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# PHASE RELATIONSHIP BETWEEN F-REGION ELECTRON DENSITY AND ELECTRIC FIELD FLUCTUATIONS - SOME NEW OBSERVATIONS

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ABSTRACT

In-situ measurements of the height variation of the ionospheric electric field and electron density variations were made with a rocket-borne electric field double probe and two different types of electron density probes. A Brazilian made SONDA III rocket carrying these experiments in addition to other airglow experiments was launched on 18-th December, 1995 at 2117 hrs (LT) from the equatorial rocket launching station, Alcantara. The rocket reached an apogee altitude of 557km and covered a horizontal range of 589km. Several ground equipments were operated during the launch campaign with the specific objective of knowing the ionospheric conditions at the time of launch and thereby to launch the rocket into an F-region prone to the presence of large plasma bubbles. The rocket in fact passed through several medium scale plasma bubbles and the electric field double probe and the electron density probes detected the presence of a wide spectrum of electric field and electron density irregularities. In the base of the F-region the electric field double probe measurements clearly indicated the presence of large amplitude fluctuations, closely associated with large amplitude electron density irregularities But in the height region close to the rocket apogee though the electron density profile showed the presence of large scale spatial structures, the electric field measurements did not show fluctuations of similar amplitude. Being a nighttime launch one would expect the electron density irregularities, if generated by the well-known cross-field instability mechanism, in height regions where the electron density gradient is downward, i.e in the same direction as the ambient Hall electric field. An FFT algorithm was then used to estimate the spectral distribution of the electric field and electron density fluctuations, thus estimating the height variation of the spectral variation. Some new results on the phase relationship between the electric field and electron density fluctuations are presented here.

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INTRODUCTION

Electron density irregularities present in the ionosphere manifest themselves in different forms at different heights and times. Sporadic-E, spread-F, radio star scintillations and VHF radar echoes are a few of such phenomena, familiar to ionospheric physicists. Basic knowledge of the plasma irregularities, responsible for these phenomena, has progressed considerably, both in theory and observations, since the discovery of the strong VHF radar echoes from the equatorial ionosphere (see Bowles et al 1963 and Balsley, 1969), from their spectral characteristics as observed by the VHF radar, classified the plasma irregularities into two groups, namely Type I and Type II. While the Type I irregularities are now identified to be consistent with the two-stream instability mechanism (Farley, 1963), the Type II irregularities are known to be produced by the nonlinear cross-field instability mechanism (see Rogister and d'Angelo, 1972; Balsley and Farley, 1973). Direct observations by Prakash et al (1970) using rocket-borne Langmuir probes flown from India, confirm the existence of the Type II irregularities in the equatorial E-region. Type II irregularities are characterized by scale sizes extending from a few meters upto tens of kilometers. The short wavelength irregularities apparently seem to be generated from larger scale sizes through nonlinear coupling or cascading processes (see Rogister and d'Angelo, 1972; Sato 1973; Sudan et al 1973). Neutral turbulance also seems to be another probable mechanism responsible for the generation of plasma irregularities (Prakash et al, 1970). The spectral characteristics of the different types of irregularities have been studied in detail (Prakash et al, 1970; Ott and Farley, 1974).

In-situ measurements of the height variation of the ionospheric electric field and electron density variations were made with a rocket-borne double probe and two different types of electron density probes. A Brazilian made SONDA III rocket launched on 18-th December, 1995 at 2117 hrs (LT) from the equatorial rocket launching station, Alcantara reached an apogee altitude of 557km and covered a horizontal range of 589km. Several ground equipments were operated during the launch campaign with the specific objective of knowing the ionospheric conditions at the time of launch and thereby to launch the rocket into an F-region prone to the presence of large plasma bubbles.

**EXPERIMENT AND FLIGHT DETAILS**

The rocket payload designated IONEX-II had the principal objective of measuring the electric field, the electron density, the electron kinetic temperature and the spectral distribution of plasma irregularities associated with what are known as ionospheric plasma bubbles. The payload consisted of the following experiments in addition to other airglow photometers.

