'Aeronomy & Radio Wave Propagation' Symposium Papers

Indian Journal of Radio & Space Physics
Vol. 3, September 1974, pp. 248-252

Regional Differences in Ionospheric Scintillation near the Magnetic Equator

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Received 6 *April* 1973

Scintillations of signals from a number of geostationary satellites (ATS-1, ATS-3 and the Canary Bird) were observed from Huancayo—a magnetic equatorial station in the American zone. The observations made during January 1967 to December 1968 are compared with those obtained at an African equatorial station, namely, Legon. The comparison shows some differences. Particularly remarkable are the seasonal patterns at the two places. The pattern at Huancayo shows a predominantly annual periodicity while that at Legon shows a primarily semi-annual variation. These differences are described here and discussed as zonal effects.

1. Introduction

OBSERVATIONS of ionospheric scintillation of radiowaves made from stations near the magnetic equator, reveal the existence of an equatorial scintillation belt within which the phenomenon shows a very high incidence and many other distinctive features. These were first reported by observers in the African zone[1-5]. Recently similar observations of scintillation were made at Huancayo, in the American zone, which though generally confirmed the African observations, also revealed some interesting differences. For example, the seasonal pattern at Huancayo exhibited a predominantly annual periodicity whereas that at Legon showed a semi-annual variation. Attention to such zonal differences was drawn by us in an earlier paper[6]. Here we discuss these differences more closely.

2. Observations

The geographic coordinates of the stations whose data are compared here are: Huancayo, (12° 3′S, 75° 20′W, dip 2°N) and Legon, (5° 36′N, 359° 48′E, dip 8° 30′S). The Huancayo observations were made on the 136 MHz beacon transmissions from two (sometimes three) geostationary satellites (namely, ATS-1, ATS-3 and the Canary Bird). Besides, records of the 40-41 MHz beacons of the travelling satellites BE-B and BE-C were also utilized. Details of these observations have already been reported by Bandyopadhyay and Aarons[7] and Chatterjee *et al.*[6]. The observations at Legon have been reported by Koster[8].

3. Results

3.1 Seasonal Variation of Scintillation

Nighttime variations of scintillation occurrence at Huancayo during different months are given in Fig. 1.

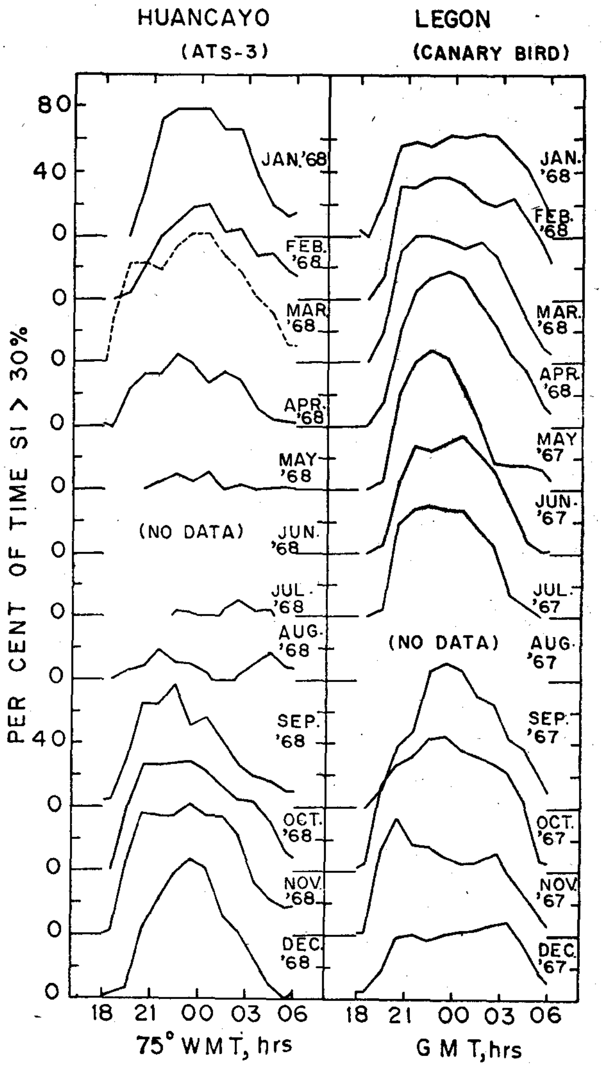

Fig. 1—A month by month comparison of scintillation occurrences at Huancayo, Peru and Legon, Ghana

