EXPERIMENTAL RESULTS FOR THE 144 MHz TRANSEQUATORIAL PROPAGATION IN THE EURO-AFRICAN SECTOR

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INTRODUCTION

The Transequatorial propagation (TEP) has been firstly observed by radio amateurs on the American sector during the peak of the solar cycle 18 (1), on frequencies well above any predicted maximum usable frequency (MUF).

The study of TEP on the Euro-African sector by several authors (2),(3),(4),(5) indicated that the equatorial ionosphere is able to support reliable radio circuits for frequencies as high as 144 MHz. In this paper some new experimental TEP results are reported specifically for the top 144 MHz frequency band and for radio circuits between Athens (Greece), Limassol (Cyprus) on Europe and Harare (Zimbabwe), Pretoria (S. Africa) on Africa. Parameters such as circuit reliability, duration and signal strength during the "openings" signal fading and spreading are presented in this paper for the three radio circuits. The geographic areas where the "mean" TEP is observable is also discussed.

EXPERIMENTAL PROCEDURES

In order to investigate the characteristics of the TEP on 144 MHz two powerful African beacons initiated transmission during the first part of 1978, as already reported in a previous paper (5). These beacons were located at Harare (Zimbabwe) and Pretoria (South Africa), beaming towards the north at an effectively radiated power level of approximately 10 kW each. The transmissions were recorded in Athens (Greece) and Limassol (Cyprus) well before and after the maximum of the solar cycle 21, for a period of 50 months. During this period of time, characteristics of the radio circuits were monitored between 18:30 and 22:30 local mean time (LMT), when the "pure" TEP condition took place (evening type TEP). In order to resolve different signal paths as well as Doppler shifts, the south African beacon during the year 1980 was synchronized with Coordinated Universal Time (UTC), (using a local very high frequency (VHF) signal) and transmitted narrow radio frequency pulses accurate in carrier frequency. The receiving station in Athens monitoring these pulses was also synchronized with UTC, using the low frequency (LF) signals of Mediterranean Loran C system (4). The propagation time measurement accuracy was less than 0.1 ms.

EXPERIMENTAL RESULTS ON 144 MHz

Circuit reliability

The monthly mean circuit reliability histograms shown in fig. 1, have been realized after continuous monitoring of the transmissions of the two African beacons at Athens and Limassol over a period of 50 months. The reliability is defined as the percentage of evenings with positive reception of the beacons over the total number of monitoring evenings. Employing the same time scale with the reliability curves, the monthly mean geomagnetic activity and solar flux (on 2.8 GHz) are given in fig. 2 for comparison purposes. The reliability histogram of the Pretoria-Limassol circuit is not shown in fig. 1, since it failed to realize at any evening. From these results, it is evident that during the early 1980 there is a strong correlation of the solar cycle 21 peak with the maximum of the reliability for all circuits. During this period, reliability figures as high as 90% for the Harare-Limassol, 87% for the Harare-Athens and 72% for the Pretoria-Athens circuits were observed. Near the solstices the monthly averaged reliability shows a dramatic decrease to a minimum value of 3÷14%, even for the most reliable Harare-Limassol path and to zero for the other two circuits. The influence of the high geomagnetic activity during April 79, April 81 and Feb. 82 was to reduce the reliability of the Harare-Athens circuit, but not of the Pretoria-Athens or Harare-Limassol circuits during April 81. The latter circuits were reliable even at geomagnetically disturbed evenings with an Ap index up to 30 units. The relation between monthly circuit reliability, geomagnetic activity and solar flux seems to be complex. In general terms the high solar flux is essential for TEP and the geomagnetic disturbances perturb the propagation. However under a solar flux less than about 180 units, TEP during solstices is enhanced only after a solar outburst and before the arrival of the disturbance. Furthermore, it should be noted that prior to 1979 when the solar flux was low there was a trend the reliability histograms to follow the geomagnetic activity index. However after this time histograms were following the solar flux more closely under low geomagnetic indices.

