VHF IONOSPHERIC PROPAGATION

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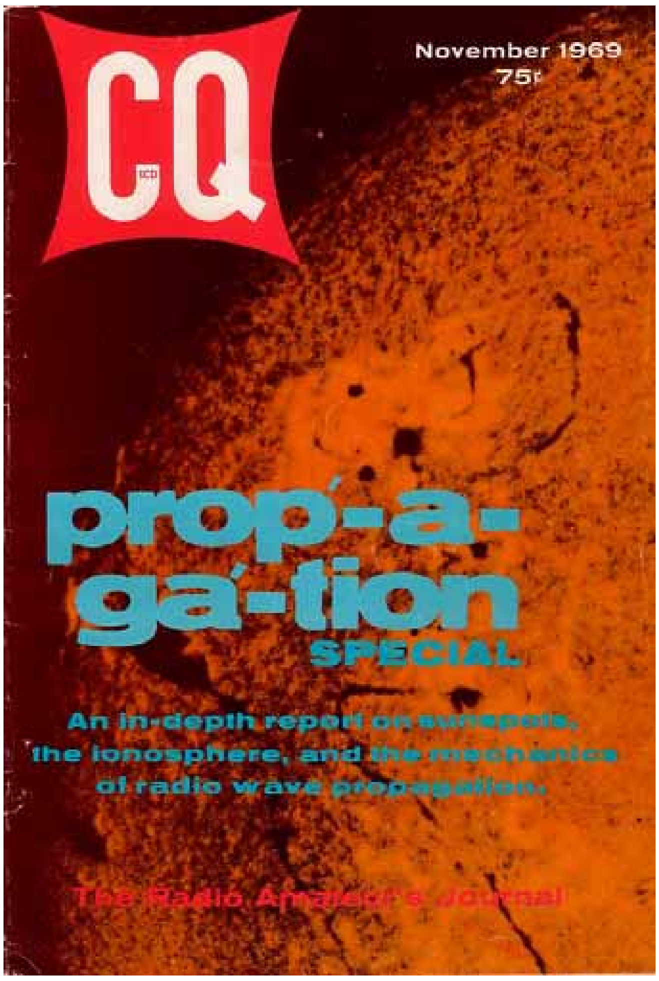

Long-distance propagation via ionospheric re-flection normally takes place over the frequency range 3 to 30 mc. Higher frequencies are generally propagated through the troposphere and are often limited to distances not much greater than line-of-sight. From time-to-time, however, ionospheric propagation is possible in the lower v.h.f. range and openings on the 50 mc amateur band may take place over distances of up to several thousand miles, while openings on 144 mc may be possible up to approximately 1300 miles.

This article reviews the conditions under which ionospheric propagation may be possible on the 50 and 144 mc bands, and the characteristics of such openings that may result from regular F2—layer reflection sporadic-E, auroral and meteor ionization, and trans-equatorial andionospheric scatter.

Regular F2-layer ionospheric openings may be possible on 50 mc during years of high solar activity. Openings on this band took place for many hours at a time for distances of 2000 miles or more, and between the United States and all other continents during the maximum periods of the past two sunspot cycles, 1947-1950 and 1956 to 1960. Many trans-continental openings and openings between north and south America have been reported during the present period of peak solar intensity.

F2-layer openings on the 50 mc band peak during the winter months to Europe and the Far East, and during the spring and fall months to Africa, South America, Australasia and other areas in a more-or-less southerly direction. Signal levels are often exceptionally strong during these openings, and communication over very great distances may be possible with relatively low power levels.

Regular F2-layer openings on 50 mc are a daytime propagation phenomena, with the band opening to Europe during the hours before noon, to Africa during the noontime period, to South America during the afternoon and sometimes extending into the early evening, and to the Far East and Australasia during the late afternoon and early evening hours, local standard time in the United States.

Propagation conditions in the 28 mc band may often provide clues to 50 mc openings during the fall, winter and spring months. When F2-layer openings are observed on 28 mc over distances of 1200 miles or less, the m.u.f. is rising rapidly and 50 mc may also be open in the same general direction, but over a considerably greater distance.

For the next year or two, solar activity may still be high enough to permit some F2-layer 50 mc openings from the fall through the spring months in the United States. Openings of this type will, however, decrease as the solar cycle declines, with little likelihood of any taking place during years of low solar activity.

