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Detection and Measurement of Cosmic Rays through Intellectual Global Setup of Antenna Array

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Abstract: ***Here we are introducing the new Innovative Approach for the detection and study of Mysterious characteristics of Cosmic rays. Research and analysis have proved that it requires a very large area even for a very low probability of detection of cosmic rays on Earth. It is very difficult to observe the detection of such high energy radiation with a setup of just a few hundreds or thousands square of kilometers. And bigger setups may cost enormous financial investment. So we thought of using the biggest existing setup i.e. The Array of Satellite Dish Antennae, which are already being used worldwide by billions of people. We are never going to have a bigger Global Setup than this. Hence we named it IGSAA (Intellectual Global Setup of Antenna Array).***

Keywords: Cosmic Rays, Global Antenna Array, Intellectual Global Setup, Cosmic Ray Detection Circuit, Study of Cosmic Rays

1. Introduction

Study shows that Cosmic Rays consist of photons, electrons, protons and some heavier nuclei, as well as antimatter particles. Approximately 85-90% of cosmic rays are protons, 6-9% of them are alpha particles and the rest are other particles. These particles of very high speed collide with gas molecules while entering into atmosphere which produces secondary particles like muons, positrons. These Cosmic Rays have few million times more energy than any accelerator made by man.

Many experimental setups have been employed in the last few decades but the actual characteristics of Cosmic Rays are still a mystery. It is only because of very less probability of incidence of High Energy Cosmic Rays on a particular area where experimental setups are installed. We, therefore, have thought of using the widest setup area already established and which consists of satellite dish antennae, which covers the most part of the earth nowadays and to enhance this widest setup by modifying it a little bit for our purpose of Cosmic Ray detection.

2. A Brief Overview on Cosmic Rays

Cosmic rays can be broadly defined as the massive particles, photons (X-rays, ultra-violet and infrared radiation), neutrinos and exotics striking the earth. The primary cosmic rays are those entering the upper atmosphere, the cosmic rays of the interstellar medium. Secondary cosmic rays are those produced by the interactions of the primary rays in the atmosphere or in the earth. Also products of cosmic ray interactions in the interstellar medium (e.g., spallation products from cosmic ray - cosmic ray collisions) are also labelled as secondary cosmic rays. Cosmic rays can be of either galactic (including solar) or extragalactic origin. Cosmic rays are subatomic particles having high speeded nuclei and protons that travel around space in all directions (isotropic). Cosmic rays can be characterized by the showers they produce after colliding with gas molecules. The source of the Cosmic rays is still a topic of great research and investigation but it is presumed that they may come from collision of galaxies, supernova remnant or from the relativistic jets of material along the poles of black holes. The Energy Spectrum of Ultra High Energy Cosmic Rays (UHECRs) is indicated in Figure 1.

