A Newly Discovered Mode of VHF Propagation [1978]

Shattering the 2-meter DX record has become commonplace lately. Equatorial FAI is one theory on what's behind these super band openings.

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On October 29, 1977, at 0200 UTC, LU1DAU, La Plata, Argentina, worked YV5ZZ/6, Bocha de Uchire, Venezuela, on 145.9 MHz cw! By 0310 UTC, the signals had improved greatly, and a two-way ssb contact was made. Both stations were running less than 100 watts and used 10 to 12 dB gain antennas. When the signals faded at 0400 UTC, a new terrestrial-only 2-meter record of 3135 miles (5045 km) had been set.

For many years, vhf operators have known of transequatorial (TE) radio propagation on 6 through 15 meters[1-4]. While it was speculated that this mode could support the propagation of 2-meter signals under the right circumstances, such conditions had never been reported. It now appeared that .TE had made it to 2 meters. Again and again, YV5ZZ worked into Argentina. By the end of November, such contacts became almost commonplace. With reports of bigger and better openings coming each day, we began trying to correlate contemporary solar-terrestrial conditions with those present during prior TE-mode QSOs.. We noticed many discrepancies, leading us to conclude that this fantastic propagation was not TE, but possibly a result of magnetic- *field-aligned irregularities* (FAI) in the equatorial ionosphere.

Some Background Information

The push for a new 2-meter record had been spurred on by the observations of YV5ZZ. On November 8, 1976, Edgar heard OSCAR 7 Mode A uplink (145.9 signals from LU7DJZ. He was not listening to the downlink signal on 10 meters what he heard was really on 2 meters! This prompted weekend schedules at first, eventually leading to nightly attempts at a QSO. Contact was made on either 21.4 or 50.1 MHz. If conditions looked good, attempts were made on 145.9 MHz. To prevent OSCAR QRM, the frequency was later changed to 145.1 MHz.

After nearly a year of trying, they made it. Since the first contact, there have been over 40 days when known openings have occurred, and they have been observed on all continents. The more noteworthy events are listed in Table 1. Also shown are the times during which the openings were observed. Fig. 1 is a map showing the location of stations active in these openings. The bulk of the favorable conditions seem to occur within the period from sunset to midnight. Signal strength was not the same for each opening and varied considerably during the course of a contact. Stations sometimes reported that received signals "sounded like moon-bounce," but more often they were well above the noise. Even low-power (100 watts effective radiated power) ssb and fm stations participated. Stations over 500 miles (800km) apart often participated in an opening.

TE-Mode Propagation

By reviewing some prior work and findings in the field of TE propagation, we hope to point out comparisons that indicate another mode is responsible for the more recent contacts.

Table 1
Propagation "Firsts" via FAI

Date	UTC	From/To	Comments
November 8, 1976	0037	YV5ZZ/LU7DJZ	LU7DJZ OSCAR Mode A uplink signal heard
July 1, 1977	unknown	PY2OD/TU2EF	TU2EF OSCAR Mode A uplink signal heard
October 29, 1977	0200-0400	YV5ZZ/LU1DAU	First reported QSO via this mode
February 12, 1978	0005-0020	LU/KP4-YV	No 6-meter path but good 2-meter signals
February 13, 1978	0004-0110	LU/KP4-YV	YV5ZZ heard LU3AAT on 432 MHz but no QSO
February 20, 1978	0400-0405	YV6ASU/LU3AAT	LU3AAT only station heard in north. Note relatively late time
February 24, 1978	1200	VK8GB/JH6TEW	First VK-JA QSO on 2 meters
April 10, 1978	1800	ZE2JV/5B4WR	First Asia-Africa QSO via this mode
April 12, 1978	1800	SV1AB/ZE2JV	First Africa-Europe QSO via this mode

A TE path is generally considered to be between stations located 1500-2500 miles (2400-4000 km) either side of the magnetic equator[5]. No east-west paths have been reported. Backscatter sounding studies have identified the paths as being the result of two or more successive reflections in the F-layer region of the ionosphere.

