provided by equipment operated by ZE2JV as part of a research project sponsored by a scientific agency. The solid line shows the *average* evening m.u.f. observed for the month up to nearly 70 Mc. briefly in the post-sunset period, with the 50-Mc. band being open for nearly 5 hours. On peak evenings, the m.u.f. reached 87 Mc.! This is shown by the broken line with dots.

It is of interest to note that the predicted m.u.f. for the path, shown in a dashed line, flirted with the 10-meter band for several hours, but 5B4WR tells us that the 10-meter band was still holding up well through the early evening hours into June, when he left Cyprus for an extended stay in Britain. Clearly, a great deal of 50-Mc. DX could be worked from Southern Rhodesia, even this late in the solar cycle, if there were use of the 50-Mc. amateur band in Southern Europe and the Mediterranean area. Unfortunately, this is not the case, Europe having given over this portion of the spectrum to television some years ago.

For the balance of this discussion we quote more or less verbatim from a detailed report recently received from 5B4WR, which was also the source of the graphs and other data given above.

—*E. P. T.*

How Does TE Work?

BY R. A. WHITING,* 5B4WR

ANY explanation of the ionospheric mechanism which produces the rise in *TE* m.u.f. after sunset must, of course, take into account the known characteristics of the ionosphere in equatorial regions. Because of the effect of the earth's magnetic field on the ionized layers of the earth's atmosphere, in the vicinity of the geomagnetic equator, they display characteristics peculiar to this region. These characteristics have been observed on ionospheric sounders in areas close to the geomagnetic equator.

One such characteristic is an increase in the degree of ionization of the F_2 region, with peaks in electron density contours occurring at around 15 degrees from the geomagnetic equator. The presence of these high-density zones, plus the higher level of ionization in general, accounts for the higher m.u.f.s observed over north-south *TE* paths. This is illustrated in Fig. 3A for the normal two-hop signal path from Salisbury to Limassol via the F_2 region.

What then of the rise of *TE* m.u.f. after sunset, and the flutter fade observed? Although several explanations have been advanced to account for this effect, perhaps the simplest and most readily understood is illustrated in Fig. 3B. It also has the merit of taking into account the observed behavior of the F_2 region of the ionosphere after sunset in the vicinity of the geomagnetic equator. This manifests itself as an increase in height of the F_2 layer immediately after sunset, accompanied by the breakup of the layer into clouds of ionization, the effect lasting for several hours. Because the echoes returned from vertical-incidence sounders during this period are diffused or spread out, due to scattering by the ionized clouds, the effect has been termed "Equatorial Spread *F*."

The phenomenon is illustrated in Fig. 3B, which also suggests diagrammatically how an increase in m.u.f. is possible. Due to tilts introduced in the F_2 region, the radio wave encounters the layer at a lower angle of incidence than is

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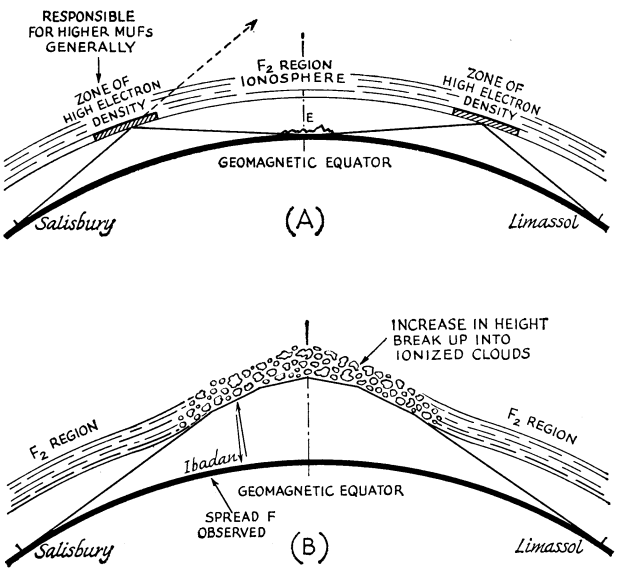

Fig. 3—Normal and post-sunset trans-equatorial propagation between Salisbury and Limassol. The normal path, A, involves two-hop F_2-layer propagation, with a bounce at the geomagnetic equator. The increase in height and breakup of the layer after sunset allow the wave to propagate across the underside of the layer. The result is a diffused multipath signal, showing some distortion but high reliability.

normally possible, and by successive refraction is guided around inside the region to be returned to earth, in this case at Limassol, without an intermediate ground-reflection point.[5] Because of the presence of a higher degree of ionization and the lower angle of incidence, higher frequencies are refracted and the path m.u.f. rises.