For comparison, similar curves for Legon are included. Fig. 1 reveals the existence of a marked difference in the scintillation behaviour at these two stations. For example, during April, an equinox month, when one might expect similar behaviour the scintillation level at Huancayo is seen to be much less than that at Legon and points to the existence of a zonal difference between the two stations. Sometimes during the same month reliable scintillation data for two geostationary satellites were available for Huancayo. The data for two such months (April 1968 and September 1968) are plotted in Fig. 2 which shows a fairly good agreement between the two curves for the same months and also gives an idea of the variability in the scintillation observations of the two satellites at Huancayo.

The full gamut of the difference in scintillation behaviour between the two stations can be appreciated by comparing the two seasonal patterns (Fig. 3). The patterns were obtained by determining from the monthly median curves, such as those of Fig. 1, the fraction of time each month SI exceeded some selected levels. The curves for Legon are from Koster[8].

While comparing the two sets of curves one should note that although the variation over a one-year period has been presented for each station, the months at the beginning of the two sets are not the same. The most striking difference between the two sets of curves is that while Legon shows semi-annual periodicity with peak occurrences at the equinoxes, Huancayo shows a predominantly annual periodicity with peak near the December solstice.

3.2 Comparison with Spread-F

The close correlation that is known to exist between scintillation and spread-F[9-13] has led us to look

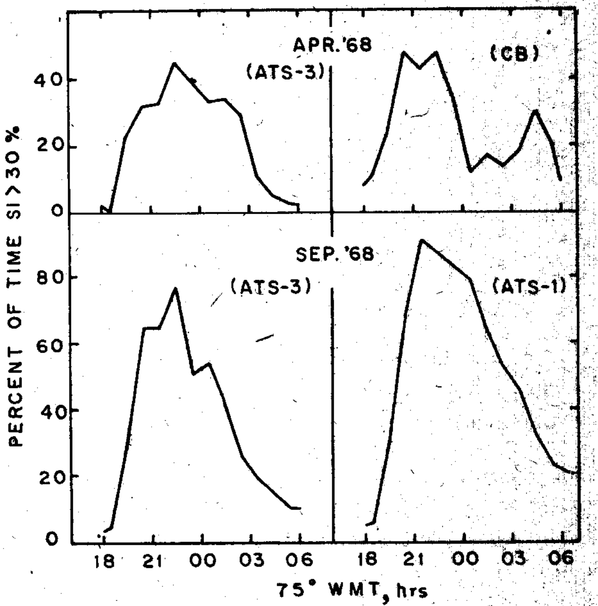

Fig. 2—A comparison of scintillation occurrences in the signals of two geostationary satellites observed from Huancayo, Peru

