RADIOLOCATION OF A HOM SOURCE IN THE PEP-II RINGS*

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Abstract

A signal from an antenna situated in the Low Energy Ring (LER) was used to find a broken shield in a bellows in the High Energy Ring (HER) during a single-bunch HER operation.

INTRODUCTION

Heating effects due to Higher Order Modes (HOMs) became very prominent in the LER ring, downstream the Interaction Point (IP). We lost several BPM buttons in this region, when we tried to shorten the LER bunch length by increasing the RF voltage [1]. BPM button heating was associated with a resonance at 7 GHz [2]; the higher frequency part of the HOMs, excited by the shorter bunches. To study the spectrum of the HOM fields in this case we installed a HOM antenna in this region of the LER ring.

HOM ANTENNA

We did not want to disturb the smoothness of the vacuum chamber, so we used an existing vacuum port that had an RF screen, through which the HOM fields may be coupled to RF antenna. The screen was modified to allow more HOM power to leak through the screen. We had previously measured the spectrum of the HOMs using antennas, installed in the high voltage connections of a vacuum pump [3]. In that case, the HOM fields had to penetrate the RF screens and the pump itself in order to arrive at antenna.

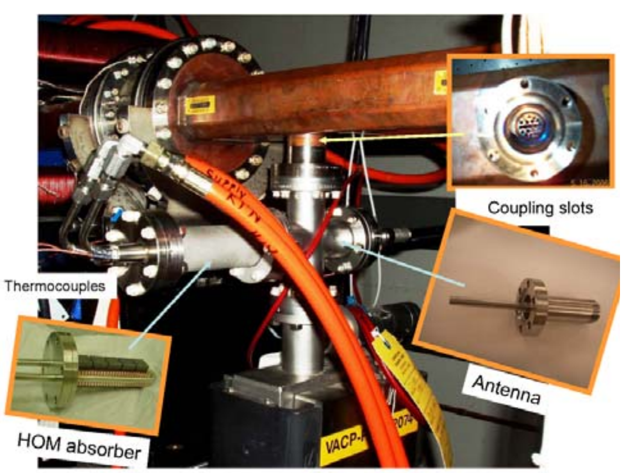

Figure 1: LER ring. Pump cross with a rod type antenna and HOM absorber. Coupling slots in the RF screen filter the transverse fields.

In this case, we have decided to install a rod type RF antenna inside the one arm of the pump cross to make it easier for the fields to go from the beam vacuum chamber to the antenna. In the arm, opposite to the antenna, we installed a water-cooled HOM absorber to capture and measure the HOM power. Thermocouples were attached to supply and return water pipes to measure the difference in water temperatures. A photo of the pump cross is shown in Figure 1. To increase the coupling between the beam vacuum chamber and the antenna we made longitudinal slots by connecting the holes in the RF screen (Figure 1). Longitudinal slots allow only the transverse fields to couple to antenna. In this way, we did not increase the longitudinal impedance of the beam pipe. The cross pipe size is 35 mm in diameter, so the minimum frequency, which may be seen by antenna, is 4.8 GHz.

HOM SPECTRUM AND OSCILLOSCOPE SIGNALS

We connected the spectrum analyzer or oscilloscope through Heliax coaxial cable, with an attenuation of 12 dB/100 ft at eight GHz. Total attenuation was about 30 dB. The HOM spectrum measured with this antenna is shown in Figure 2. This spectrum was taken during a multi-bunch operation.

