing mode rather than signal averaging mode. The envelope of the spectrum can be used to distinguish location of cavity resonances. The klystron was set up in a focusing solenoid, but the oil tank was replaced by a simple open air insulating socket structure. E3712 has a pair of output branches, one was 50 Ω terminated and the other was connected to a spectrum analyzer by way of a coaxial-to-waveguide transformer. The heater power (AC 92V, 5A) was supplied through an insulating heater transformer (see Fig. 3).

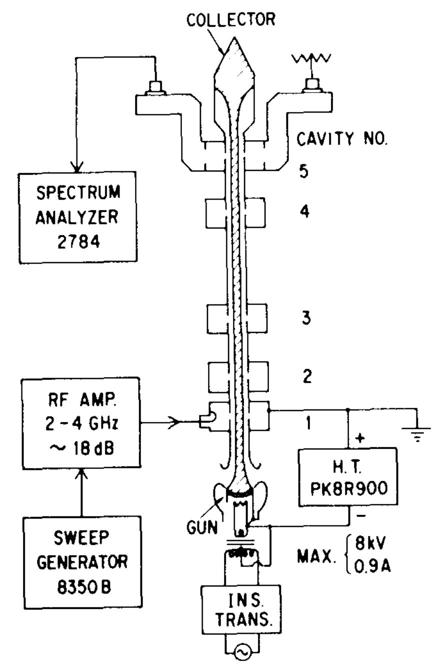

Fig. 3 Setup of the white noise method applied to a diode pulsed klystron E3712.

The beam is affected by focusing as well as tube vacuum conditions. The gain of the klystron is, therefore, dependent on both the beam current and the focusing coil current. According to the experiment, the optimum power level of the klystron input seemed about 25dBm that was made by combining 7dBm SG signal and 18dB amplification. Cavity resonances can be found in the spectrum as peaks, dips or intermediate dispersive forms, depending on the beam voltage and beam current conditions (see Fig. 4). The resolution band width of the spectrum analyzer can be less than 100kHz.

Shown in Table 3 are results of tuning measurements by the white noise method on a tube E3712 (S25) in comparison with the factory tuned values at the stage of subassembly. Both are consistent well each other but for No.2 cavity in which unnegligible tune shift about +2.8MHz can be found.

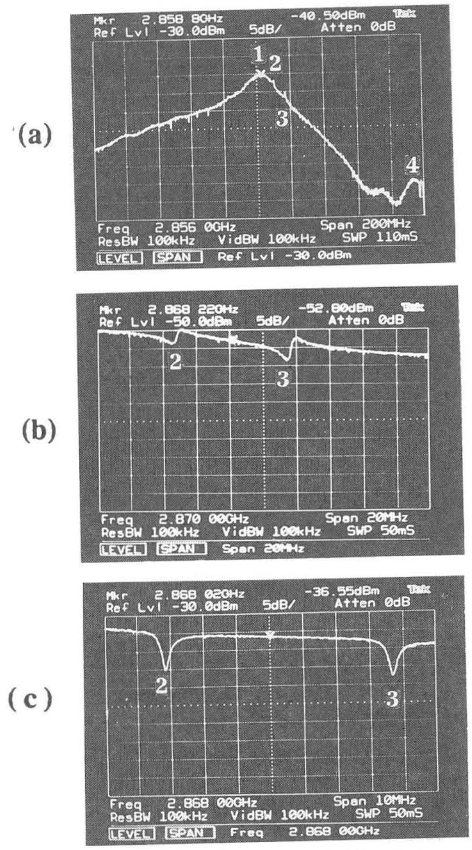

Fig. 4 Spectrum of the rf output of E3712 (S25) as seen on a spectrum analyzer 2784. (a) A whole view showing 1st, 2nd, 3rd peaks and 4th dip (on the extreme right). I_f 19A, V_k 5.42kV, and I_b 0.801A. (b) Enlarged view of 2nd and 3rd dips. I_f 14A, V_k 3.10kV, and I_b 0.352A. (c) Dispersive signals of 2nd and 3rd cavity resonances. I_f 16A, V_k 3.10kV, and I_b 0.350A.

