Search for isotropic microwave radiation from electron beam in the atmosphere

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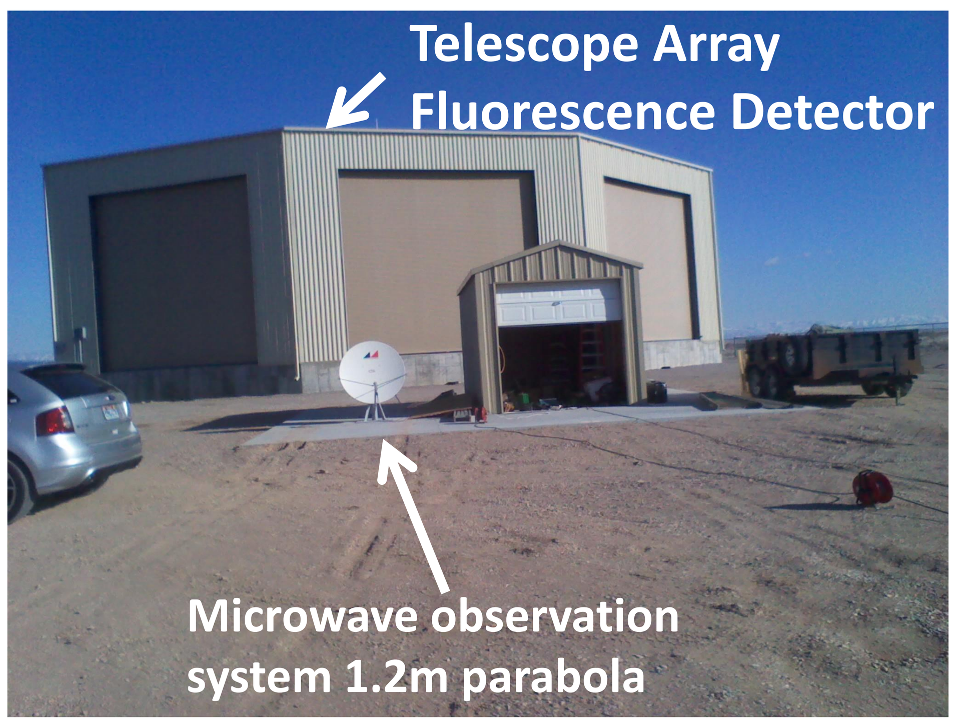
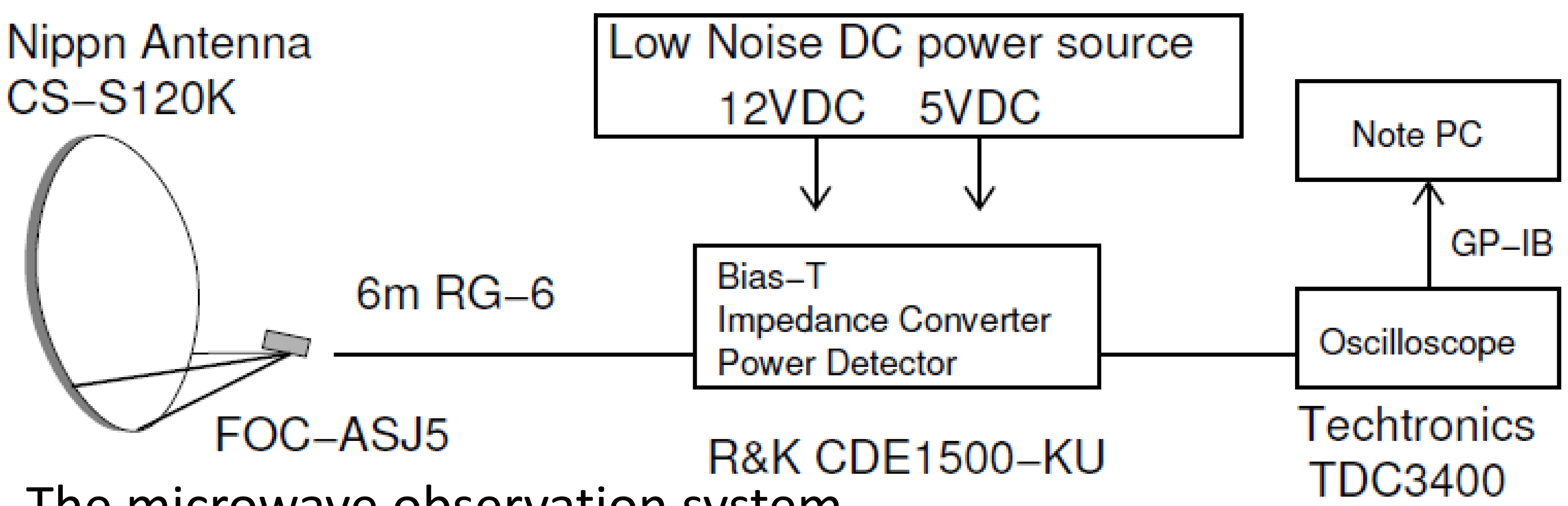
Isotropic microwave radiation from extensive air showers can be exploited by next-generation techniques to observe UHECRs, thereby allowing us to make unbroken observation of entire air shower just like fluorescence detector with 100 % duty cycles like particle detectors. To study microwave radiation from air showers, we used Electron Light Source (ELS) located at the Telescope Array Observatory in Utah, USA.