Diurnal characteristics

The openings on the 144 MHz circuits have been concentrated around 20:00 LMT (18:00 UTC) with commencements seldomly before 19:00 LMT and never before 18:20 LMT. The termination of the openings has been recorded to be as late as 22:30 LMT, but not often after 21:00. Short duration openings have been observed at some evenings, but during some long duration openings (for the Harare-Athens path) signals have been present almost for 150 minutes. On the average the TEP was starting about 17:40 LMT and was lasting approximately at 18:20 LMT. Not any systematic preference for the first appearance of signals from Harare or Pretoria has been observed in Athens. However the opening between Harare-Limassol was usually preceding the others. The longest and strongest openings have been observed during the period of the maximum monthly circuit reliability, at the early 1980. The diurnal reliability of the three circuits is maximum during the period just after the setting of the sun on the magnetic dip equator and close to 20:00 LMT. Some very rare openings during sunrise have been observed only on the Pretoria-Athens path, around

08:00 LMT, but the duration and the strength of the signals were poor, as compared to the evening TEP.

Signal strength and characteristics

Although the African beacons were emitting approximately 10 KW effective isotropically radiated power (EIRP), the received signals were mostly weak and rather difficult to monitor automatically. For this reason manual recording on most evenings took place. The signal amplitude was reaching a sharp maximum shortly after the commencement of the opening and a long tail, as shown in fig. 3, was following. The minimum observed excess attenuation over the equivalent free space attenuation for the Harare-Limassol circuit was 40 dB and for the Pretoria-Athens and Harare-Athens paths was 43 dB and 47 dB respectively. The average values of the measured attenuations were at least 6 dB higher than observed minimum values.

On all occasions the received signals on the three circuits suffer severe distortion. The amplitude distortion is observed in the form of a fast flutter fading and chopping-out of the signal for intervals of few ms, although the average amplitude is constant for short periods of the order of few seconds. The frequency distortion is characterized by broadening of a monochromatic carrier over a bandwidth of several KHz. Doppler shifts were also encountered almost on any opening, with preference to the negative values, ranging from -350 Hz to +40 Hz, as shown in fig. 4. The average value of the Doppler shift found to be approximately -100 Hz for the Pretoria-Athens path. During some openings when the signal strength was rising very quickly, the Doppler shift was changing so fastly that it was listening as a whistle. Because of these fading characteristics TEP sounds very much like the signals reflected from aurora. No single beat tone could be hear when the receiver was tuned across the signal bandwidth and the transmission was identified as an increase of the background noise at the receiver output. Under these circumstances no any voice transmission was intelligible and only slow CW was readable. In general, after the opening, the signal progressively gets less distorted and some rough tone could be heard before the end of the opening. The distortion seems to be more pronounced on longer paths, and the most distorted signal has been recorded on the Pretoria-Athens circuit. The use of more antenna gain at the receiving site did not gave "cleaner" signals although stronger signals were received.

Propagation delay

The one way propagation time measurements for the Pretoria-Athens path resumed on a figure of 26.0±0.2 ms (for N=20 measurements during 1980) for the first arriving pulse. Strong multipaths producing extra delays up to 4 ms have been observed. This multipath was affecting the quality of all monitored signals above at least 20 MHz, characterizing the TEP. The average propagation delay, for the first arriving pulse, on 144 MHz has been by 0.8 ms and 1.4 ms longer than of the corresponding delays at 50 MHz and 28 MHz respectively. The observed propagation delays are attributed to the $2F_2$ dominant propagation mode at 28 MHz, to the $2F_2$, "F type" TEP (afternoon type) and "pure" TEP (evening type) modes at 50 MHz (where the standard deviation of the delay is 0.3 ms) and only "pure" (evening type) TEP mode at the 144 MHz.