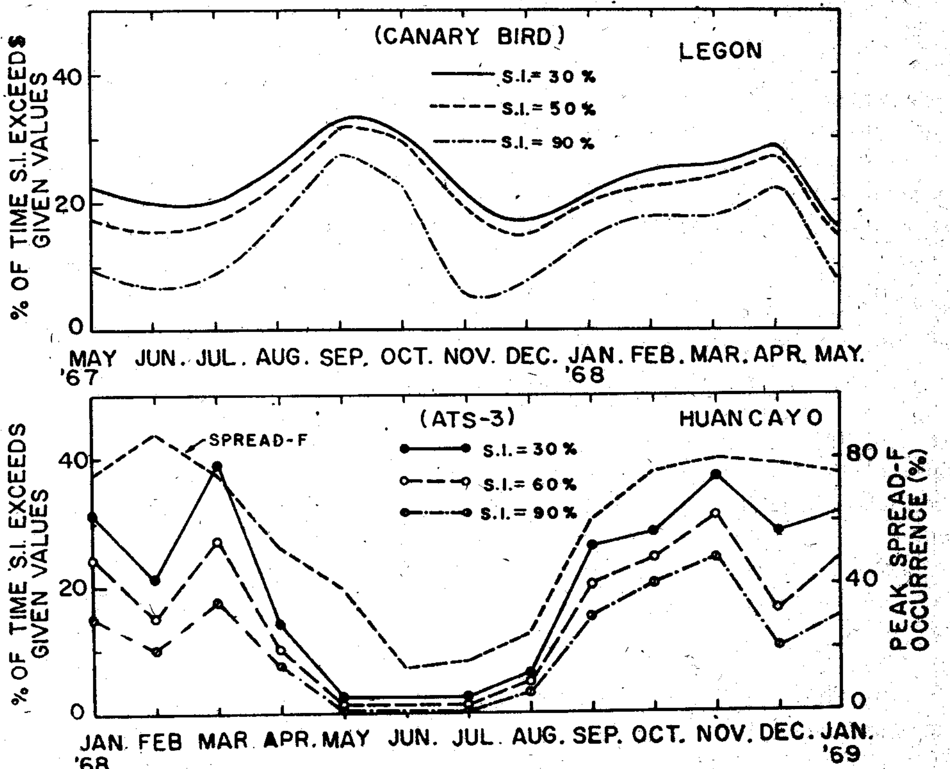

Fig. 3—Seasonal variation of scintillation occurrences at Legon, Ghana and Huancayo, Peru (The points for March 1968 were obtained from Canary Bird observations. The seasonal variation of peak spread-F occurrences at Huancayo is also included)

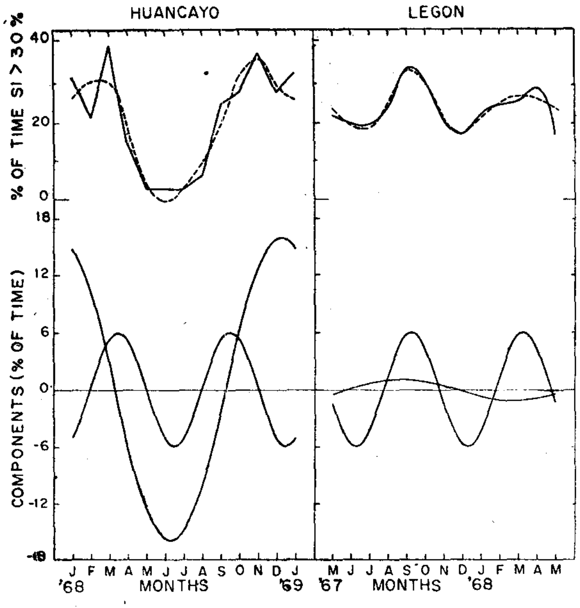

Fig. 4—Harmonic analysis of the seasonal variation of scintillation occurrences at Huancayo, Peru and Legon, Ghana

critically into equatorial spread-F data to find support of these zonal differences. The seasonal variation of peak spread-F occurrence at Huancayo has been incorporated in Fig. 3. It can be seen that it closely follows the curves of scintillation occurrence at Huancayo. Good spread-F data at Ibadan (geogr. coord., 7·4°N, 3·9°E; dip 6°S), a station quite close to Legon, are not available for the same period as that of the scintillation data at Legon. For another period (1957-59), however, Chandra and Rastogi[14] have shown that the seasonal variation of spread-F at Ibadan shows a predominantly annual periodicity. Thus, whereas for Huancayo the seasonal pattern of scintillation is confirmed by that of spread-F, no such confirmation is available for Legon.

3.3 Harmonic Analysis of the Seasonal Patterns

The seasonal curves of Fig. 3 for Legon and Huancayo have been subjected to harmonic analysis to obtain the annual and semi-annual components. Fig. 4 shows the results of the analysis. The full line curves at the top are the experimental curves (reproductions of those of Fig. 3). The derived annual and semi-annual components are shown below the respective experimental curves and the kind of fit to the experimental curve obtained by considering only the annual and the semi-annual components is shown by the dotted line.

