

# LF-MF Radioemission from neutrino initiated Extensive Ice Showers and Lunar Regolith Showers-A comparative Study

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Investigations on LF-MF Radiopulses emitted by ultra high energy (UHE) neutrino initiated Extensive Ice Shower (EIS) was presented in the 28th ICRC, 2003. An UHE neutrino entering the lunar regolith can initiate an electron-photon cascade and hence emits Radio Cherenkov Radiation (RCR). Detail theoretical as well as experimental investigations are going on in different laboratories for this RCR emitted from the lunar regolith. The charged particle of the electron-photon cascade developed in the lunar regolith can emit transition radiation (TR) while crossing the moon-vacuum surface. The possibility of detection of TR from the lunar regolith with the help of apparatus at the moon's surface was suggested by Askaryan in the year 1965. In this paper, characteristics of TR pulses emitted by UHE neutrino (coming vertically as well as with inclination) due to interaction with the lunar regolith are investigated and a comparative study between the radioemission from EIS and LRS is made.

## 1. Introduction

Detection of radioemission (RE) from EAS (of  $E_p \sim 10^{16}$  eV) by Jelley et al in 1965 [1] opened a new era of cosmic ray studies, with most interest centering on the radio detection of high energy particles. Theoretical as well as experimental aspects of the whole spectrum of the radiation from  $\sim 50$  KHz to  $\sim 550$  KHz (for mean energy  $10^{16}$  eV) have been studied extensively by different groups all over the globe [2][3] in a period of four decades since 1965. From the middle of this period, some laboratories are being engaged in detection and investigation of GAS with  $E_p > 10^{19}$  eV. Unexpectedly high flux of protons (and/or heavy nuclei) with  $E_p > 5 \times 10^{19}$  eV observed by these labs gives rise to GZK puzzle between the observed showers exceeding the threshold energy and non-detection of sources within 50-100 Mpc. Under this circumstance, any experimental evidence for cosmic neutrinos with  $E_\nu > 5 \times 10^{19}$  eV would definitely bring a ray of hope to the CR physicists working on GZK puzzle.

Theoretical as well as experimental advances gained in the field of RE studies over the pretty long period of four decades and the necessity of detection of high energy cosmic neutrinos has given birth to UHE neutrino astronomy based on radio methods. It is worth mentioning that theoretical prediction by Askaryan in 1965 of negative charge imbalance in electron-photon cascade produced by a HE particle in a dense medium forms the base of radio astronomical method (RAM) of neutrino detection. Experimental confirmation of Askaryan effect in 2000 [4],[5] concretizes the base of the RAM. Different laboratories working on theoretical and/or experimental aspect of RAM are mainly concentrated in the HF-VHF band. However, inspired by the findings of LF-MF RE from EAS, the Gauhati University group has turned their attention towards the LF-MF band for RAM. A method for neutrino detection taking Antarctic ice as medium for development of electron photon cascade viz EIS was proposed by the G.U. group developing supportive theoretical model [6].

In this paper, necessary theoretical model is developed for RAM of neutrino detection utilizing the LF-MF band of radiation from lunar regolith showers (LRS) and a method is proposed for investigation on RE from LRS.

## 2. Method

### (a) Theoretical

For a neutrino initiated lunar regolith shower having zenith angle  $\phi$ , the magnitude of the vertical component of the transition radiation (TR) field is obtained by modifying the expressions formulated for EAS [7]. For this, relations between  $E_p$ ,  $N$  given by Matthews [8] are adopted. The modified equation for  $N = 6.5 \times 10^9$  is

$$E = \frac{\epsilon N e \eta_2 k^2}{68.9228 \pi^2 v \zeta} \cos^2 \theta - 0.11 \phi \quad (1)$$

where  $N$  = Size of the LRS at the boundary surface

$\epsilon N e$  = Excess negative charge

$k = \omega / c = 2\pi v / c$  = wave number,

$$\lambda_1^2 = \frac{\omega^2}{c^2} \chi_1 - k^2 \quad ; \quad \chi_1 = \epsilon_1 \mu_1$$

$$\lambda_2^2 = \frac{\omega^2}{c^2} \chi_2 - k^2 \quad ; \quad \chi_2 = \epsilon_2 \mu_2$$

$\epsilon_1, \epsilon_2$  are dielectric constant of lunar regolith and air respectively,

$\mu_1, \mu_2$  are permeability of lunar regolith and air respectively,

$$\eta_2 = \frac{\epsilon_1 / \epsilon_2 + (v/\omega)\lambda_1}{k^2 - \chi_2 \omega^2 / c^2} - \frac{(v/\omega)\lambda_1 + 1}{k^2 - \chi_1 \omega^2 / c^2}$$

$$\zeta = \lambda_2 \epsilon_1 + \lambda_1 \epsilon_2$$

$$\tan \theta = Z / R$$

$Z$  = height of the antenna above the ice surface

$R$  = distance of the antenna from the shower axis

$\phi$  = zenith angle.

### (b) Experimental method

i) Radio antennas (a minimum of five) of frequency  $< 1$  MHz are to be erected at the lunar surface to register TR pulses.

ii) Output of radio channels is to be applied to a coincidence circuit and the output of the coincidence circuit is to be taken to trigger the recording system employed for detecting the pulse height of individual channels.

iii) Field strengths at five different positions of antennas are to be measured.

iv) Frequency of the output of the coincidence circuit is to be raised to some suitable VHF frequency for transmission to some earth based radio telescopes.