Geographic zones of the TEP and path geometries

The geographic area, where the transmission on 144 MHz from Harare (Zimbabwe) was being received, extents at least between the points: Athens-Zante Isl.-Crete Isl.-Thessaloniki (Greece)-Limassol (Cyprus). No persistent reception has been reported from Malta, Sicily, Southern Italy, Bulgaria or Yugoslavia, but it seems possible that on few special evenings weak reception took place in Northern Yugoslavia, in Ibiza Isl. (Spain) and in Southern Germany by the spreading of the normal "main" TEP zone. The reception area of the Pretoria beacon observed to be smaller, with no reception at any evening at Limassol (Cyprus). Considering the circuit reliability curves and signal strength levels, Limassol stays closer to the center of the "conjugate zone" of Harare than all the other reception points. This statement is also valid for the conjugancy of the Pretoria and Athens points. The "conjugate zones" seems to be symmetrically distributed across the geomagnetic dip equator as it is verified from the achieved contacts on 144 MHz and are summarized in fig. 5. Probably the most interesting example is the dual conjugate zone of the area close to Puerto-Rico, giving the possibility of traffic either into Argentina or South Atlantic (see fig.5). The maximum deviation from the symmetry condition refers to the circuit Harare to Ibiza Isl., with an angle between the path and the magnetic dip equator 70°. Finally it should be noticed that distances covered on 144 MHz by this exotic mode of propagation on the Euro-African sector are of the order of 6000 km to 8000 km.

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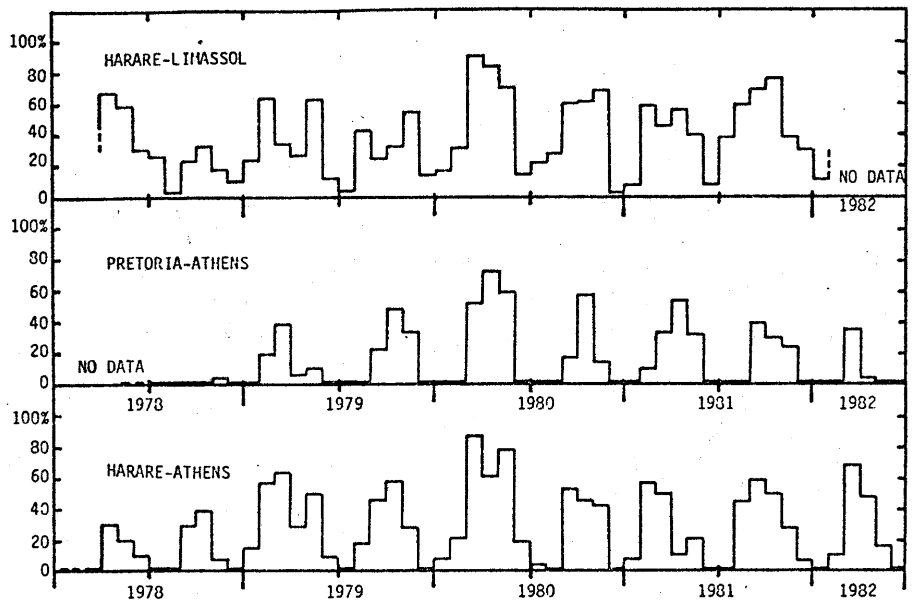

Figure 1 Monthly circuit reliability on 144 MHz.

