RF Radiation Measurement for the Advanced Photon Source (APS) Personnel Safety System*

J.J. Song, J. Kim, R. Otocki and J. Zhou
Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439 USA

Abstract

The Advanced Photon Source (APS) booster and storage ring RF system consists of five 1-MW klystrons, four 5-cell cavities, and sixteen single-cell cavities. The RF power is distributed through many hundreds of feet of WR2300 waveguide with H-hybrids and circulators. In order to protect personnel from the danger of RF radiation due to loose flanges or other openings in the waveguide system, three detector systems were implemented: an RF radiation detector, a waveguide pressure switch, and a Radiax aperture detector (RAD). This paper describes RF radiation measurements on the WR 2300 waveguide system.

I. INTRODUCTION

As shown in Fig. (1), the APS personnel safety system consists of RF radiation monitors, X-ray radiation monitors, klystron shield switches, and waveguide air pressure gauges.

The RF radiation monitors are installed at the injection site, extraction wing, and the connecting corridor. Two cooling blowers are installed to provide air pressure in the WR2300 waveguide system. Three sets of photohelic meters are installed to monitor the air pressure in the waveguide and blowers. In case there is a gap in any of the waveguide flanges, the air pressure will drop and RF radiation will be generated from the gap. The RF system will be automatically shut down if the air pressure drops below the preset trip point. The trip point is set at a value based on the "air pressure – gap size" relationship. The purpose of this study is to develop a relation between the gap size and the amount of RF radiation which will allow a direct comparison between the pressure and the RF radiation in the waveguide system.

II. Measurement Setup

According to IEEE standards, the radiation threshold limit value (TLV) at 352 MHz is 3.52 $\mathrm{mW/cm^2}$. The APS high-power RF system consists of five 1-MW klystrons which operate at about 400-kW RF output power. Each cavity in the booster or storage ring receives about 100-kW RF power. We will use this input power level as the normalized power for RF radiation measurement.

The measurement setup is shown in Fig. (2). An HP 8753C network analyzer is used as the signal source, followed by a 100-W 50-dB power amplifier. An HP 8594E spectrum analyzer is used to monitor the signal in the waveguide, coupled through a 50-dB directional coupler. At the ends of the waveguide there

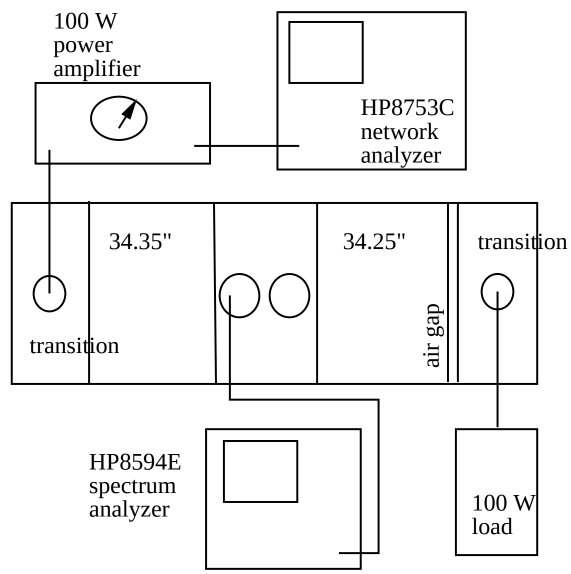

Figure. 2. Measurement setup for the waveguide radiation test

are two coaxial transitions, one connected to the source and the other to a 100-W load.

A flange gap between the straight waveguide section and the transition section is created by placing washers between the flanges. The gap size is controlled by the number of washers used. The reflected power due to the gap and the load is also monitored by the output signal of the directional coupler.

The waveguide is placed in a position where one of the narrow walls is on the ground. The RF radiation is measured at two broad walls and one of the narrow walls facing upwards. The radiation is measured at different distances from the gap: one right at the gap with zero distance and the other one foot away from the gap. This practice is aimed at evaluating the reduction in radiation with respect to the increasing distance. The measuring instrument is a Narda RF radiation detector with probes.

III. Measurement Results

The frequency of the continuous wave (CW) signal is set at 351.93 MHz, which is the operating frequency of the APS booster and storage ring RF system. The input signal level in the waveguide is set at 17, 20, 47, and 50 dBm, respectively, corresponding to 50 mW, 100 mW, 50 W, and 100 W. The signal level in the waveguide is monitored by the spectrum analyzer connected to the coupler with a -50.5-dB coupling coefficient. The attenuation of the cable is 1.5 dB. Thus the correction factor is 50.5+1.5=52 dB. Fig. (3) gives the forward signal

*Work supported by U.S. Department of Energy, Office of Basic Energy Sciences under Contract No. W-31-109-ENG-38.

