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Simultaneous Observation of Fading Rates on Two Transequatorial H.F. Radio Paths

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Abstract

Fading rates of transequatorial h.f. signals are evaluated from observations on the paths Lindau–Roma and Tsumeb–Lindau which cross the equatorial zone of Africa. The fading characteristics on both paths are shown to be correlated. A comparison with transequatorial pulse transmission, which indicates off-great-circle propagation due to spread-*F* irregularities, gives evidence for a high correlation between the fading of c.w. signals propagating on transequatorial paths and the occurrence of off-great-circle propagation due to equatorial spread-*F* irregularities.

Radio signals propagating via transequatorial paths often exhibit rapid phase-incoherent fluctuations (flutter fading) associated with equatorial spread-*F* conditions (see e.g. Yeh and Villard 1960; Koster 1963; Carman *et al.* 1973). In the present note, preliminary observations of equatorial flutter fading rates on two different paths are compared and correlated with observations related to the occurrence of equatorial spread-*F*.

Simultaneous c.w. transmissions at 14·7 MHz from Lindau, W. Germany (51·7° N., 10·1° E.), to Roma, Lesotho (29·7° S., 27·7° E.), and at 14·0 MHz from Tsumeb, south-west Africa (19·2° S., 17·7° E.), to Lindau (Fig. 1) were made for some evenings covering the period of equatorial sunset during April and May 1972. Additionally, pulse transmission on 14·7 MHz was carried out between Lindau and Tsumeb to obtain indications of off-great-circle propagation due to side scatter and reflection caused by equatorial spread-*F* irregularities. Use of pulse transmission and a rotating direction finder antenna enables the determination of different off-great-circle paths, which can be separated from normal great-circle paths by means of the increased propagation time delay. It has been shown by Röttger (1973) and Kelleher and Röttger (1973) that these side paths are evidently caused by equatorial spread-*F* irregularity patches.

Since the two transequatorial paths Lindau–Roma and Tsumeb–Lindau cross the equatorial zone at different longitudes, characteristic variations of the flutter fading rate caused by west–east moving equatorial spread-*F* irregularity patches should have a high probability of occurring at different times if the propagation is via great-circle paths only, and especially if the patches are small and infrequent. However, the results of the present work indicate that the occurrences of characteristic flutter fading of transequatorial signals are closely correlated in time and are associated with off-great-circle propagation during equatorial spread-*F* conditions.

Fig. 2 shows some examples of the observed fading rates determined by counting the number of field strength maxima per minute. For the present analysis it is assumed that the frequencies of 14·0 and 14·7 MHz are sufficiently close to permit a comparison of the fading rates. Differences in equipment characteristics (such as the rise time of the receiver AGC or the time constant of the pen recorders) are taken to be unimportant in comparing the trend and short-time variations of these fading rates. It is evident from Fig. 2 that the fading rates on both frequencies follow the same diurnal variation. The correlation between these two time series, taken over the entire observed interval of 1–2 h, is set out below.

17 April 1972	$r = 0{\cdot}88$	25 April 1972	$r = 0{\cdot}74$
18 April 1972	$r = 0{\cdot}56$	27 April 1972	$r = 0{\cdot}58$

All four correlation coefficients r indicate a significance to at least a 95% confidence level for the long term trend of fading rates. A good correlation is still evident for time lags between both series of about 20–30 min on 17 and 25 April.

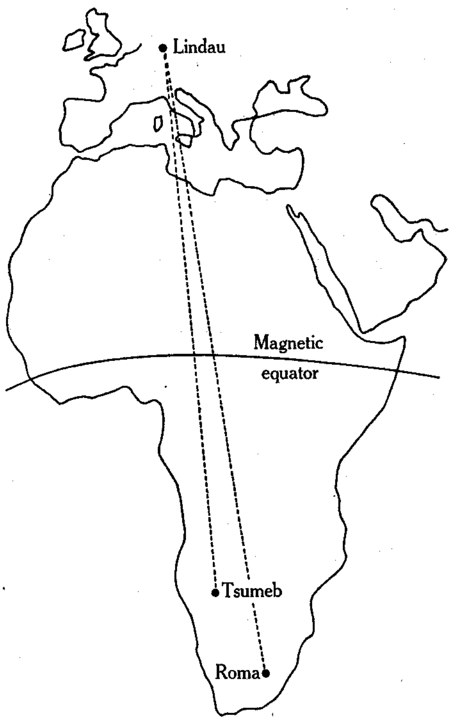

Fig. 1. European–southern African transequatorial h.f. paths used in the present work.