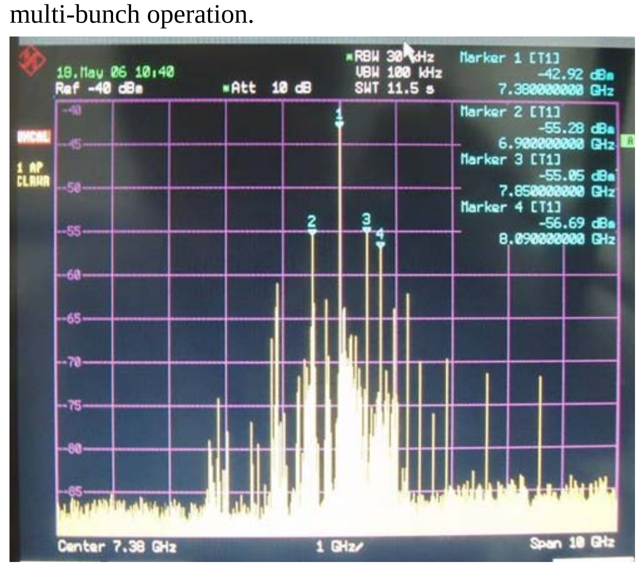

Figure 2: HOM spectrum, measured in a multi-bunch operation.

The observed spectrum has a maximum at 7.38 GHz and smaller peaks in 3 GHz frequency band. That confirms that HOMs generated in this region have significant power at the BPM resonant frequency. Unfortunately, the coupling was not good enough to remove much HOM power from the beam chamber. The thermocouples did

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not show any noticeable difference between incoming and outgoing water temperatures.

An oscilloscope signal in a multi-bunch two beam (LER and HER) operation is shown in Figure 3. One revolution turn is equivalent to 7.3 μsec. The detailed signal structure is shown at the picosecond scale. Every division is 500 psec. It can be seen that the signal has beat waves around 7 GHz.

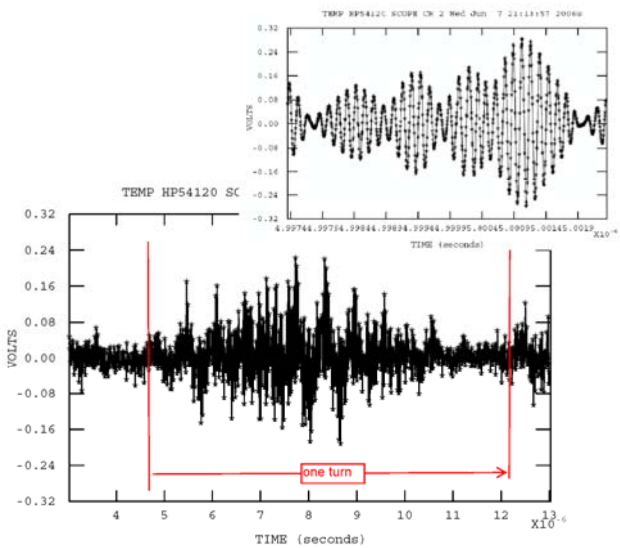

Figure 3: Oscilocope signal from the antenna in a multi-bunch two beam operation.

An antenna signal in a single-bunch LER operation is shown in Figure 4. The signal amplitude is larger at the beginning and then decays. We may assume that the signal consists of two parts. One part corresponds to the field, which is excited by a bunch at the antenna position. The second part of the signal may consist of wake fields, excited at different locations in the ring. As the LER bunch is coming from the Interaction Region (IR), then the high frequency IP wake fields travel with the bunch, pehaps with some small delay. Signal with a large delay may only come from beam chamber elements, located downstream of the antenna position.

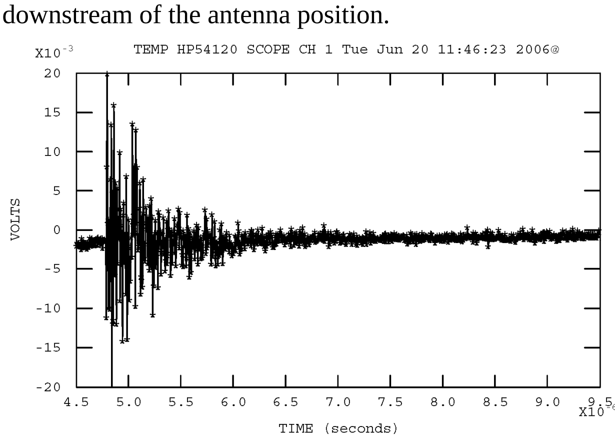

Figure 4: Oscilocope signal from the antenna in a single bunche LER operation.