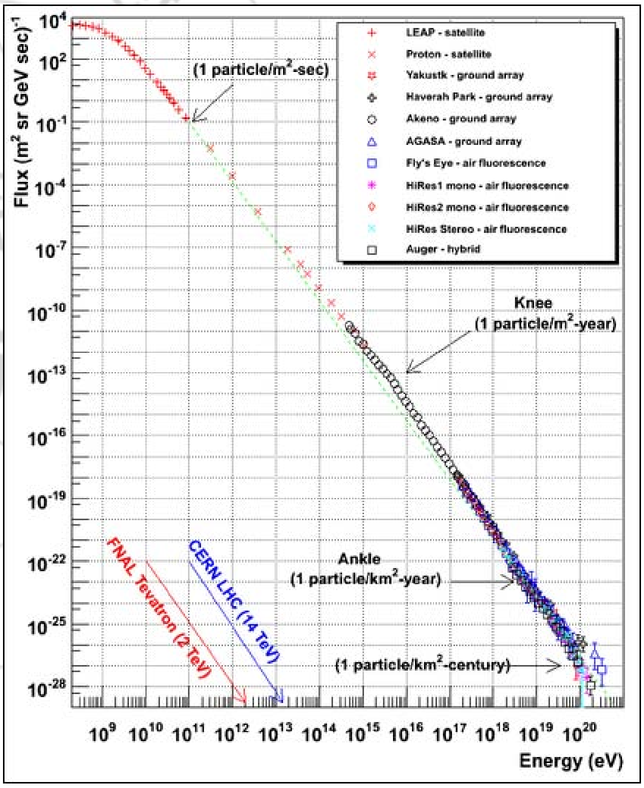

Figure 1: Spectrum of Cosmic Rays with Various Experimental Data, compiled by the University of Utah

Two features of the spectrum are the "knee" at 1015 eV and the "ankle" around 1018 eV. A change in the spectral index, such as seen at the "knee" and "ankle" region, suggests a changing of the source of flux as one mechanism overtakes another. The cause of these changes in spectral index has been the subject of much speculation. The flux of these regions varies dramatically from 1 particle per square meter per second at 1010 eV to 1 particle per square meter per year at the "knee".

As per this study, this flux further decreases to 1 particle per square kilometer per year at the "ankle". And at energies in excess of 1020 eV a flux of less than 1 particle per square kilometer per century is found. The extremely low flux of Ultra High Energy Cosmic Rays presents a detection problem. A detector needs a large detection area, high duty cycle and a long run time in order to build a sufficient statistical database for study. After encountering the Earth's atmosphere, the UHECRs particle will collide with an atmospheric gas molecule setting off a cascade of particle interactions resulting in what is known as an Extensive Air Shower which consists of three main components: an Electromagnetic (EM) portion, a muonic component and a the hadronic core. If we detect the EM portion, the major part of analysis of Cosmic Rays can be achieved. There are also other methods available to detect photons, Gamma rays and some other particles from UHECRs.

3. The Necessity of Study of Cosmic rays

The Cosmic Rays Analytics are useful to study the properties of Galaxies, their basic structure and their composition, what kind of nuclear collisions take place within the interstellar medium, how nuclei accelerate to high speeds and other common physical processes. By the study of Cosmic Rays, Scientists can sample the real matter outside of our solar system. By identifying the various nuclei dispersed throughout our Galaxy, scientists hope to discover the mechanisms that actually produce these nuclei - from "stellar nucleosynthesis" to "nucleosynthesis within supernova" to nuclear fragmentation.

Once the origins of the Cosmic Rays are found, some of the celestial events like solar storms and other may also be predicted. A role of cosmic rays directly or via solar-induced modulations in climate change was suggested by Edward P. Ney in 1959 and by Robert E. Dickinson in 1975. The idea has been revived in recent years, most notably by Henrik Svensmark, who has argued that because solar variation modulates the cosmic ray flux on Earth, they would consequently affect the rate of cloud formation and hence the climate.

4. Usefulness of Global Setup in Detection of UHECRs

The question arises why there is a need of Global Setup. Firstly we need to understand the energy of Cosmic Rays received on earth. Cosmic Rays are very wide range of spectrum and hence have wide range of energies too. The probability of "Particle Rate" against "Particle Energy" for Ultra High Energy Cosmic Rays (UHECRs) is as under.

Table 1: Particle Energy vs. Particle Rate

Particle Energy (eV)	*Particle Rate (per sq. meter per second)*
$1x10^{9}$ (GeV)	$1x10^{4}$
$1x10^{12}$ (TeV)	1
$1x10^{16}$ (10 PeV)	$1x10^{-7}$ (a few times a year)
$1x10^{20}$ (100 EeV)	$1x10^{-9}$ (once a century)