The regular F 2 layer of the ionosphere is never sufficiently electrified to propagate signals on the 144 mc band. Not even during the unprecedented peak years of 1957-58 were frequencies in this range propagated via the F2-layer.

Sporadic E- Ionization

There frequently forms in the vicinity of the normal E-layer of the ionosphere, clouds or patches of abnormally intense ionization, which are capable of reflecting radio waves of frequencies much higher than those reflected by the regular E or F layers. These clouds usually cover a rather small geographical region, approximately 50 to 100 miles in diameter. They occur more or less at random and are relatively short lived, usually dissipating within a few hours. This sporadic ionization generally occurs about 60 miles above the earth's surface, at about the same height as the regular E layer. For this reason it is called sporadic-E ionization, or Es.

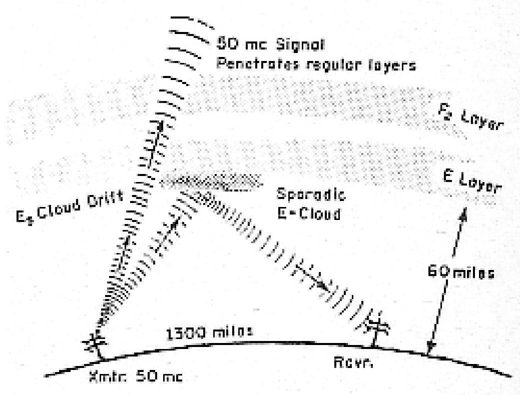

Fig. 1—50 mc short-skip propagation by means of sporadic-E reflection.

As a result of an intensely ionized sporadic-E cloud, it is at times possible to communicate over relatively long distances on the 50 mc band, and on some occasions on 144 mc as well (See fig. 1).

The height at which sporadic-E ionization occurs limits one-hop propagation to a maximum distance of approximately 1300 miles. During periods of widespread Es ionization, two-hop propagation may sometimes be possible up to distances of approximately 2400 miles. Band openings due to Es are often referred to as short-skip openings for this reason.

Reflection from sporadic-E clouds takes place with very little signal loss, resulting in exceptionally strong signal levels during most openings, even when very low power levels are used. Quite often it is possible to maintain communications considerably off the great circle path between two stations by means of back and side scatter from sporadic-E clouds. For example, a station in eastern New York State may work another station in the central part of the State by both stations pointing their antennas toward a common Es cloud, say for example, located over Georgia.

Sporadic-E ionization varies diurnally, seasonally and geographically. It occurs most frequently, and with greatest intensity, in polar and equatorial regions. In mid-latitudes, for example in the United States and Europe, it occurs most often during the late spring and summer months and during December, and has a tendency to peak during the late morning hours and again about sunset, although it can occur at any time.

In equatorial regions, Es is essentially a daytime phenomenon, with little seasonal variation. In polar regions, sporadic-E occurs most frequently during the nighttime hours, and again there is little seasonal variation, except for somewhat of an increase during the spring and fall.

Sporadic-E ionization is subject to erratic and often rapid variation. The ionized clouds are known to drift, generally in a westerly or north-westerly direction, at approximately 150 to 250 miles per hour. The drift appears to be due to winds that are believed to exist in the ionosphere. Because of this drift, reception areas can change within a relatively short period of time, and it is not uncommon for a sporadic-E opening to fade out completely from an S-9 plus level in a matter of a few minutes.

While the relationship between Es and the sunspot cycle is not yet fully understood, it appears that Es occurs somewhat more frequently in mid-latitudes as the solar cycle declines. Lf this is true, sporadic-E propagation on 50 mc is likely to be more prevalent during the next several years.

What causes sporadic-E ionization is not yet fully known. Since it occurs more often during the hours of daylight, it seems that ultra-violet radiation might play some role in its formation. Since it also occurs at night, especially in polar regions, auroras and meteor trails are other suggested possible sources of ionization. More recent theories indicate that the ionization might be caused by shearing forces associated with rapid wind movements in the ionosphere.

Since little is known about the ionizing sources for Es, its behavior cannot be predicted by positive means at the present time. Statistical studies show, however, that a sharp increase takes place at mid-latitudes during the late spring and summer when short-skip openings up to distances of about 1300 miles should be possible on the 50 mc band between 5 and 10% of the time, during the daylight hours. Occasional openings up to approximately 2400 miles may also be possible on 50 mc, and up to 1300 miles on 144 mc. The optimum time for v.h.f. short-skip openings is between 8 and 11 A.M. and 6 and 8 P.M., local standard time.