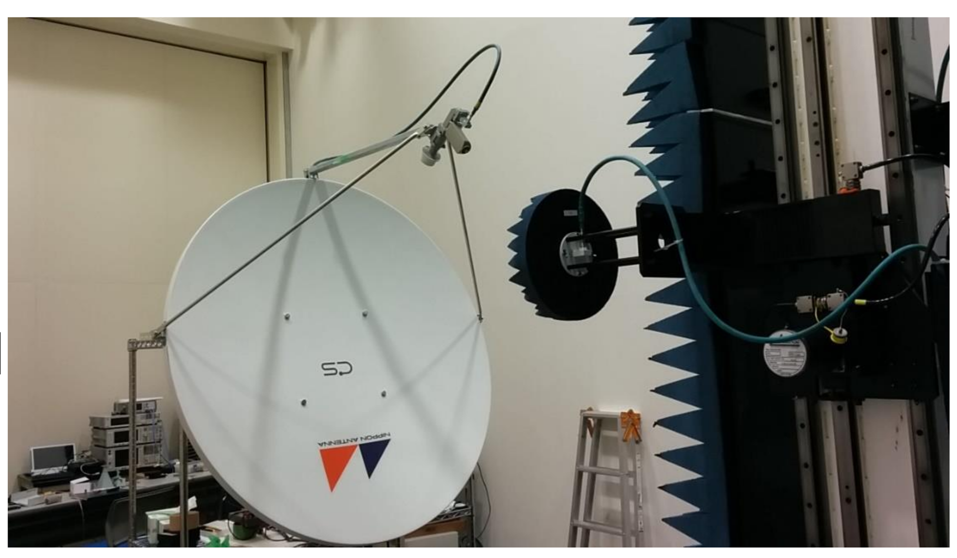
The ELS is located in one of the fluorescence detector site. This device had been constructed to calibrate the fluorescence detectors that detect the ultra violet photons from air shower. To simulate extensive air showers, the ELS emits an electron beam into the atmosphere.