From Fig. 4 one can see that the semi-annual components at both the stations are nearly of the same amplitude and phase. However, the relative amplitudes of the annual components at the two stations are quite different : at Huancayo the amplitude of the annual component is about 2·8 times that of the semi-annual, whereas at Legon it is about 1/5th of the semi-annual component. The phases of the annual components at the two places are also quite different : Huancayo shows maximum during December solstice, while at Legon the maximum occurs during September equinox.

4. Other Evidences of Regional Differences

Besides scintillation occurrences the width of the scintillation belt in the American and the African zones also appears to show some difference. The width for the African zone was determined by Sinclair and Kelleher[5] using the scintillation data of the travelling satellites BE-B and BE-C. Their results indicate that the belt extends between ± 16° magnetic latitude (half occurrence limits). Following the same method Chatterjee *et al.*[6] have obtained the values of about ± 7° for the American zone. Thus the belt in the American zone appears to be narrower.

Some indications of the narrower width in the American zone are also available from other sources of data. For example, one may look into the curves of Coates and Golden[15] (Fig. 5) showing a comparison of the number of minitrack passes missed at Lima (Peru), Quito (Equador) and Santiago (Chile) due to propagation distortion[10]. The approximate dip latitudes of the above three stations are respectively 1°N, 11°N and 16°S. Thus, Quito lies outside the northern half-occurrence limit (7°N) of the belt determined by us. Accordingly, we would expect that the number of passes missed at Quito should be much less than half the number missed at Lima. Actually, however, this was so during September to January. But during February to April the number was equal to or greater than half the number at Lima suggesting a greater half-occurrence width of the scintillation belt encompassing Quito during the above mentioned period. The belt, however, did not encompass Santiago where the number of passes missed is almost always less than half of that for Lima. So the minitrack results suggest

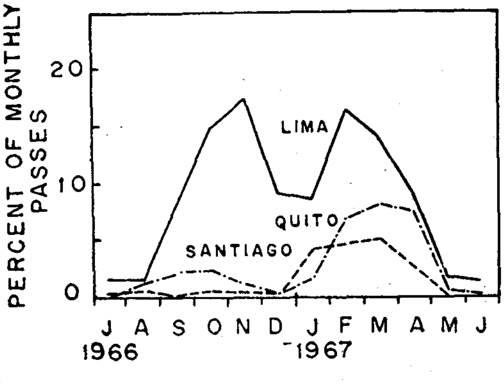

Fig. 5—Scheduled minitrack passes missed by month due to propagation distortion[15]

that during some months the belt may extend between ± 11° but not to ± 16°, the value obtaind for African stations by Sinclair and Kelleher[5].

It may be noted here that the seasonal pattern of scintillation at Huancayo is confirmed by the propagation distortion data at Lima. The curve for Lima also shows a strong annual periodicity.

Another confirmation of the existence of zonal effects on scintillation is obtained from observations, reported by Craft and Westerlund[16], of scintillation on 4 and 6 GHz from an equatorial chain of stations spread round the globe (Fig. 6). A casual glance at this figure shows that there is a considerable scatter of points at low geomagnetic latitudes. Of particular interest are the two points (filled circles), one almost on the geomagnetic equator, showing a value of about 17% and the other just a few degrees south of the same, showing a widely different value (46%). The names of the stations corresponding to these two (and other) data points have not been mentioned by the authors. However, considering that the data refer to the same period (August 1970-July 1971) and that the two stations considered are so close to the geomagnetic equator, such differences (by more than a factor of two) cannot be readily ascribed to anything else other than a difference in the longitudes of the two stations. In other words, Fig. 6 indicates the existence of zonal differences.

4.1 Regional Differences in Spread-F

Because of the close correlation between scintillation and spread-F it is of interest to look into equatorial spread-F data for regional differences of the same kind as observed by us in the scintillation data.