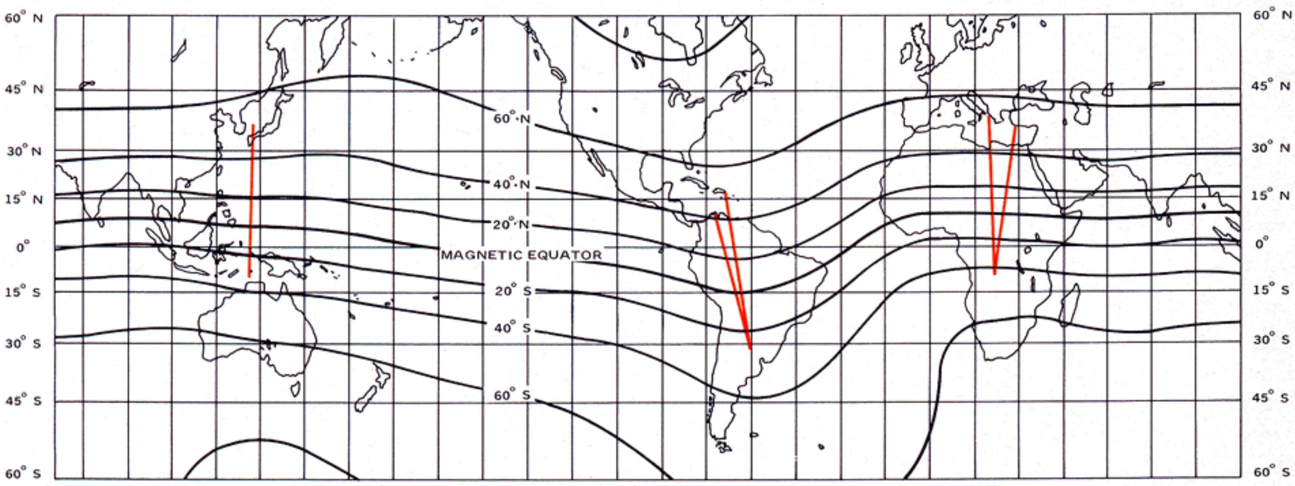

Fig. 1 - Approximate location of stations which successfully made use of FAI can be seen on this map. The contour tines indicate geomagnetic latitudes.

The ray path for such a signal is shown in Fig. 2. Because no intermediate ground reflections are involved, signal strength is greater than might expected. TE depends on a phenomenon called "ionospheric tilt." Instead of an ionosphere which is concentric with Earth, a tilt may occur, especially after sunset or sunrise at the ionosphere. An ionosphere having opposite tilts over a large area is required to support successive reflections. In the equatorial region, tilts occur daily near sunset, when the height of the ionosphere begins to increase, rising higher than that to the north and south. Later in the evening the ionized layer settles and the tilts disappear. Waves striking this tilted layer have a lower angle of incidence then would normally be the case. This allows higher frequencies to be propagated, typically 1.5 times the daytime maximum usable frequency 80-100 MHz is severe [6]. Six-meter openings are usually coincident with enhanced 10-and 15-meter propagation, and signals are usually distorted with a characteristic flutter fading. TE propagation is most often noted between 1700 and 2100 local time at the path midpoint, moving from east to west as the earth rotates, but some afternoon openings have been observed as well [1,7]. TE occurs most often during the equinoctial periods (around March 21 and September 23). It is least common during solstitial periods (around June 22 and December 22).[1,5]. The best TE conditions seem to occur at or near a sunspot-cycle peak.

Comparison with Recent Openings

The 2-meter contacts between Australia and Japan and in South America have been between stations located approximately 1500-2000 miles (2400-3200 km) from the geomagnetic equator. One exception was the reception of OSCAR 7 Mode A uplink signals (145.9 MHz) from TU2EF, Ivory Coast, by PY2OD, Santos, Brazil. This path lies along the geomagnetic equator and represents the only known east-to-west propagation of this type. Because this observation was made prior to the first confirmed 2-meter contact, it was met with no small amount of scepticism! Classical notions of TE do not account for this path. Since the effect was noticed, on July 1, 1977, YU2EF has moved to Brazil. It is hoped that other African stations will be found who are willing to experiment with South American amateurs on this path.