For a more detailed analysis it is necessary to study the short-term variation in fading rates on both paths. This should indicate effects caused by the same equatorial spread-F irregularity patches. The variation v_i of the fading rate N during a fixed time interval Δt_i (= 5 min in the present work) is defined by the relation

$$v_i = (N_{i+1} - N_i)/|N_{i+1} - N_i|.$$

To test the variation, coincidences between the direction of increase or decrease of fading rates on both paths were investigated. The relative number V of events when an increase or decrease was observed simultaneously on both paths was evaluated for the respective complete periods of observations. The results were as follows.

17 April 1972	$V = 0{\cdot}67$	25 April 1972	$V = 0{\cdot}50$
18 April 1972	$V = 0{\cdot}50$	27 April 1972	$V = 0{\cdot}71$

Only chance correlation occurs when $V = 0{\cdot}5$ (neglecting the rarely occurring event $v_i = 0$). To determine the significance limits of V, a normal distribution was assumed and used to find the standard deviation σ_V. For chance correlation, the value $\sigma_V = 0{\cdot}104$ was obtained. Thus for a normal distribution of V, the 5% boundaries of error probability are given by the 2σ limits, and all values exceeding $V+2\sigma$ ($= 0{\cdot}708$) are 95% significant, i.e. the probability that these values are due to chance is less than 5%. In the present case, the above results for V show that there is a good correlation between the 14·0 and 14·7 MHz fading rate variations on 27 April, when the significance is 95%. On 17 April the correlation is 90% significant, which still may be assumed to be relevant. There is little correlation on 18 and 25 April, however.

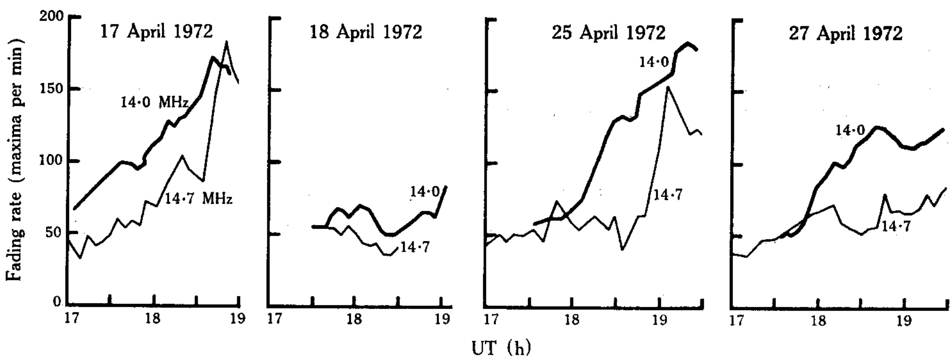

Fig. 2. Examples of observed fading rates of simultaneous c.w. transmissions at 14·0 and 14·7 MHz over the paths Tsumeb–Lindau and Lindau–Roma respectively.

The quasi-simultaneous occurrence of intermediate maxima and minima (deduced from the simultaneous increase and decrease of the fading rate) on 17 and 27 April indicates that the propagation was not restricted only to the great-circle plane but that off-great-circle transmissions also occurred throughout the period of observation. The intermediate maxima on both paths may have been caused simultaneously by the same patch of irregularities, and this implies off-great-circle propagation since, if the propagation had been in the great-circle planes only, the maxima would probably have occurred at different times, coinciding with the times the patches crossed the great-circle planes. To confirm this, the fading rate was compared with the occurrence of side paths due to equatorial spread-F irregularities as determined from 14·7 MHz pulse transmissions (Kelleher and Röttger 1973; Röttger 1973). The results of this comparison for hourly values between 1700 and 1900 h UT for 16 days in the interval 17 April to 10 May 1972 were as follows.

Presence of spread-F side paths Lindau–Tsumeb (14·7 MHz)	Fading rates Tsumeb–Lindau (14·0 MHz)	
	higher than mean	lower than mean
Yes	27	6
No	3	11

A χ^2 test shows that the significance of correlation between these two observations is better than 99·9%. Thus the fading rate and the occurrence of off-great-circle propagation due to equatorial spread-*F* are highly correlated.

Conclusions

From simultaneous observations of the fading rates of h.f. signals on two paths crossing the equatorial region at different locations, this work has shown, in spite of the relatively short observation period of a few days, that for some events the fading characteristics on both paths are comparable. It has been established that these fading characteristics are highly correlated with the occurrence of off-great-circle paths due to the presence of equatorial spread-*F* irregularities.

Acknowledgments

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