5. CR Detection by Satellite Dish Antenna

The parabolic shape of a dish reflects the signal to the dish's focal point. Mounted on brackets at the dish's focal point is a device called a feed horn. This feed horn is essentially the front-end of a waveguide that gathers the signals at or near the focal point and conducts them to a "Low-Noise Block down converter" or LNB. The LNB converts the signals from electromagnetic or radio waves to electrical signals and shifts the signals from the downlinked C-band and/or K_u-band to the L-band range. The theoretical gain (directive gain) of a dish increases as the frequency increases. The actual gain depends on many factors including surface finish, accuracy of shape, feed horn matching. A typical value for a consumer type 60 cm satellite dish at 11.75 GHz is 37.50 dB. Cosmic rays have a wide range of spectrum. We can use the parabolic dish antennae to detect those Cosmic Rays frequency which falls in the range of C-band.

In a single receiver residential installation there is a single coaxial cable running from the receiver in the building to the LNB on the dish. The DC electric power for the LNB is provided through the same coaxial cable conductors that carry the signal to the receiver. In addition, control signals are also transmitted from the receiver to the LNB through the cable. The receiver uses different power supply voltages (13/18 V) to select antenna polarization and pilot tones (22 KHz) to instruct the LNB to select one of the two frequency bands.

6. Introduction to "Intellectual Global Setup of Antenna Array" (IGSAA)

Satellite Dish Antennae of consumer type are mostly designed to receive C-band and/or Ku-band of frequency range, we can use them for detecting the Electromagnetic Spectrum from Cosmic Rays which falls under this range. The purpose of separating frequencies received from an antenna can be served firstly by using coaxial splitter, which gives parallel connectivity and then following active circuits to avail desired ranges of frequency. To separate the frequencies which are useful for TV signals, we are going to use Band pass filter to pass the frequency range of "Low VHF" (54 – 88 MHz) to "UHF" (470 – 806 MHz) at the one end of coaxial splitter and input it to set top box for further process. Additionally we are going to use band stop filter at other terminal of coaxial splitter to stop the frequency range of low VHF to UHF and allow other higher and lower frequencies of C-band. The design of the cosmic ray detector circuit is given by block diagram in Figure 2. Which gives idea about how the detection can be achieved and information can be stored for further process.

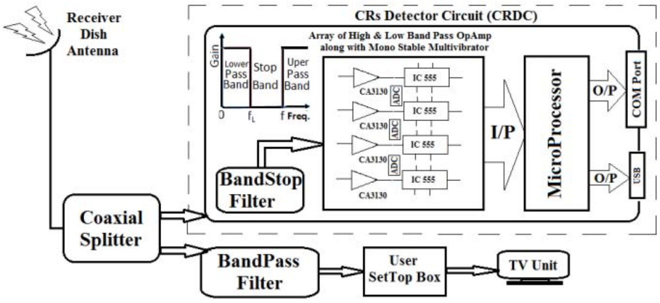

Figure 2: Block Diagram of Cosmic Ray Detector Circuit to be attached in IGSAA Network at various premises

For this whole experimental setup, we need only two additional things at the premises of every user of dish antenna, one is coaxial splitter and the other is "Cosmic Ray Detector Circuit" (CRDC).

6.1 Function of CRDC Unit

Once the band frequencies of VHF and UHF are stopped by band stop filter in CRDC unit, the lower band and upper band frequencies are given to the various band pass filters. The more range of frequency we want to detect, the more number of band pass filters defining with different frequencies are required. At low and high frequencies the circuit of band pass filter acts like an open circuit because inductor and capacitor are connected in series. By this it is also clear that at mid frequencies the circuit acts like a short circuit. Thus the mid frequencies are not allowed to pass through the circuit. The mid frequency range to which the filter acts as a short circuit depends on the values of lower and upper cut-off frequencies. This lower and upper cut-off frequency values depends on the component values. These component values are determined by the transfer functions for the circuit according to the design. The transfer which is the ratio of an output to the input is calculated by

$$H(\omega) = {j\left(\omega L - \frac{1}{\omega C}\right)} \Big/ {\left(R + \left(j\left(\omega L - \frac{1}{\omega C}\right)\right)\right)}$$