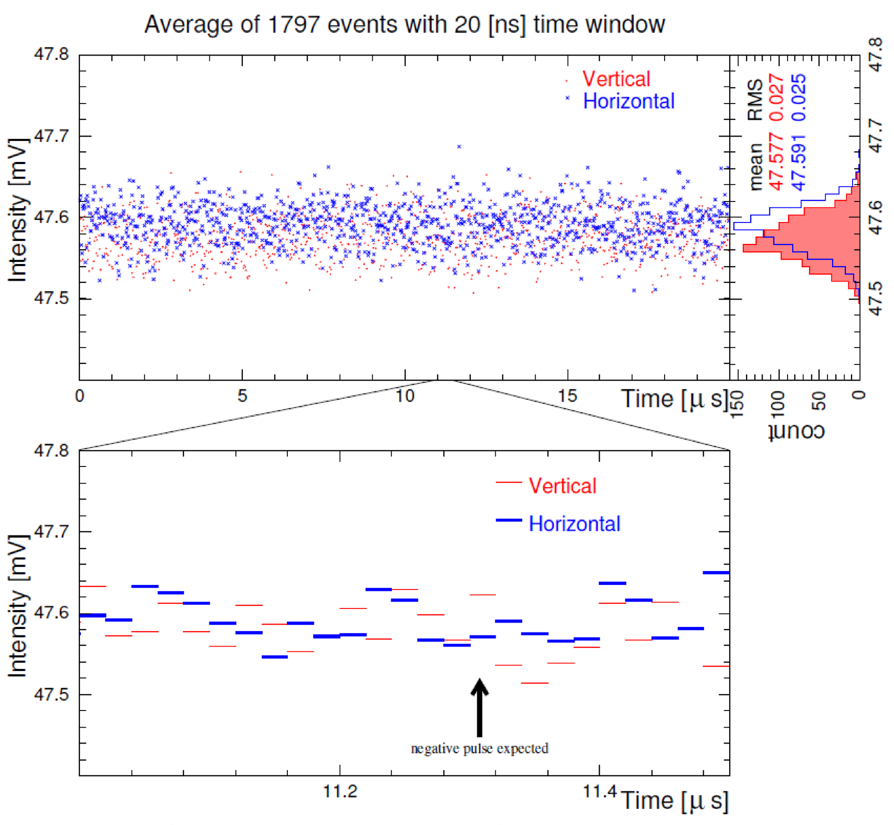
In our measurement, 6.3×10^{8} electrons with energy of 40 MeV are contained in a beam. The total energy deposited by the electron beam at 20 m above ground is 1.4×10^{15} eV/(g/cm^2) which is equivalent to the energy deposited by an air shower with an energy of 10^{18} eV at Xmax. Pulse shape of the beam has a triangle of which base width is 20 ns.



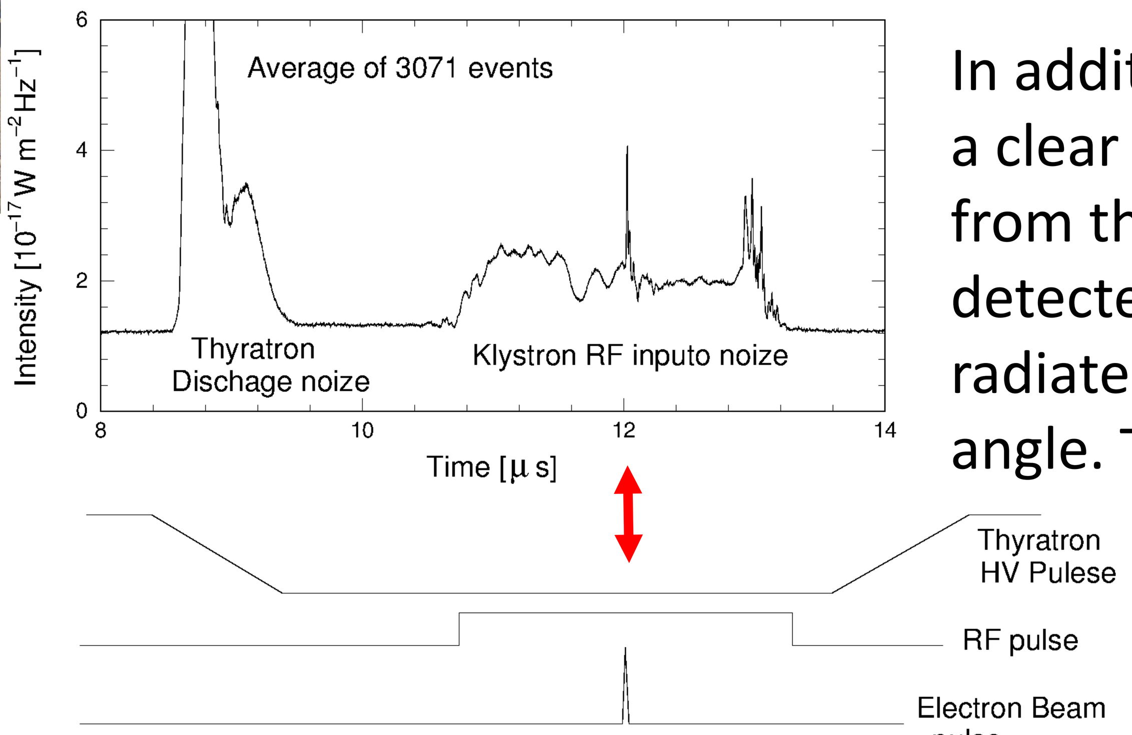
The microwave observation system uses devices from satellite communication. The system uses an off-axis parabola (Nippon Antenna CS-S120K) which is equivalent to 1.2-m-diameter circular reflector. The effective aperture is 0.742 [m^2]. The parabola is located at 88 m from the ELS.