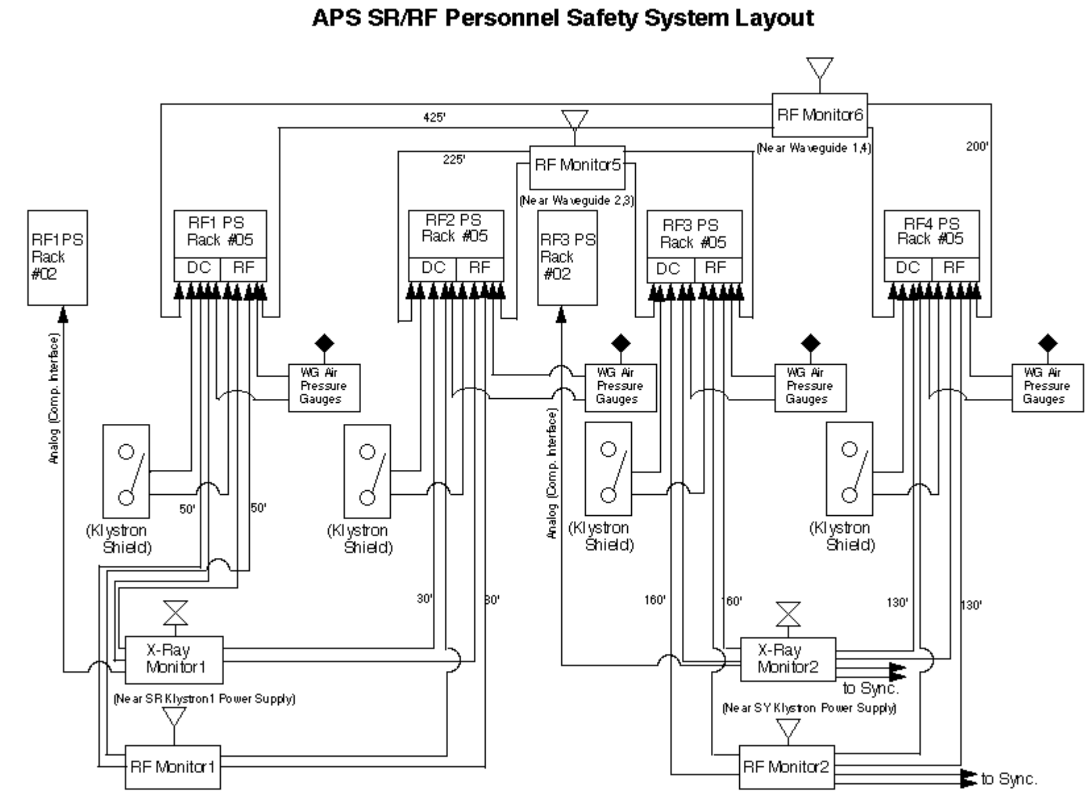

Figure. 1. APS Storage Ring Personnel Safety System

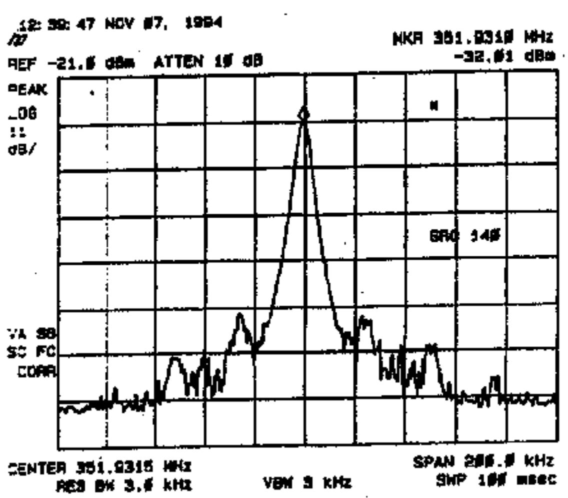

Figure. 3. Forward signal in the waveguide measured by the spectrum analyzer

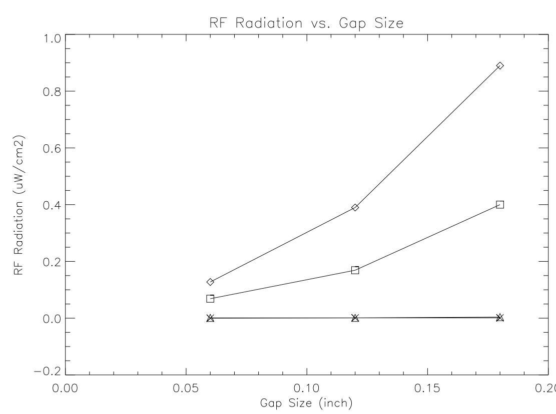

Figure. 4. RF Radiation vs. Gap Size.