- Electric Field Double Probe (EFP)
- Langmuir Probe (LP)
- High Frequency Capacitance probe (HFC)

Figure 1. shows the schematic of the rocket payload indicating the locations and mounting of the various experiment packages including the EFP, LP and HFC probes and the sensors of these experiments mounted on deployable booms.

The main objective of the EFP was to measure the dc electric field and the fluctuating component of it associated with the ionospheric plasma irregularities. Two spherical electric field sensors were mounted at the extremities of two booms that were deployed after the rocket nosecone was ejected at an altitude of about 65km. Though, in the fully deployed state the separation between the sensors was expected to be more than 3m, the booms did not open fully due to the unexpectedly low spin rate attained by the rocket and the separation between the sensors obtained was only about 1.3m.. This made the already difficult task of obtaining the dc component of the electric field practically impossible. However the ac component of the horizontal electric field were made in the altitude region of about 95 to 557km, the apogee altitude reached by the rocket and are being analysed.

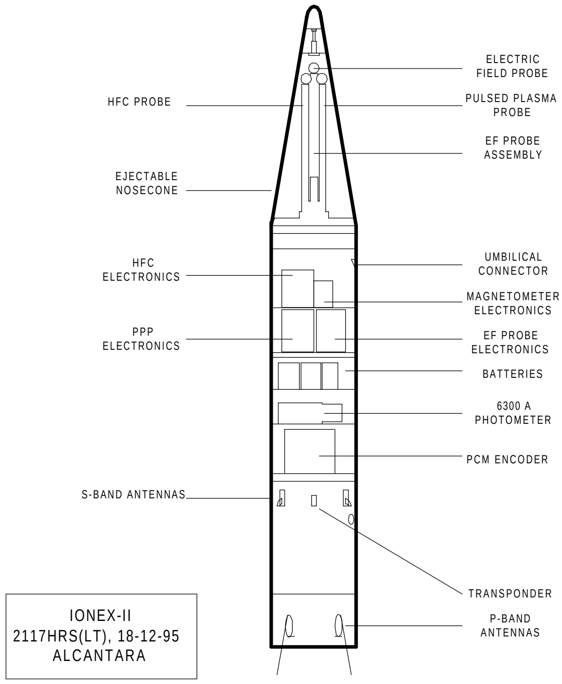


Figure 1.: Schematic of the IONEX-II rocket payload

The basic principle of operation, and the details of the electronic subsystem of the LP and HFC experiments are given in Muralikrishna and Abdu (1991). The Langmuir Probe was used to measure the electron density and the electron kinetic temperature. A spherical LP sensor of diameter about 60mm was mounted at the extremity of a short boom of about 50cm in length that remained inside the rocket nosecone. This boom was deployed along with the EFP booms soon after the ejection of the rocket nosecone. A sweep voltage varying from -1V to +2.5V in about 2.5sec. was applied to the LP sensor in order to measure both the electron density and the electron kinetic temperature. The main objective of the HFC probe was to measure the electron density height profile. The HFC sensor was identical to the LP sensor and was mounted also at the extremity of a short 50cm boom kept folded inside the rocket nosecone till the ejection of the nosecone like the LP sensor boom. The sensor formed part of the tank circuit of an electronic oscillator and any change in the sensor capacitance caused by changes in the ambient electron density, is measured through a counting circuit and this information is telemetered to the ground.