Here's a useful tip for predicting 50 mc *short skip* openings. The geometry of propagation is such that as the skip distance decreases on the 28 mc band, the highest frequency that will be reflected by a sporadic-E cloud is increasing. By observing the minimum skip distance heard on 28 mc during an Es opening, and using the chart shown in Fig. 2, it should be possible to tell whether or not 50 mc is open, and what the skip distance might be.

For example, if the minimum skip heard on 28 mc in a south westerly direction is observed to be 400 miles (it's the distance to the nearest skip station heard that counts, not others), from fig. 2 the intersection between 400 miles and the 28 mc curve corresponds to an muf of 60 mc. This means that 50 mc short-skip openings in a south- westerly direction is very likely. The minimum skip

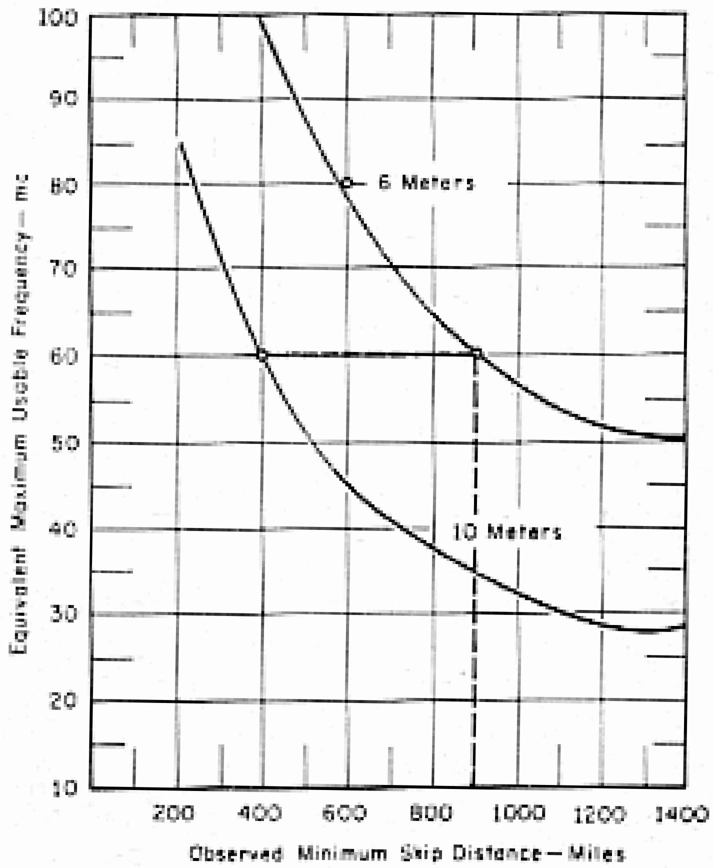

Fig. 2—Chart describing correlation between sporadic-E openings on the 10 meter amateur band and possible 6-meter openings at the same time. The example shows a minimum skip distance of 400 miles observed on 10 meters; from the chart 6 meters should be open with skip greater than 900 miles.

distance that can be expected on 50 mc can be found from fig. 2 by locating the intersection between 60 mc and the 50 mc curve. The resulting distance is found to be 900 miles. A useful rule of thumb to remember is that when skip stations are heard less than 500 miles away on 28 mc, the chances are very good that 50 mc will open in the same general direction.

Auroral Ionization

Corpuscular radiation, consisting of charged particles emitted time-to-time from the sun's surface (usually from solar flares), bombard the atoms and molecules of the gases present in the rarified atmosphere at the extremities of the earth, causing them to ignite, forming an auroral display.

Of all natural phenomena, auroras are probably the most breathtaking and spectacular. They arc across the night sky as weird, yellowish-green, dancing ribbons and violently throbbing rays, or as great draperies folding and unfolding. Some of the rarer displays may also contain shades of red and purple. They occur at E layer height in the ionosphere, about 60 miles above the earth's surface, and can be seen obliquely from the ground for distances up to about 600 miles from the zenith point (See fig. 3).

Observations made over the past 100 years, and intensified during the past decade with investigation by high flying airplanes and satellites, have defined areas of the world where auroras occur most frequently. The zones of maximum occurrence, where they are seen on approximately 250 nights a year, are belts about 23 degrees wide centered on the northern and southern magnetic poles. In the northern hemisphere, the zone arcs across northern Alaska, central Canada, the southern tip of Greenland and Iceland, the northern tip of Norway, and the northern coast of European Russia and Siberia.