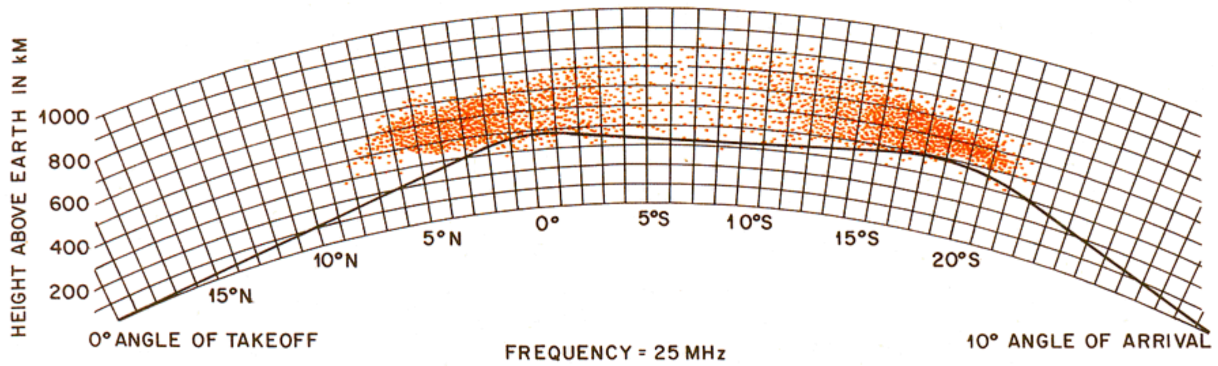

Fig. 2 - Cross section of a transequatorial ray path, showing the effect of ionospheric tilt on a 25 MHz signal. This drawing shows a typical example of TE propagation. (From Davies, "Ionospheric Radio Propagation," U.S. Government Printing Office, Washington, DC 1965.).

The 2-meter openings to date have shown little correlation with equinoctial periods. In fact, 10 openings have occurred within 30 days of a solstice. It remains to be seen whether the frequency of openings increases as an equinox approaches. Two meters is 2 to 3 times higher in frequency than the greatest mufs observed during the 1957-58 peak of sunspot cycle 19. This period was an all- time high for solar activity. In fact, 2 meters is not the highest frequency at which this phenomenon has been ob served. On February 13, 1978, YV5ZZ heard weak but identifiable signals from LU3AAT, on 432.1 MHz. Two-meter and 432 propagation far exceeds the capability of the TE mode YV5ZZ was using his satellite antenna system, which is steerable in azimuth and elevation. In the direction of LU3AAT, his horizont is obstructed by a range of mountains. The lowest elevation angle which allows for clearance of the mountain range is 8 degrees. On February 16, 1978, YV6ASU heard LU3AAT on 432 MHz, with his antenna at about the same angle of elevation. On yet another occasion, KV4FZ heard LU3AAT on 145.1 MHz. He reported that a peak in signal strength occurred when the antenna elevation angle was 8-10 degrees. This geometry suggests that single-hop F-layer reflection isn't involved. The angle also seems high for the tilt associated with TE.

At first, 2-meter tests were conducted only when strong 50 TE signals were noted. However, on February 12, 1978, KP4EOR contacted two Argentine stations at a time when no 50-MHz path existed. This effect, which was also noted by YV5ZZ on occasion, would not normally be expected for TE.

When the occasions of openings were compared with solar flux and geomagnetic indices for the dates involved, no correlation was seen. The first contact did take place on a day when auroras were reported in the Northern Hemisphere. This appears to have been coincidental as the condition did not repeat. TE is most prominent at a solar cycle peak. We are presently ascending from a solar minimum.

Because these observations indicated the recent contacts did not result from fantastic TE propagation, we began to look for another propagation mode to account for them. Our attention was immediately drawn to the possibility that they were somehow related to irregularities in the equatorial ionosphere.

Scattering Mode

One phenomenon related to the ionosphere is called scintillation[8]. This is seen as amplitude and phase variations of signals which transit a nonuniform ionized region. Scintillation causes the signal to fade by breaking it up into several ray paths which may or may not arrive in phase at the receiver. The ionospheric irregularities which cause the scattering may be thought of as bubbles of electron density different from that of the surrounding medium. These bubbles can become directional reflectors of radio signals. They behave roughly as thin elongated rods aligned with Earth's magnetic field[9]. A representation of one rod is shown in Fig. 3. The angle of reflection of a wave is equal to the angle of incidence, but both paths need not lie in the same plane. A wave incident on a cylinder excites conically shaped reflections. If the transmitter properly illuminates irregularities aligned with the magnetic field, the cone will intersect Earth. Signals may then be received within the area covered by the cone. Scattering tends to add still more paths, allowing reception throughout a belt-shaped area, rather than a circular or elliptical one.