**RESULTS AND DISCUSSION**

The electron density and the electric field fluctuation data have a sampling rate of 1250 per second that decided the lower limit for the measurable scale size. The maximum observable fluctuation frequency is 625Hz. This corresponds to different scale sizes at different height regions beacuse of the continuously changing rocket speed. For example in a height region where the rocket velocity is about 2km per second the LP and EFP experiments could measure the ac fluctuations of wavelength down to about 3,2m. Close to the region of apogee where the vertical component of the rocket velocity is very small the lowest vertical scale size of irregularities that can be measured with the LP and EFP goes down to practically zero. The HFC data does not permit the measurement of fast fluctuations in the electron density. Since the time duration needed to obtain one measurement with the HFC experiment is about 120ms, the distance between data points in a height region where the rocket velocity is about 2km/sec. is roughly 240m, or in other words the minimum scale size of irregularities that can be measured with HFC in this height region is about 480m. It should be noted here that the rocket was launched at a time when the network of ground experiments indicated possible development of plasma bubble events. The electron density profiles show that the rocket indeed passed through a series of plasma bubbles of varying amplitudes during the ascent and descent of the rocket. It should also be noted here that the E-Filed double probe measurements are modulated by the rocket spin and precession and there exists large base level noise in the fluctuation amplitude indicated. This base level noise can be removed by passing the E-field fluctuation data through appropriate band pass filters. However the existence of fluctuations with amplitudes higher than the base level noise can be clearly seen both in the electron density and the elctric field. Typical electron density and electric field fluctuation data observed at different times during the rocket ascent are presented in figures 2 to 5. Time after launch is indicated along the x-axis and the electron density and electric field fluctuation amplitudes on a relative scale are shown alon the y-axis. The total time duration of each block of data is about 0.8 seconds.

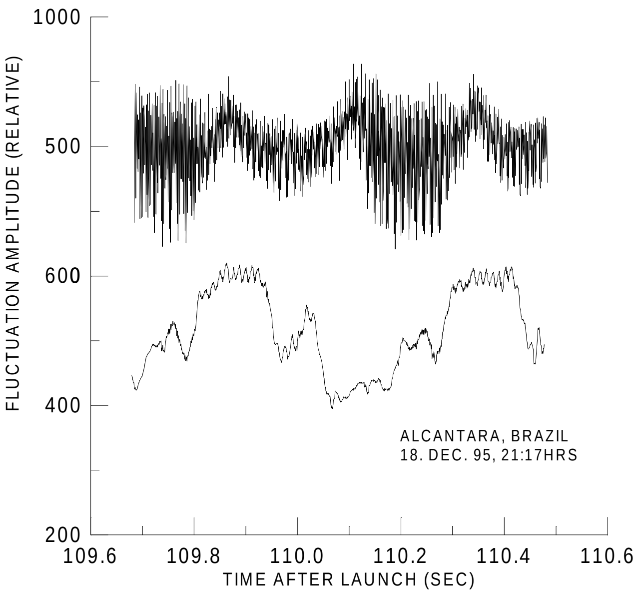


Figure 2.: Amplitude fluctuations in electron density (top) and electric field (bottom) on a relative scale as measured by the LP and EFP

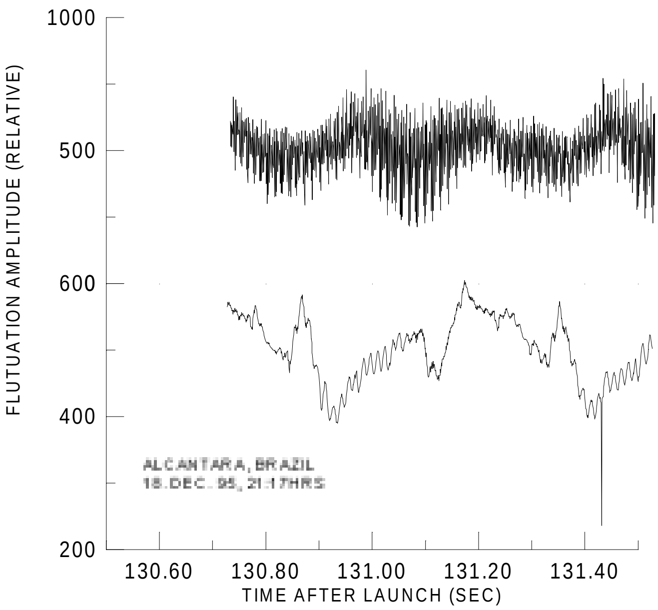


Figure 3.: Amplitude fluctuations in electron density (top) and electric field (bottom) on a relative scale as measured by the LP and EFP