ANTENNA SIGNAL IN A SINGLE-BUNCH HER OPERATION

PEP-II has two separate LER and HER rings, which have a mutual 5-meter long vacuum chamber at the IR. Therefore, wake fields excited in one ring can propagate to another only through the IR. In a single-bunch HER operation we expect to see the signal of the wake fields generated by the HER beam at IR. The signal will be approximately the same as what we see during single-bunch LER operation (Figure 4), but with a smaller amplitude. However, what we actually saw was very different. Figure 5 shows this signal.

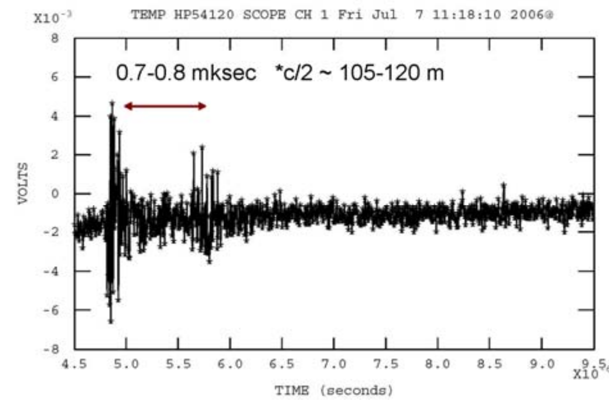

Figure 5: Oscilocope signal from antenna in a single bunche HER operation.

There was a second large maximum or second signal with a delay to the first one of approximately 07-0.8 μsec. The HER bunch travels in the opposite than the IP to the LER antenna, so the second signal can come from some chamber element (HOM source), which is located after the IP (see Fig. 6).

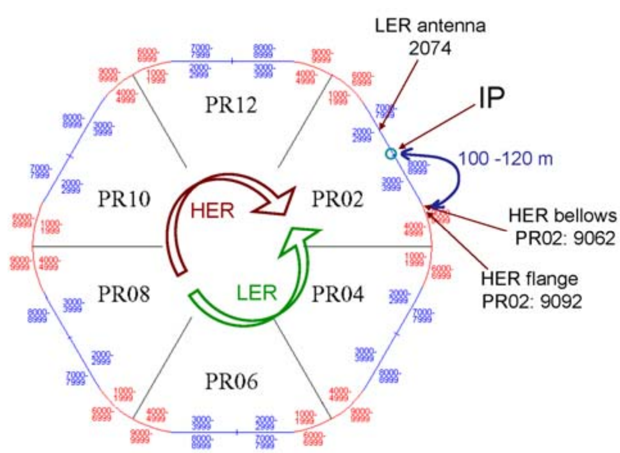

Figure 6: PEP-II region map with position of LER antenna, IP and HER bellows at the distance of 120 meters from the IP.

The second signal will arrive at the antenna after the first one with a time delay which is equal to twice the time needed for a bunch to travel from the IP to this element – or HOM source. We can therefore estimate the distance between the HOM source and IP. It is to be about 105-120 m. This places the HOM source in Arc 3 (Fig. 6). In 2006, when we did this measurement, there was no indication of HOM heating in this region; however, we already knew that some octagonal bellows and flexible omega RF seals for our flex flange joints flanges might become HOM sources. Later when we increased the HER current and RF voltage, HOM heating became a problem in this region as well. We found a temperature rise and temperature oscillations at the 9062-bellows and 9092-flange. The location of these elements was in 100-120 m from IP, i.e. in the same place, predicted by the antenna measurement. In June 2007, this bellows and omega seal were removed. Their photos are shown in Fig. 7-8.