The elimination of an intermediate ground-reflection point will reduce signal attenuation, and the scattering from the clouds of ionization produce the effect known as *TE* flutter fade. In fact, Equatorial Spread *F* has become closely associated with the flutter fade noticed on short-wave signals in general, propagated across the geomagnetic equator during the period after sunset. The effect has become known to communication engineers as the "tropical sunset fading effect" — sufficiently descriptive, I think you will agree. The presence of Equatorial Spread *F* undergoes generally the same seasonal changes in intensity and duration as have been observed on the post-sunset propagation of six-meter *TE* signals.[4]

One other aspect of the ionosphere observed in the region of the geomagnetic equator is the presence of a permanent daytime belt of sporadic-*E* which breaks up and disappears after sunset. On the two-hop signal path illustrated in Fig. 3A certain frequencies would be reflected from the top of this layer, on past records as high as 55 Mc. on occasions. If signals are being reflected from the top of this layer, then its disappearance after sunset, by introducing additional attenuation, could account for the rather pronounced dip in signal levels observed on the six-meter band at sunset during the equinoxes. The presence of the sporadic-*E* layer is indicated in Fig. 3A. It has been observed to occur in a narrow belt centered on the geomagnetic equator and bounded by the dip latitudes of 10 degrees north and 10 degrees south. It should be noted that Figs. 3A and 3B are not to scale.

Fig. 4 illustrates the incidence of Equatorial Spread *F* after sunset, as observed at Ibadan, dip latitude 6 degrees south. It also shows the disappearance of sporadic *E* at sunset. It records for both phenomena the percentage of hourly observations when they were observed during

[5] This is essentially the "billiard-ball mode," proposed by Villard, Stein and Yeh: "Studies of Transequatorial Ionospheric Propagation by the Scatter-Sounding Method," *Journal of Geographical Research*, Vol. 62, p. 399.

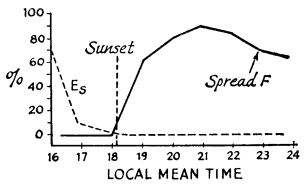

Fig. 4—Percentage of occurrence of Spread F at Ibadan, Nigeria, near the midpoint of the observation circuit and the geomagnetic equator, September, 1958. After Bennington, *Wireless World*, October, 1960.

September 1958. In the case of sporadic *E*, its presence was registered when its critical frequency was greater than or equal to 5 Mc. This graph should be compared with the diurnal 6-meter signal level variation for the same period over the Salisbury-Limassol path.

Uses of TE

Propagation information of the nature discussed provides the amateur a useful tool to extend the range of his contacts in both distance and frequency. From the information presented we now know from what geographical locations we can take advantage of the peculiarities of *TE* propagation, what frequency bands can be used, and the time of day and season of the year when we can expect the best results. The most efficient mode of communication is c.w., in view of the fading pattern encountered, though voice is readable much of the time.

To summarize, on north-south transequatorial circuits over paths symmetrically disposed with respect to the geomagnetic equator and of between 3000 and 4000 miles in length (this may be extended by other modes of propagation), reliable communication is possible using the amateur bands as high as 50 Mc. during the three hours after local ground sunset time in the equinoctial periods. Signals propagated across *TE* circuits during these hours are subjected to a form of rapid fading. Less-reliable communication is possible on frequencies at least as high as 70 Mc. All this is possible using low-power amateur transmitting equipment and without special receivers or antennas. In view of its great potential for reliable communication, it must be assumed that the *TE* mode will take on ever greater importance, as this potential becomes more widely known and appreciated. QST

Strays

Are you an ex-G ham and will you be at the Dayton Hamvention on April 27? If so, contact W8LUZ, who is going to have a little breakfast for you at 0830 that day. In Dayton phone TU 5-7811, or leave your name at the registration desk, or write to him at 8981 Clyo Rd., Dayton 59.

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The Long Island Tri-Banders ARC has a 6-meter Bunny Hunt the second Friday of every month. The hunts start from Jolly Roger's in Bethpage, N.Y., at 2030 EST. For further info contact Michael Camerire, WN2BHH, 1870 Oakland Ave., Wantagh, N.Y.

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Any hams acting as amateur radio instructors at summer camps in New York state during this coming summer please contact Robert M. Zitter, WA2PIX, 697 Bruce Drive, East Meadow, N.Y., to see about an inter-camp net.