Where angular frequency $\omega = 2\pi f$

The gain after the second order notch filter with active component op-amp in non-inverting configuration is calculated by

$$V_{out}/V_{in} = {1 - \left(\frac{f}{f_c}\right)^2} \Big/ {1 - \left(\frac{f}{f_c}\right)^2 + \left(\frac{1}{Q}\right) j\left(\frac{f}{f_c}\right)}$$

Where Quality factor $Q = 1/2 \times (2 - A_{max})$

We can chose random area for setup or some area based on previous studies. Here set top box of user and CRDC unit are separated and will run on individual supply voltage. So even if user has switched off set top box, the CRDC unit can run separately and record the events of Cosmic Rays incidence. CRDC unit is equipped with necessary electronic and logic circuit, the explanation of which is given below. It has COM port and USB port to be connected to computer and/or cell phone respectively. After converting to digital signals using ADC, we provide these signals to monostable multivibrator that triggers the output of the circuit to input ports of MicroProcessor. Hence, actually an input port of MicroProcessor is triggered due to incidence of particular EM frequency of Cosmic Rays. Preprogrammed software in MicroProcessor determines which was is triggered and hence which band pass filter has captured the incidence. The duty cycle and the samples of signal are detected and their data is stored in real time in the memory in CRDC unit.

6.2 Setting up Intellectual Global Setup

The large setup of Network from different geographical area on earth can be established by developing a server at one location and hence forming many to one connection as shown in Figure 2. The data collected are stored in the CRDC units at real time and are received by the server computer maintained by the organization. Whenever a computer having internet connection is connected to the COM Port of the circuit, the log of the data with location information is sent to the Server in IGSAA Network for further study and analysis. Sophisticated Web Portal can serve the purpose. Data can also be collected using cell phone app after connecting to USB port of the circuit.

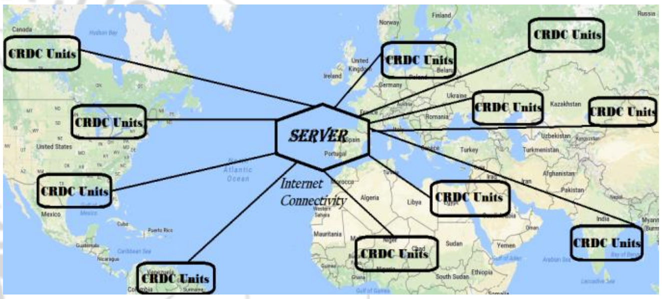

Figure 3: Data Collection at Server from Worldwide CRDC Units from Intellectual Global Setup of Antenna Array (IGSAA)

This whole setup is based on Client-Server model. CRDC Units don't need to be connected to the computer all the time. Whenever these units are connected through COM port or USB port to the computer or to mobile, preinstalled software/application in the devices will redirect to the IGSAA web server and log of events captured and stored in CRDC units will be fetched by the server. Another approach for implementing Client-Server model is also possible nowadays i.e. IoT (Internet of Things). Using IoT at CRDC units, data captured are sent in real time to the cloud or server. IoT is comprised of microprocessor, other sensory units, storage part, network connectivity, actuators and many other things on a single platform. It is considered as an event-driven architecture based on the context of processes and operation in real. Therefore, model driven and functional approaches coexist with new ones able to treat exceptions and unusual evolution of processes. In an internet of things, the meaning of an event will not necessarily be based on a deterministic or syntactic model but would instead be based on the context of the event itself. Building on top of the internet of things, the web of things is the architecture for an application layer of the internet of things looking at the convergence of data from IoT devices into Web applications to create innovative use-cases. IoT based Client-Server Model is capable enough of handling the large flow of data and information received from worldwide Cosmic Ray Detector Circuit (CRDC) units.

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