### 3. Result

For LRS, the frequency spectrum (fig1) and variation of fieldstrength vs. zenith angle ( fig 2) are obtained from equation (1). The depth vs. negative charge excess graph (fig3) is obtained from the results of findings from Saltzberg et al [4 ].

Fig 1: Frequency spectrum of vertical component

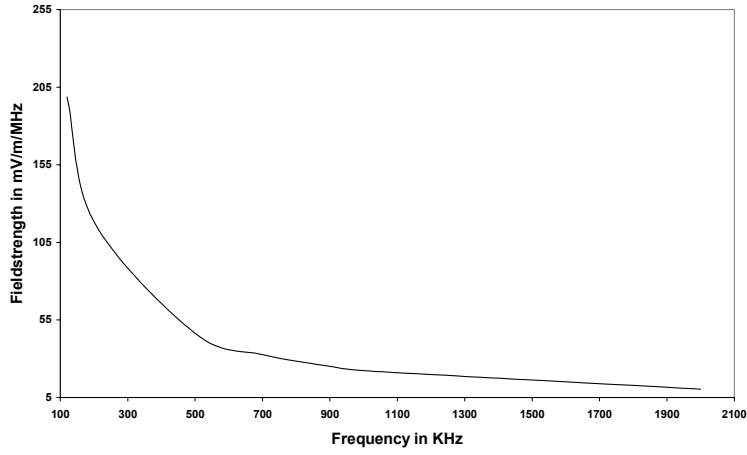
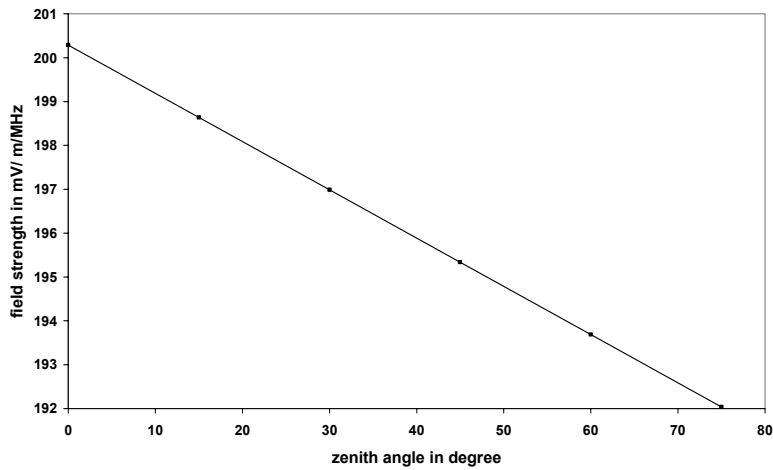
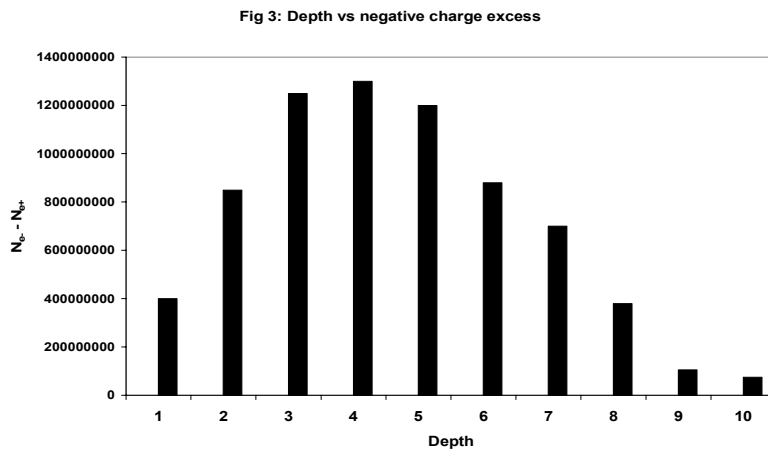


Fig 2- Variation of field strength with zenith angle (N=6.5\*10<sup>9</sup>, R= 30 m)





#### 4. Discussion and Conclusion

From fig.1 it is seen that for LRS, fieldstrengths are significant. In LF-MF band values are much higher than the corresponding values for EIS[6]. Fig.2 shows that fieldstrengths decreases linearly with increase in zenith angle. Measuring fieldstrengths at five different positions, parameters  $\epsilon$ ,  $N$ , core co-ordinates and  $\phi$  can be estimated by using equation (1) by the method of steepest descent or by Artificial Neural Nets. Knowing  $N$  and  $\epsilon$ , depth of first interaction can be estimated from fig (3) for different neutrino energies, from which interaction characteristics of neutrino in lunar regolith can be obtained.

It is worth mentioning that radio detection by RAM with earth based detectors are interrupted by atmospheric noises including noise pulses from EAS RE, whereas radio detection by moon based detectors is free from all these noises.

Thus from the method proposed in the present work there will be some possibility for VHF pulses recorded on the earth to be correlated with LF-MF pulses recorded by moon based detectors. Results obtained in the present work are encouraging and paves the way for more theoretical and experimental work. As only the outline of the proposed method is presented here, there is enough scope for improvement of the same.

#### 5. Acknowledgements

Authoresses are thankful to the DST, Govt. of India for providing the computation facility to the Deptt. of Electronics Science, Gauhati University under DST-FIST scheme.

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