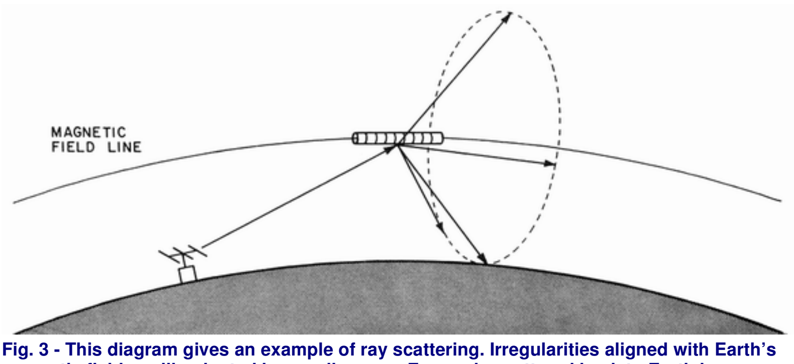

Fig. 3 - This diagram gives an example of ray scattering. Irregularities aligned with Earth's magnetic field are illuminated by a radio wave. Energy is scattered back to Earth in a cone-shaped pattern. Stations within the area intersected by the cone can receive the signal.

Vhf signal-scattering irregularities can occur daily in the equatorial region. In fact, the occurrence of scattering ir regularities is greatest near the magnetic equator and in the polar regions. The phenomenon is least seen in the middle latitudes. Polar-region aberrations are associated with the auroras. In the equatorial region they commence abruptly about 1900 local time, become more patchy and sporadic through the night. Disruption in the equatorial F region has been linked with an increase in the height of this layer, the same phenomenon responsible for TE. The optimum time for scatter propagation via these field alignment irregularities (FAI) is about one hour later. FAI show seasonal variations. The precise pattern also depends on the longitude and period of the solar cycle. FAI tend to be more common during equinoctial periods, the winter months and years of high solar activity[10]. In the Americas, FAI seem to be concentrated in the period from October through March, all but disappearing during June, July and August. In the Africa-Mediterranean region, occurrences also are frequent from October to May. There are many openings in the period June through August. For the Asia-Australia region, present data indicate the maximum may even be in June and July.

FAI tend to occur within 10 degrees of the geomagnetic equator. Satellite studies have indicated that irregularities large enough to scatter 144-MHz signals exist at heights of up to 620 miles (1000 km) just at and shortly after sunset. Recently, studies have been made with the 50 MHz scatter radar in Jicamarca, Peru. They indicate that the irregularities may last as late as midnight, local time. It was found that plumes of electrons in the otherwise depleted regions form ducts which can trap vhf signals. They are then scattered back to Earth at the point they exit the duct. Strong scintillations noted on satellite signals received near the geomagnetic equator have been tied to these features. FAI ranging in height from 375 to 500 miles (600 to 800 km) could ac count for propagation on even the longest of the observed paths[11].

In the early 1970s, several government, agencies participated in an experiment to study the effects of artificial irregularities in the ionosphere[12]. Since naturally occurring auroras were known to scatter vhf signals, man-made irregularities were tested for the same properties. Reflection of frequencies up to 430 MHz was found at times when normal transmission was possible only through 10 MHz. So strong were the reflections that cw and ssb communication at frequencies of 20-50 MHz was possible using 100-watt-output transmitters and 10 dB-gain antennas. Above 50 MHz the reflection coefficient fell off steadily, so that 430-MHz receiver- noise figures on the order of 1 dB were needed to produce usable signals over long paths. Fading rates increased with frequency. Naturally occurring ir regularities in the nighttime equatorial ionosphere can produce similar effects and the geometry is correct for long-distance north-south propagation. If there is a coherence (adding effect), from the banded structures which occur naturally in the equatorial FAI, the observed signal strengths could be supported with modest amateur equipment. It is interesting to note that, since the geomagnetic field lines in the ionosphere above the magnetic equator are nearly parallel to the Earth's surface, communications in both north-south and east- west directions should be possible, given adequate power levels[13]. In the case of north-south propagation across the geomagnetic equator, the propagation mode is as depicted in Fig. 4. East-west propagation via FAI is theoretically possible near the geomagnetic equator. Possible coverage is diagrammed in Fig. 5. This could account for the reception of OSCAR uplink signals from TU2EF in Brazil, an east-west path along the geomagnetic equator.