measured from the spectrum analyzer with a gap size of 0.18 inch. In this case the signal level in the waveguide is given by -32.01+52=20.01 dBm. The reflected power is roughly 30 dB lower than the forward power, indicating the fact that even for a large flange gap, the reflected RF power is fairly small. Measurement results of RF radiation are given in Fig. (4). The top curve with a $\diamond$ symbol is measured at the flange with 20 dBm input power; the middle curve with a box symbol is measured at the flange with 17 dBm input power; the bottom curves with a $\times$ symbol is measured at one foot away from the flange with 20 dBm input power; and the bottom curve with a triangle symbol is measured at one foot away from the flange with 17 dBm input power. The input power mentioned above is the actual forward power in the waveguide.

In order to interpret these data in terms of the threshold limit value (TLV), we need to normalize these data to the input power

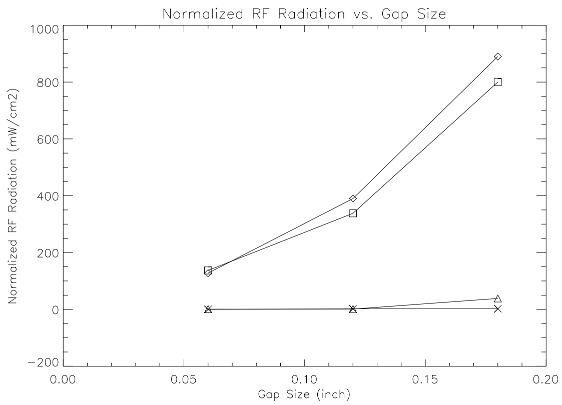

Figure. 5. RF radiation vs. gap size normalized to 100 kW input power

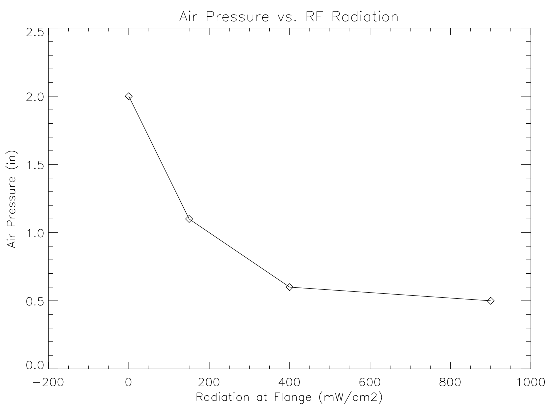

Figure. 6. Air Pressure vs. RF Radiation

of 100 kW,

$$R_{\mathrm{site}} = \frac{100\mathrm{kW}}{P_{\mathrm{in}}} \cdot R_{\mathrm{lab}}, \tag{1}$$

where R_{site} is the projected radiation level with a 100-kW input power and R_{lab} is the measured radiation with P_{in} input power. From the measured result of Fig. (5) we can see that the radiation measured at the flange is much higher than the threshold limit value (TLV). But the radiaton at one foot away falls below the TLV for a fairly large gap size of 0.12 inch. This indicates that special safety provisions may not be necessary if this procedure is a realistic simulation of what might occur in the APS RF system.

From the measured results of radiation versus gap size, and the air pressure versus gap size, we can find out a direct relationship between the radiation and air pressure, as depicted in Fig. (6). This curve can be used as a guideline to set the air pressure trip point for RF protection.

IV. The RAD System

An RF monitor can effectively detect RF radiation leaks, but it is a localized device which can only be located in a number of scattered places. In order to develop a cost effective way to detect RF radiation in a widely distributed system, the Radiax aperture detector system was proposed and is being implemented. Radiax cables with apertures on the outer conductor will be installed along the waveguide system. Any RF radiation from waveguides will penetrate into the cable through the apertures and deliver a signal to the detector connected to the end of the cable.

V. Conclusions

RF radiation due to waveguide gap is measured. For a fairly large gap (0.12 inch), the projected radiation level from 100 kW input power falls below the threshold limit value ($3.52\mathrm{mW/cm^2}$) at one foot away from the flange gap. A Radiax aperture detector system will be installed as a more cost-effective way to monitor RF radiation in a wide area.