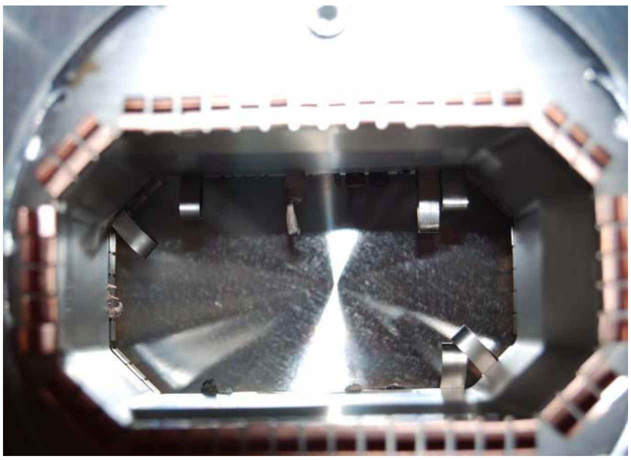

Figure 7: Damaged and melted fingers of 9062-bellows.

Figure 8: Melted omega seal of the 9092-flange.

HOM power was strong enough to melt bellows fingers and omega RF seals. Damaged bellows fingers were inside the beam pipe. This caused high amplitude wake fields, which came to the antenna as a second signal.

After the replacement of the bellows and omega seal, we did another antenna measurement and found that the second signal had disappeared (Fig. 9). The history plot of the temperatures in 9062-bellows and 9092 flange (Fig. 10) shows that the HOM antenna found the damaged elements a year before the temperature started to elevate.

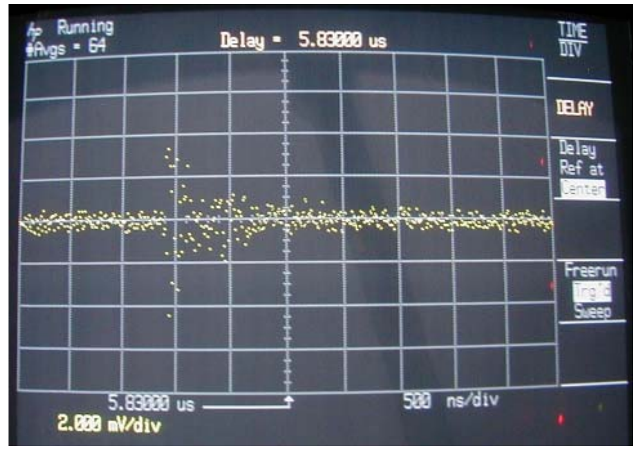

Figure 9: Oscilloscope signal from the antenna in a single bunch HER operation after we had replaced the damaged bellows and omega RF seal.

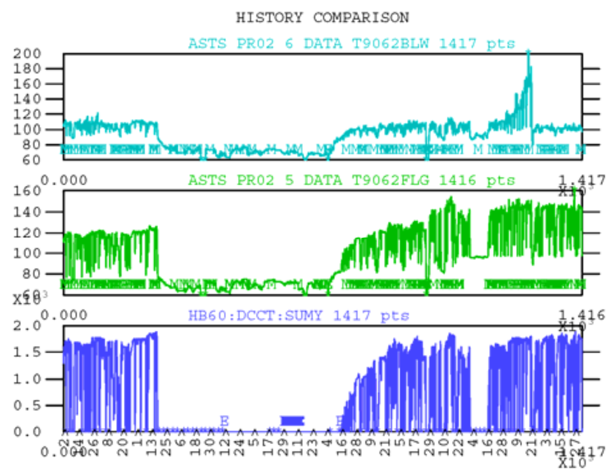

Figure 10: History plot of the 9062-bellows convolution temperature (upper plot), 9092-flange temperature (middle plot) and HER current (lower plot) during the period form June 1, 2006 to August 1, 2007.

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