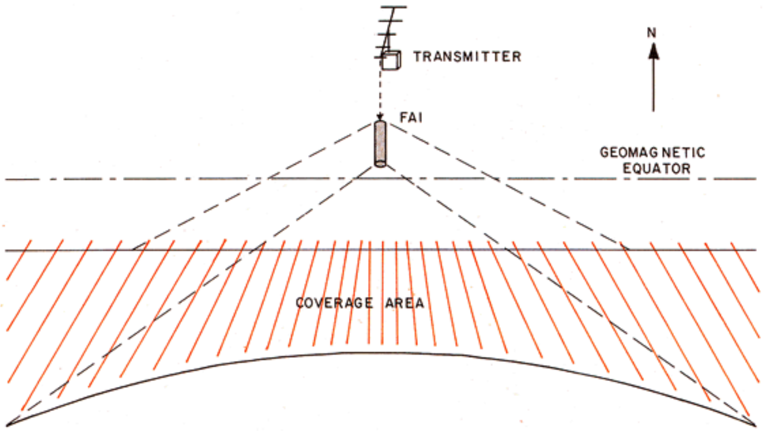

Fig. 4 When a station north of the equator is transmitting in a southerly direction, the southern coverage area will be similar to that shown in this drawing, shown as if looking down from a great height. Size of this area is dependent upon the length and horizontal extent of the scattering medium, and its position relative to the transmitter and receiver. The coverage pattern for a southern station beaming north would be a mirror image of that shown here.

Another interesting property of propagation via FAT is that long-range transmission from within or above the ionosphere to the ground is possible. The cone of signals generated by satellite transmissions incident on equatorial FAT can intersect the ground when the geometry is correct. Such a mode could explain the reception of OSCAR downlink signals when the satellite is well below the listener's horizon.

Scatter propagation causes the signal to flutter. Either or both increased frequency and fewer reflections will enhance the severity of flutter. KP4EOR noted that received signals sounded like a buzz saw! Tests conducted after midnight, local time, have uncovered no recurring openings. Radar data from Jicamarca indicate that such openings, if possible at all, should be rare, because of the absence of suitably sized scattering surfaces after local midnight. Prediction of FAT presence may be possible with the aid of amateur satellites. Ionospheric scattering results in an observed Doppler frequency shift which differs from the expected value. An accurate Doppler plot may reveal shifts in a patchy ionosphere. Amplitude flutter on the beacon and downlink signals might also reveal the existence of an opening via FAI.

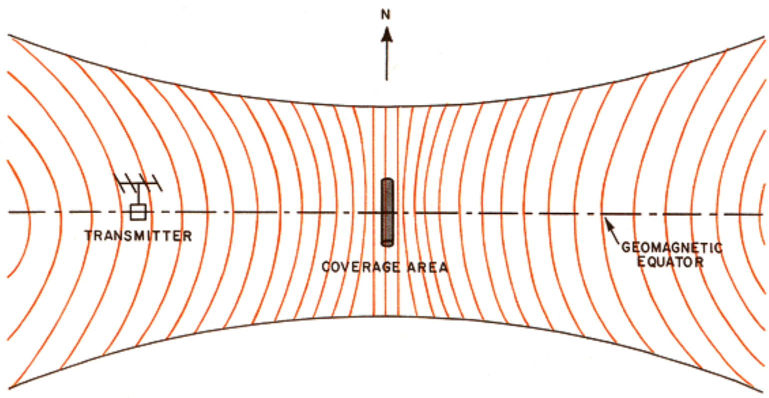

Fig. 5 Scatter-mode coverage in an east-west direction along the magnetic equator. As in the case shown in Fig. 4, coverage area is dependent upon the horizontal extent of the scattering medium. A relatively wide coverage area may be possible if north-south alignment of the irregularities is not an important aspect of the phenomenon.

Conclusions

The recent record-breaking 2-meter openings exhibited many characteristics which were previously unobserved and unexplained. In an effort to explain to ourselves what was happening, we noted many characteristics directly related to the occurrence of irregularities in the alignment of Earth's magnetic field. It seems likely that these contacts resulted from propagation by the fine-scale structure of the equatorial ionosphere, rather than broad tilts related to normal ionospheric conditions. Confirmation awaits further testing by amateurs. If we are correct, the implications are exciting for vhf operators worldwide. Contacts between South America and Africa, and Africa and Asia on frequencies up to 432 MHz may be possible. We congratulate the avid vhf operators who have participated in this work so far, and urge them to continue trying for new DX records.

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