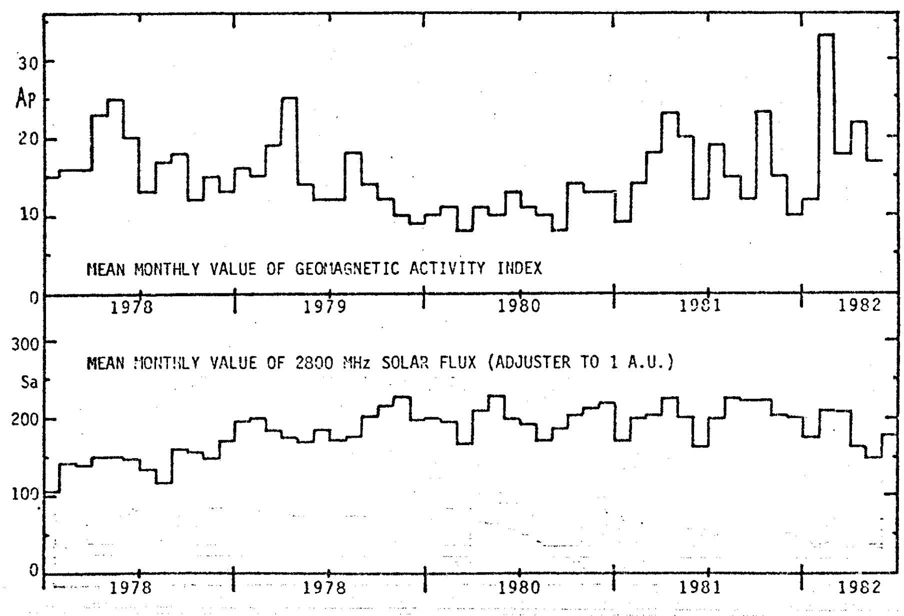

Figure 2 Geomagnetic activity and solar flux for the 1978-1982 time period.

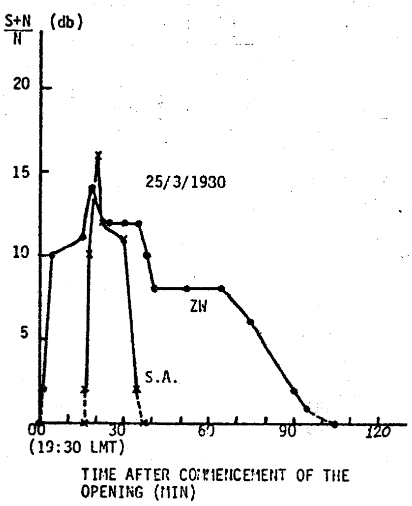

Figure 3 Typical diurnal signal strength pattern.

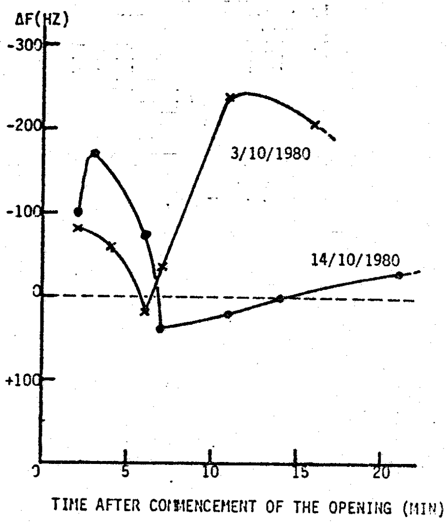

Figure 4 Diurnal frequency shift pattern.

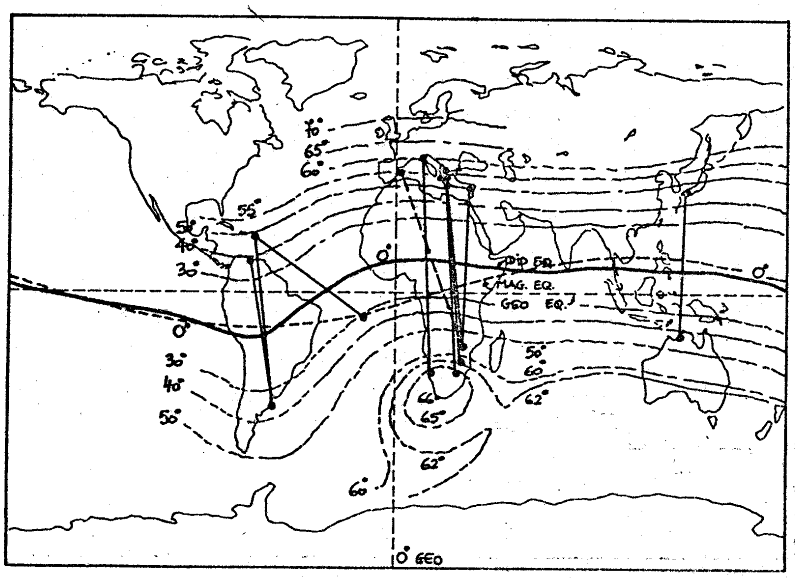

Figure 5 TEP path geometries on 144 MHz (numbers indicate magnetic dip latitudes).