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Search for molecular bremsstrahlung radiation signals in Ku band with coincidental operations of radio telescopes with air shower detectors

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Abstract. Microwave radiation from extensive air showers is expected to provide a new technique to observe UHECR. We insatlled and operate radio telescopes in Osaka and at Telescope Array site in Utah, USA. In Osaka, we are coincidentally operating two Ku band radio telescopes with an air shower array which consists of nine plastic scintillators with about 10 m separation. In Utah, we installed two telescopes just beside the Black Rock Mesa fluorescence detector (FD) station of the Telescope Array experiment, and we operated the radio telescopes coincidentally with FD event triggers. We report the experimental setups and the results of these measurements.

1. INTRODUCTION

In order to develop a new generation of UHECR detectors with several orders of magnitude bigger target volume, the most actively studied and most promised method is related to techniques at radio wavelength band [1, 2]. Radiations in some specific frequency bands have a better transmittance and a longer mean free path in the air than visible light and charged particles.

Here we report our research into detections of microwave radiations from extensive air showers (EAS) in Ku ($\sim$12 GHz) band. The method of shower detections in this band has some remarkable feature, a small expected angular resolution of 1° and negligibly small atmospheric attenuation of radiation. Moreover, since operations of the array are unaffected by weather and regardless of day or night, we can expect calorimetric measurements with 100% duty factor.

2. EXPERIMENT AT OSAKA CITY UNIVERSITY

In order to detect and to study microwave signals coincident with EAS, we operated radio telescopes with an air shower array. In this experiment, we used the air shower array is located in Sugimoto campus of Osaka City University. The array consists of nine surface scintillation detectors of 0.5 m^2 area. The detectors are arranged in three rows, and the spacing of the detectors are about 7 m to north-south and about 10 m to east-west directions. The total effective area of the array is about 294 m^2. All the detectors

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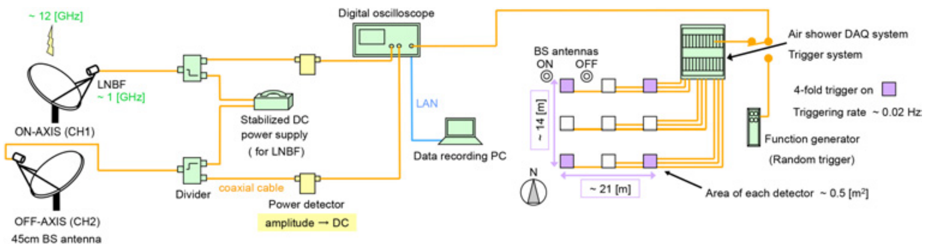

Figure 1. The experimental setup of the microwave antennas with the EAS array at Osaka City University.

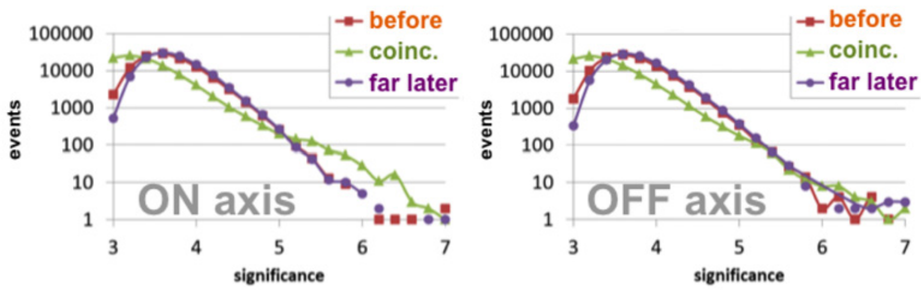

Figure 2. Histograms of the significance values in three different ranges in the waveforms.

are calibrated to be a same hit rate of about 200 Hz. This array makes a trigger by a four fold coincidence of the detectors at the corners of the alignment.