A feed-horn receiver with a bandwidth of 12.25~12.75 GHz (Nippon Antenna FOC-ASJ5) is mounted at the focal point. The receiver has two channels to measure vertical and horizontal polarization. The microwave signal is down converted to 0.95~1.45 GHz by a local oscillator with a frequency of 11.3 GHz. The radio frequency signal from each channel goes through an amplifier (Nippon Antenna CSB-C25-SP) which amplifies input signal with a gain of 20~25 dB. Total gain from the feed horn through the amplifier is 77 dB. After the amplifier, the RF signal is transferred to an electronic device. The electronic device (R&K-CDE1500-KU) provides Bias-T, impedance converter, and power detector. The output signal from this device is transferred to an oscilloscope and digitized when triggered by a signal from the ELS. The digitized data is then recorded by a notebook computer. The whole observation system had been calibrated in laboratories.

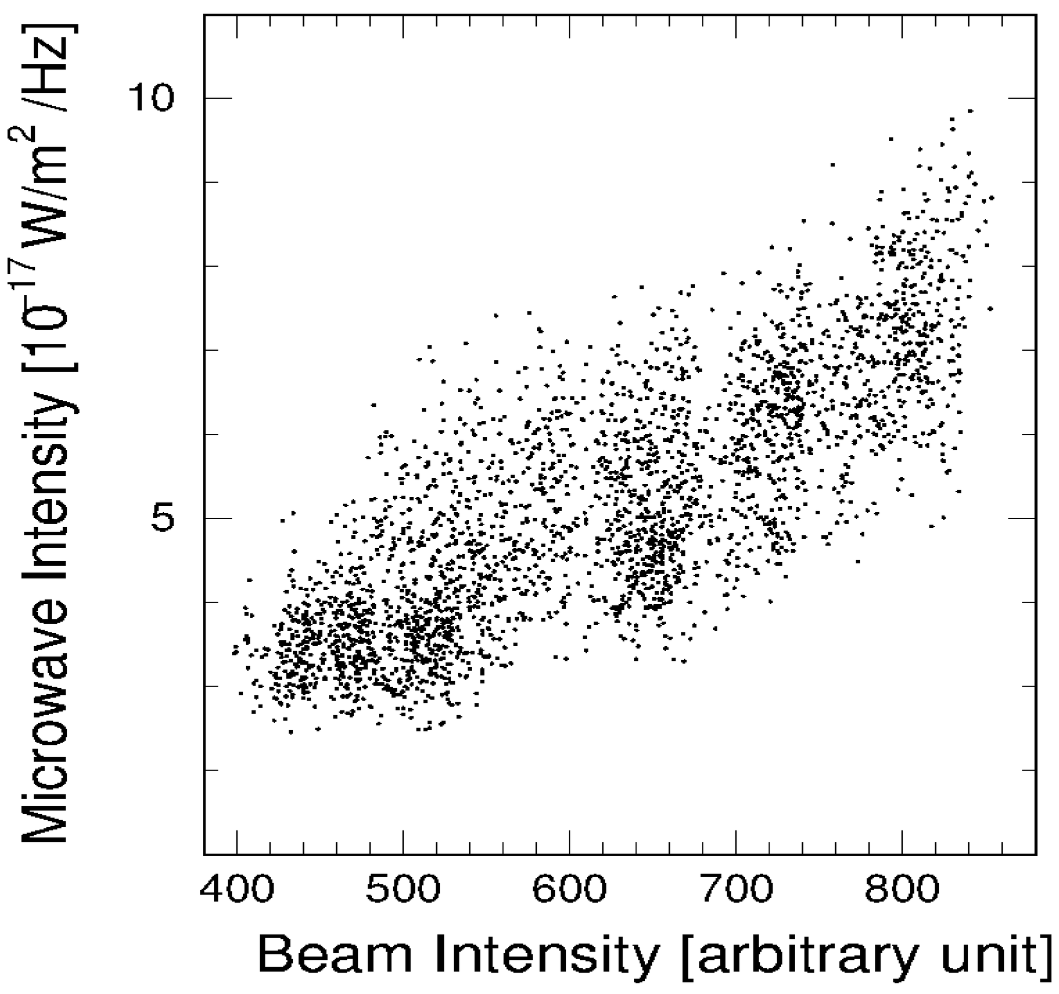




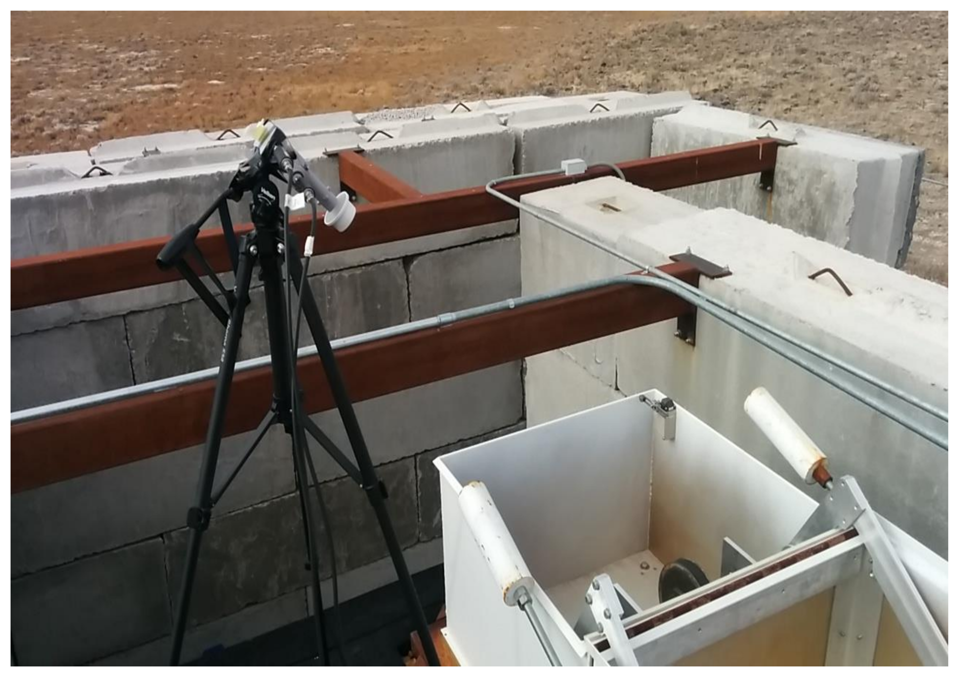
We also measured microwave intensity near the electron beam. The feed horn was fixed on the roof of the ELS without the parabola. On the ELS, various electric noises are detected depending on the status of the ELS. The largest noise comes from high voltage discharge in the Thyratron. Also noise from RF pulse in the Klystron can be seen.



The microwave was strongly polarized to the beam direction. The intensity of the radiation was correlated to the electron beam intensity. If the electron beam was dumped into a Faraday cup just before the beam exit, the radiation disappeared even if the ELS was creating the electron beam. Rapid change of the electric field around the beam exit can be a source of this radiation. A detail analysis of this data is under way.



1797 beams were measured. If the microwave signals from the electron beams were detected, negative pulses with 27.4 ns width were expected. We estimated an average waveform of the 1797 data with 20 ns time window as shown in the left panel but no clear pulse was seen. Preliminary upper limit on the intensity of the isotropic-microwave radiation 88 m from the electron beam with confidence level of 95 % is 3.96×10^{-16} [W/m^2/Hz]



In addition to the noise from the ELS, a clear microwave pulse radiated from the electron beam was detected. The microwave pulse was radiated at the beam exit with wide angle. This wide-angle radiation was happening only at the beam exit.