LIGHTNING INSTRUMENT FOR FUTURE VENUS ORBITER. J. P. Pabari[1], K. Acharyya[1], S. A. Haider[1], A. Bhardwaj[1], D. Kumar[2], V. Sheel[1], S. Nambiar[1], D. K. Patel[1] and B. M. Pandya[3], [1]Physical Research Laboratory, Navrangpura, Ahmedabad-380009, INDIA. Email: jayesh@prl.res.in, [2]BITS, Hyderabad-500078, INDIA, [3]CUSSC, Ahmedabad-380014, INDIA.

Introduction and Motivation: Lightning is a large electrical discharge of short duration that occurs in planetary atmosphere. It generates optical signal, electromagnetic waves in ELF and VLF range as well as acoustic waves. In Earth's atmosphere, the lightning is an outcome of convective motion of atmospheric ions and the electrification of colliding precipitation [Lhermitte and Williams, 1983]. In addition, the lightning can also be produced in volcanic clouds, dust storms and snow storms. On Earth, the lightning primarily has two forms viz., cloud-to-ground discharge and intra-cloud discharge.

On Venus, the clouds occur from about 47 to 65 km. The sulfuric acid, the major constituent of Venus cloud, has a dielectric constant of 110 (higher than that of the water, 80) at room temperature, which can change with the temperature. It also freezes at similar temperature (melting point 10 C°) as water. Thus, sulfuric acid could be reasonably good candidate in the context of lightning. Three different spacecraft experiments have provided evidence suggesting the occurrence of lightning activity on the night side hemisphere of the Venusian atmosphere, viz. (1) Radio detection from Veneras 11, 12, 13, & 14, (2) Optical detection by Venera 9 orbiter and (3) Low frequency electric field variations detected by Pioneer Venus Orbiter Electric Field Detector (OEFD) (Scarf et al., 1980). Galileo Flyby showed that although the signals were weak but only probable cause could be lightning (Gurnett et al., 1990). Fluxgate Magnetometer on Venus Express (Russell et al., 2008) observed bursts of plane-polarized magnetic waves in the frequency range from 42 to 60 Hz (whistler mode waves). Takahashi et al. (2008) built a high-speed optical detector, LAC (Lightning and Airglow Camera), on board Akatsuki spacecraft to identify the optical flashes caused by electrical discharges in the atmosphere of Venus.

Lightning Instrument for VEnus (LIVE): To understand the lightning on Venus is more detail, we have proposed a Lightning Instrument for VEnus (LIVE) for future Venus orbiter. The scientific objectives of the LIVE are to confirm lightning on Venus by simultaneously identifying multiple frequencies associated with lightning events, to determine its frequency of occurrence and study its temporal variability during the mission lifetime and to understand electrical properties of cloud and possible global distribution of lightning. The study of lightning would be carried out using LIVE, which works in low frequency range from 30 Hz to 30 kHz. The study of plasma waves could also be carried out using LIVE working in kHz range. Plasma waves play a significant role in interaction of solar wind with the ionosphere of un-magnetized planet, Venus. Upstream of the planet plasma oscillations are generated by electrons, energized and reflected at the bow shock. The spatial extent of the plasma oscillations is indicative of the amount of energy gained at the shock.

The lightning on Earth has been studied by many researchers as found in literature. It was observed that within ~30 km distance, the electric field due to lightning varies inversely with cubic power of the distance and at larger distances (> 30 km) the field due to lightning varies inversely with the distance (Watt, 1960). If we assume that the lightning on Venus follows similar distance rules, then it could be possible to detect the lightning occurring in Venus sulphuric acid cloud at ~50 km from an orbiter instrument at about 500 km. Typically, for breakdown strength of SO_2 as 0.9×10^6 V/m, the electric field at ~500 km from Veus surface would be ~74 milliVolt/m. This value is much larger than the ionospheric electric field of ~0.5 milliVolt/m.

LIVE Configuration: The LIVE is a low frequency electric field analyser operating in frequency range from 100 Hz to 30 kHz and it will be used for measurement of field emissions due to plasma and lightning in Venus atmosphere. Configuration of LIVE is shown in Figure 1 in which f_1, f_2, … f_{10} are frequencies. The frequencies may be 40 Hz, 100 Hz, 200 Hz, 300 Hz, 400 Hz, 730 Hz, 5.4 kHz, 10 kHz, 20 kHz and 30 kHz.