Simultaneously working microwave radio telescope system for this study consists of two parabolic antennas with LNBF for Ku-band, power sensors, a digital oscilloscope and a PC for controlling and recording data. The Ku-band antenna with LNBF which is CBS45AST made by Nippon Antenna, which is 45 cm diameter, the received frequency of 11.7–12.75 GHz and the converter output frequency of 1032–2072 MHz. In the experiment one antenna, called “ON-AXIS”, pointed to zenith and was covered by microwave absorbent materials (IR-K150 by TDK-EPC), and the other, called “OFF-AXIS”, pointed to north-west with 30° elevation. The noise temperature are measured as 182.9K and 201.4K for ON and OFF telescopes, respectively. Output of each LNBF is connected to a power sensor, ZX47-60-S+ by Mini-Circuits laboratory, Inc., through a bias-tee which is ZX85-12G-S+ by the same company. The digital oscilloscope is TDS 3032 by Tektronix, Inc. operated with a sampling frequency of 100 MHz and a record length of 10,000 samples. A block diagram of the experimental setup is shown in Figure 1.

The observation period is from Jun. 30th, 2011 to Dec. 12th of the same year, and the total observation time is 2664.0 hours. Although the number of EAS triggers is 235,860, the number of recorded events is 114,265 because of a large dead time in DAQ process of the oscilloscope.

Every recorded waveform has 100 μs length, and for the signal search analysis a waveform was divided into three regions, “BEFORE”, which is 40 μs range before the trigger, “COINC.”, 10 μs range after the trigger, and “FAR LATER”, which is the other region of 50 μs length. Then in each region for every waveform the maximum amplitude was determined and the significance relative to an averaged fluctuation was calculated. The histograms for the significance values for ON- and OFF-AXIS telescopes are shown in Figure 2. Comparing the histograms we found excess between 5.5 and 6.0 sigma on the ON-AXIS “COINC.”. However, radio signals are expected to be appeared in “BEFORE” region from delay time measurements of the array and the telescopes, so then we cannot conclude the excess caused by radiations induced by EAS particles before careful study of signal delays in our experiment system.

Figure 3. The two antennas are installed just beside the BRM station building. Behind the antennas and the fence the buildings for the electron accelerator called ELS are seen in this photo.

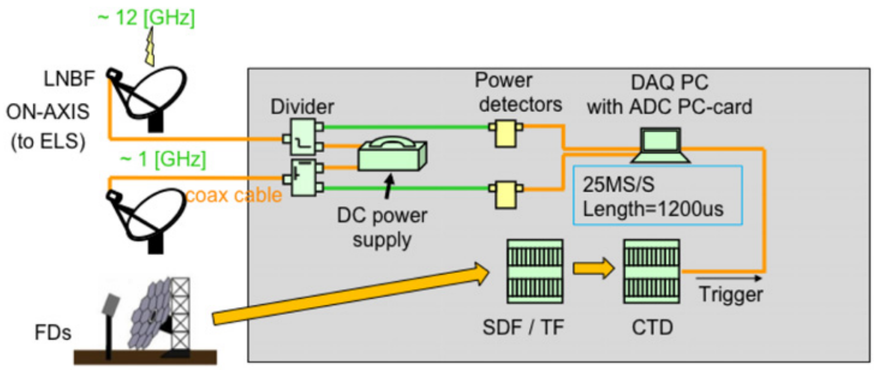

Figure 4. The experimental setup at the Telescope Array site.

3. EXPERIMENT AT THE TELESCOPE ARRAY SITE

We brought the radio telescope system to the Telescope Array site at Delta, Utah, and we installed it just beside the south-east FD station building, called “Black Rock Mesa (BRM) station” [3]. A photograph is shown in Figure 3. The system, block diagram is shown in Figure 4, is almost same as used in Osaka, but a high pass filter with the cutoff frequency of 33 kHz and an amplifier installed in the signal line. Moreover the data recording system was changed to an ADC module attached on PC-card bus, CSI-320110 by Interface, Inc., which has two input channels with a sampling frequency of 40 MHz, 10bits for ±1 V input range and 4M sample/ch record length.

In November 2011, DAQ test had been successfully done, but unfortunately planned observations of electron beams shot by the accelerator in front of the BRM station were not carried outbecause of the OS trouble of the DAQ PC. In March 2012 we plan to operate coincidentally with the accelerator.

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