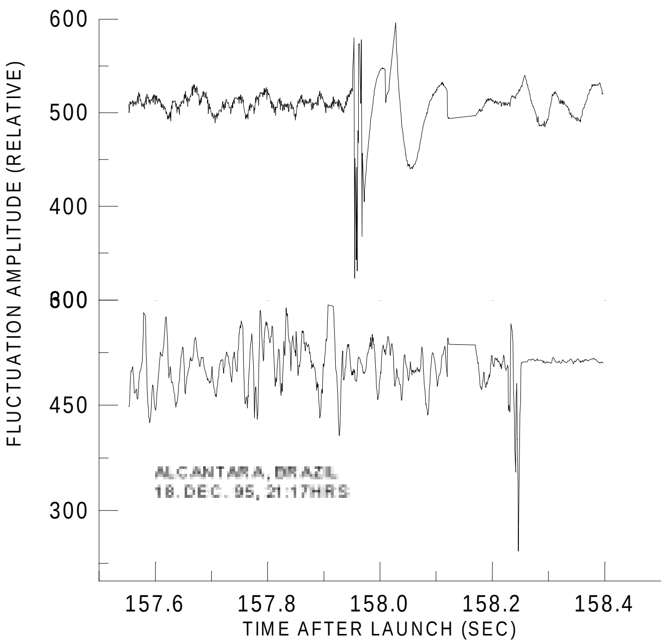


Figure 4.: Amplitude fluctuations in electron density (top) and electric field (bottom) on a relative scale as measured by the LP and EFP

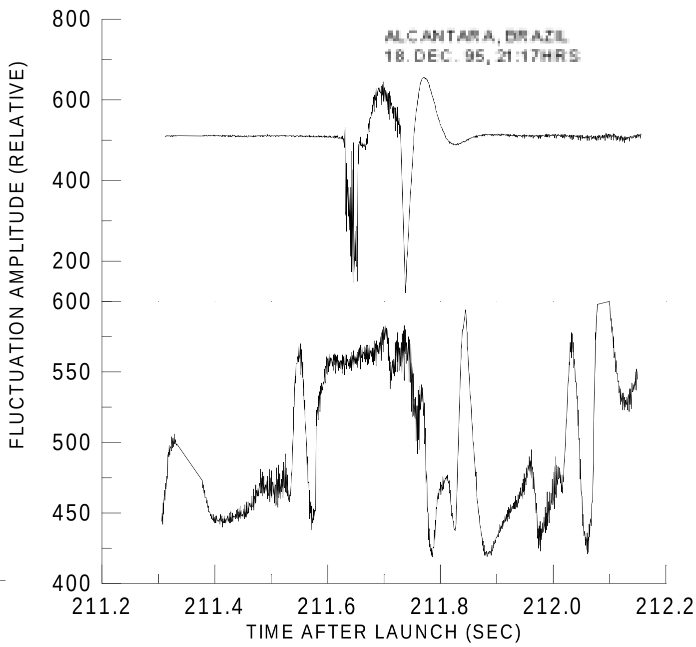


Figure 5.: Amplitude fluctuations in electron density (top) and electric field (bottom) on a relative scale as measured by the LP and EFP

The large amplitude variations seen in almost all these figures are mainly caused by the rotation and precession of the rocket. These rocket motions contribute to slow varying sinusoidal components to the signals. As one can clearly see in practcally all these figures there exist fluctuations that are not sinusoidal in nature in all these figures. A closer observation of these figures shows the following.