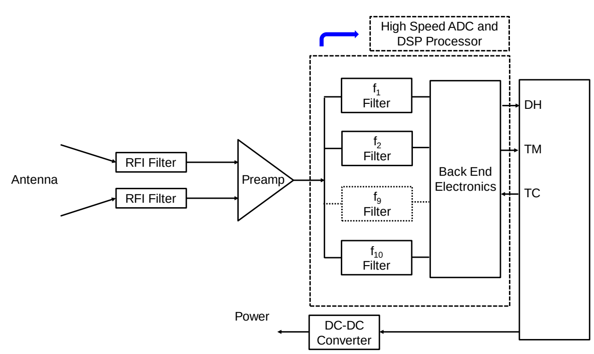

Figure 1: Preliminary design of LIVE for future orbiter

Lightning Simulaion and Field Testing: The lightning on Venus occurs as intra-cloud and it can be represented as a second order RLC circuit with almost critically damped response. The intra-cloud discgarging process is represented in Figure 2 (a) and the cloud is modelled as the RLC circuit as shown in Figure 2 (b), where R is the resistance, L is the inductor and C is the capacitance. We have simulated the lightning by a spark gap caused by a Van-de-graaff generator and carried out the field testing of a prototype using a short Vee dipole antenna. The PVO had electric field detector for similar observations (Scarf et al., 1980). The Vee antenna has 75 cm length and 60° angle between the arms. The result obtained is shown in Figure 3 (a) as an electromagnetic pulse (with arbitrary units on vertical axis). Since the lightning is a transient phenomena, it has decaying pulse nature, as expected. The spectral components (with arbitrary units on vertical axis) of the EM pulse are shown in Figure 3 (b), from where one can observe that all major components in the spectrum are covered within ~1 MHz bandwidth. We found the peak of lightning spectrum within ~30-60 kHz. The work help understand the behaviour of lightning field as a function of distance and also the frequency. It can be useful to select the design frequencies in electric field measurement for future orbiter instrument. The further work in this direction is underway.

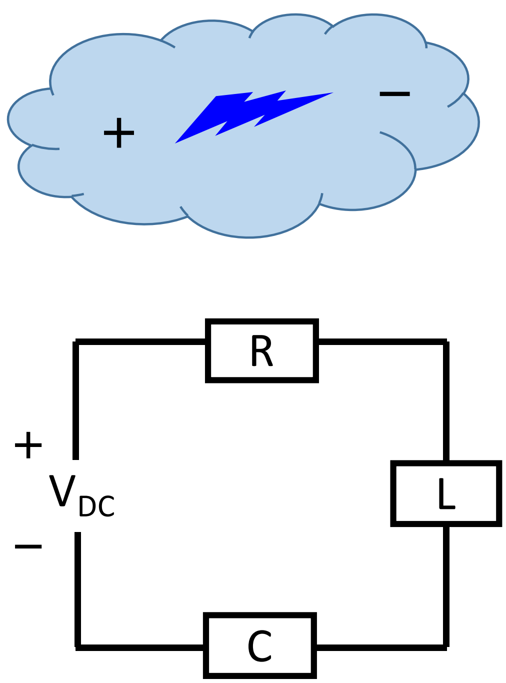

Figure 2: (a) Ilustration of intra-cloud lightning on Venus and (b) cloud model as RLC circuit.

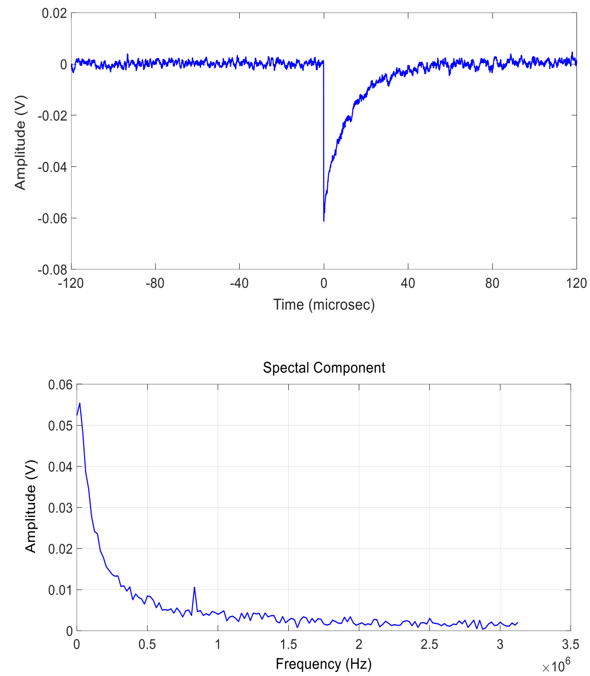

Figure 3: (a) EM pulse due to electrostatic discharge and (b) spectral components of electrostatic discharge pulse.

Summary and Implications: A LIVE is proposed for future Venus orbiter to understand the lightning on Venus. The prototype of LIVE has been made and initial testing was carried out using electrostatic discharge in the field. The identification of lightning should be possible from the orbiter for its distance behaviour similar to that observed on Earth. The study of planetary lightninig can enhance understanding about the planetary atmosphere and also suggest that the planet is active. The atmospheric chemistry may be affected due to dumping of lightning energy in the Venus atmosphere. Further work on instrument development is underway.

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