TABLE 3
Results of Tuning Measurements of E3712 (S25)

Cavity NO.	Measured values with I_f=16A, I_b=0.35A and V_k=3.10kV. (MHz)	Measured values with I_f=14A, I_b=0.352A and V_k=3.10kV. (MHz)	Factory values tuned at the stage of subassembly. (MHz)
1	~ 2860	~ 2860	2856.0
2	{2864.82}	2864.85	2862.0
3	{2871.78}	2871.66	2871.0
4	2951.41	2951.26	2951.0
5	-----	-----	2856.0

{ } shows the averaged value between a dip and a peak.

Discussion

As an example, with one typical S-band pulsed klystron, we could find out an unnegligible tuning shift in No.2 cavity. This method can be of course extended to measurements in other frequency regions, e.g., from L-band through Ka-band very easily, because the spectrum analyzer 2784 covers the frequency range up to 40GHz. In this experiment a standard focusing magnet that is completely closed with an iron yoke was used. If an air cooled open stack magnet was prepared and approaching to cavity tuners became free, fine adjustment of cavity tuning *in situ* could be realized in the production stage.

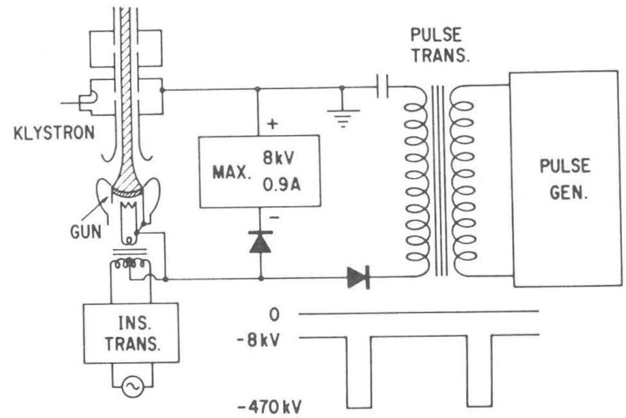

Fig. 5 A proposal to use a small cw offset voltage to suppress unwanted barium evaporation on to gun electrodes.

Furthermore, if a modification were made in a klystron modulator circuit as illustrated in Fig. 5, the similar setup could be also very useful to suppress barium evaporation on to gun electrodes. The cw operation of pulsed klystrons with relatively low level offset of high voltage, piled up to high level pulse of high voltage, would be beneficial to suppress unwanted coating of excess barium on to gun electrodes. It would protect tubes from degrading in insulation that could often be promoted during overwhelmingly long standby period lacking high voltage barium-clearing beam. Without offset voltage, barium would evaporate in isotropic directions. With the offset voltage, even about 2~3kV, the evaporation would change to the DC sputtering. In the residual gas plasma, barium would be discharged, confined and returned to cathode. Consequently much amount of barium coating on to gun electrodes would be avoided.

References

[1] S. Isagawa, Yo. Takeuchi, M. Yoshida and M. Ono, "White Noise Method to Measure the Cavity Resonant Frequencies of the Muti-Cavity-Klystrons", Proc. 6th Sympo. on Accelerator Science and Technology, Tokyo, Japan, Oct. 1987, pp123-125, KEK Preprint 87-96 (Oct. 1987).

[2] M. Yoshida, S. Isagawa, Yo. Takeuchi, M. Ono, S.Yoshimoto, K. Itoh, K. Kobayashi and K. Oya, "Characteristics and Stabilization of anode Current of TRISTAN 1.2MW CW Klystrons", Proc. 9th Sympo. on Accelerator Science and Technology, KEK, Japan, Aug. 1993, pp131-133, KEK Preprint 93-99 (Aug. 1993).

[3] H. Yonezawa, S. Miyake, K. Gonpei, K. Oya, T. Okamoto, "Development of a 100MW S-Band Pulse Klystron", Proc. 14th Int. Conf. on High Energy Accelerators, Tsukuba, August 1989, Part. Accel. **30**, pp.219-224(1990).