Regional differences in spread-F were first noticed by Lyon, Skinner and Wright[17] who have examined the spread-F occurrences in the equatorial belt during the IGY. As the occurrences appear to vary with longitudes, they grouped the observing stations into three zones: the American zone (45°W to 85°W), the Afro-Indian zone (20°W to 80°E) and the East-Asian zone (100°E to 160°E). For each zone they have given curves of variation of spread-F incidence with magnetic latitude, in different seasons. From these curves one can see that in equinox the peak spread-F occurrence in the American zone on internationally quiet days is about 40% as against 80% in the Afro-Indian zone and 70% in the East-Asian zone. These authors attributed the lower level of spread-F in the American zone to differences in scaling practice at the stations within this zone and also to different characteristics of ionosondes in common use in this zone. In view of the evidences already gathered from our scintillation data we believe that the lower level of incidence in the Americon zone is real and indicative of a zonal effect.

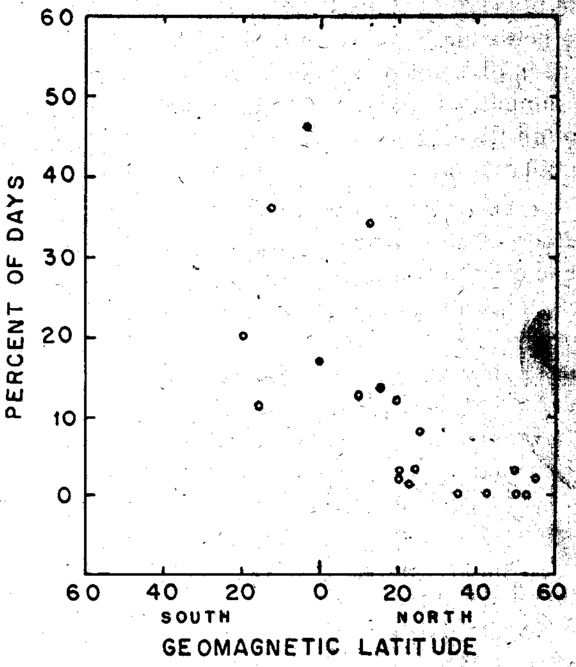

Fig. 6—Per cent of days with some scintillation activity[16]

Recently Chandra and Rastogi[14] have noted some regional differences in equatorial spread-F. They found that unlike Huancayo and Ibadan which show predominantly annual periodicities (Section 3. 2), Kodaikanal in the Asian zone does not show any perceptible seasonal variation. The effect of solar activity on spread-F index is again found by them to be different at Huancayo compared to other equatorial stations, viz. while most equatorial stations show a linear increase in spread-F index with solar activity Huancayo shows an inverse relationship. The authors attributed these differences to a significant longitudinal effect which may be associated with the large longitudinal variation in the magnetic field around the magnetic equator.

5. Discussion

A remarkable feature of the seasonal variations of scintillation at Huancayo and Legon is that they both contain a semi-annual component which has about the same amplitude and phase at the two stations. Semi-annual variations in a number of ionospheric parameters related to both neutral and ionized components have been observed by many workers. In upper atmospheric density (and hence in temperature) the variation has been discussed by Patzold and Zhchorner[18] and by Patzold[19], Priester and Cattani[20] noticed it in geomagnetic activity and Wagner[21] in the geomagnctic Sq variation. The variation in *f*0F2 and *hm*F2 have been discussed by many workers[22-25].

The presence of semi-annual variation in scintillation is a new addition to this list. The semi-annual variations in different parameters is generally characterized by minima around July and January and maxima around the equinoxes. This is what we have found in scintillation too.

No satisfactory explanation has yet been found for the semi-annual variation in general. Some attribute the effect in atmospheric density to the variable interaction between the solar wind and terrestrial atmosphere in the course of the earth's revolution around the sun[18,20]. Others relate it to a global convection pattern including meridional transport[26-28]. The semi-annual variation in scintillation seems to be closely tied to the other semi-annual variations and should be taken due note of by any theory explaining the semi-annual variation in general.

Acknowledgement

The authors are grateful to Prof. J. N. Bhar for his keen interest. Their thanks are due to Dr A. A. Giesecke M. and the staff of the Huancayo Observatory of the Institute Geofisico del Perü for collaboration in the programme of observation. The Huancayo programme was supported by the Air Force Cambridge Research Laboratories. The authors are particularly indebted to Dr Jules Aarons for his help in the computer processing of the data and for very stimulating exchange of ideas throughout the progress of the work.

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