1. A definite phase relationship between the electric field and electron density flucutions seems to exist in all the height regions. One should note here that the EFP and the LP sensors are mounted in the same horizontal plane on board the rocket, but at right angles to each other. This will result in a fixed (varying only with the rocket spin rate) phase difference between the fluctuations.
2. The rise time for a particular structure is always more than the fall time. This is particularly evident in the electric

field data. This saw tooth structure of the plasma density and electric field irregularities seems to be realted to the generatiopn mechanism these irregularities and the nature of coupling between the large scale and small scale irregularities.

Observation of bubble structures in the nighttime ionosphere is rather a familiar feature. The generation of large scale plasma irregularities by the mechanism of cross-field instability is now reasonably well understood (Reid, 1968; Tsuda et al., 1969). A necessary condition for the mechanism to operate is that there should exist an electron density gradient in the direction of the ambient electric field. In the nighttime ionosphere the Hall polarisation electric field is generally downwards and so the height regions favorable for the operation of the C-F instability mechanism are those where the ambient electron density gradients are downwards. Presence of large bubble structures in the bottom side F-region where the E-field is supposed to be downwards and the electron density gradient is upwards cannot be attributed to the operation of the cross-field instability mechanism. However, small scale plasma irregularities can be generated in the region of downward electron density gradients associated with the large scale bubbles..

**CONCLUSIONS**

- Bubble regions are associated with both electron density and electric field fluctuations.
- A definite phase relationship between the electric field and electron density flucutions seems to exist in all the height regions.
- The rise time for a particular structure is always more than the fall time. This is particularly evident in the electric field data

Spectral analysis of the ac data is being under taken, and is expected to give valuable information about the plasma instability mechanisms operating, among which the cross-field instability mechanism seems to be a definite one confirming the earlier observations. It should be noted here that the information that one gets from looking up at the phase relationship between fluctuating data is lost when one does the spectral analysis.

*REFERENCES*

*ABDU, M. A.; P. MURALIKRISHNA; I. S. BATISTA and J. H. A. SOBRAL, Rocket observation of equatorial plasma bubbles over Natal, Brazil using a High Frequency Capacitance probe, J. Geophys. Res., **96**, 7689-7695, 1991.*

*BALSLEY, B. B., Some characteristics of non-two-stream irregularities in the equatorial electrojet, J. Geophys. Res., **74**, 2333-2347, 1969.*

*BALSLEY, B. B. and D. T. FARLEY, Radar observation of two dimensional turbulence in the equatorial electrojet, J. Geophys. Res., **78**, 7471-7479, 1973.*

*FARLEY, D. T., Two stream instability as a source of irregularities in the ionospheres, Phys. Rev. Lett., **10**, 279-282, 1963.*

*MURALIKRISHNA, P. and M. A. ABDU, In-situ measurement of ionospheric electron density by two different techniques - a comparison, J. Atmos. Terr. Phys., **53**, 787-793, 1991.*

*OTT, E. and D. T. FARLEY, The k spectrum of ionospheric irregularities, J. Geophys. Res., **79**, 2469-2472, 1974.*

*PRAKASH, S.; S. P. GUPTA and B. H. SUBBARAYA, A study of irregularities in the nighttime equatorial E-region using a Langmuir probe and a plasma noise probe, Planet. Space Sci., **18**, 1307-1318, 1970.*

*REID, G. C., Small scale irregularities in the ionosphere, J. Geophys. Res., **73**, 1627-1640, 1968.*

*ROGISTER, A., Nonlinear theory of cross-field instability with application to the equatorial electrojet, J. Geophys. Res., **77**, 2975-2981, 1972.*

*ROGISTER, A. and N. D'ANGELO, On the origin of small scale Type II irregularities in the equatorial electrojet, J. Geophys. Res., **77**, 6298-6299, 1972.*

*SATO, T., A unified theory of Type I and II irregularities in the equatorial electrojet, J. Geophys. Res., **78**,2232-2243, 1973.*

*TSUDA, T.; T. SATO and S. MATSUSHITA, Ionospheric irregularities and cross-field plasma instability, J. Geophys. Res., **74**, 2923-2932, 1969.*

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