Auroras are seen less frequently as one proceeds south of this zone. In the northern areas of the U.S. mainland, they are seen between 10 and 40 nights a year, while in southern states several years may pass before one is seen.

Auroras play havoc with shortwave communications. The excessive ionization which causes auroras also causes severe signal absorption. As a result, an aurora acts like a screen, shielding shortwave transmissions from passing through. For this reason, trans-polar communication from the United States is extremely difficult and often unreliable. The presence of auroral effects on propagation can frequently be detected by a unique fading component, consisting of a low frequency "flutter" of from 100 to 1000 c.p.s. which the aurora superimposes on a signal. During intense auroral activity, this fading component is often strong enough to render a voice signal unintelligible.

There is a very close relationship between ionospheric storms and the occurance of auroras. During storms, the zones in which auroral effects are most pronounced expand and move southward. The more severe the storm, the further south the alfected area. During great storms auroras have been seen as far south as Cuba, virtually blacking out shortwave communications throughout the entire northern hemisphere.

While auroral displays can seriously disrupt communications on the amateur h.f. bands, propagation on 50 and 144 mc often improves during these periods. Ionization associated with an aurora is often intense enough to reflect or scatter 50 and 144 mc signals over distances up to about 1300 miles, when propagation over these paths by other modes may not be possible.

Auroral ionization varies rapidly in intensity and height. This often causes severe multipath distortion on v.h.f. signals reflected from an aurora. Voice modulation is often unintelligible on 50 mc signals, and nearly always on l44 mc. While voice communication may sometimes be possible using s.s.b., experience has shown that keyed c.w. is the most effective way to communicate under these conditions

While auroras may occur at any time of the year, they take place most frequently during the fall and spring months, usually peaking during March and September. A secondary peak takes place during the winter months, with the fewest number occurring during the summer.

Fig. 3—A brilliant aurora of the type associated with ionization intense enough to reflect 50 and 144 mc signals between 300 and 1300 miles.

Geographically, the more northerly the latitude, the greater the number of v.h.f. auroral openings. In the U.S., the northern tier states are favored with fairly good openings between 50 and 75 days a year. In the central states openings may occur between 10 and 35 days a year, while considerably fewer occur in the southern tier states.

While auroral displays can be seen visibly only during the hours of darkness, their radio affects are felt during the daylight hours as well. Most v.h.f. openings begin during the late afternoon and early evening hours, lasting from several minutes to several hours. During prolonged ionospheric storms, auroral openings may occur and re-occur several times throughout a day, for several days in a row. Communication by means of auroral reflection can take place over distances between approximately a few hundred to a thousand miles, with some approaching the geometrical maximum of 1300 miles.

Since auroras occur in northern areas, north is the optimum antenna bearing to establish communications by this propagation mode. Once communication is established, antennas should be rotated slowly to maximize signal reflection or scatter from the auroral ionized regions.

Since most auroras are produced by solar flares, they occur most frequently two or three years after a peak in solar activity has been reached, when flares are most numerous, and they taper off gradually thereafter, occurring infrequently during periods of minimum solar activity. With the peak of the present sunspot cycle occurring a year ago, a maximum number of v.h.f. auroral openings are expected during the next year or two.

Since v.h.f. auroral openings often coincide with ionospheric storminess, the best times to check for these openings are during periods when the ionosphere is predicted or expected to be disturbed. Warnings of v.h.f. openings may be had by carefully monitoring reception on the h.f. bands. When an ionospheric storm is noted, usually by erratic or flutter fading on signals, or a lack of signals, auroral openings may be possible on the 50 and 144 mc bands.

Meteor Ionization

Meteors, or shooting-stars as they are often called, are particles of mineral and metallic matter which are continually entering the earth's atmosphere from outer space. It has been computed that hundreds of millions of meteors, most of them microscopic in size, enter the earth's atmosphere every 24 hours. This figure increases many fold during certain times of the year, when meteor showers occur.

As large meteors enter the earth's atmosphere at velocities of up to 50 miles per second, the intense heat generated by friction with the upper air causes them to leave an ionized trial behind as they burn some 30 to 100 miles above the earth. This ionization is often intense enough to reflect or scatter v.h.f. signals over distances of several hundred miles. Signals reflected by meteor ionization can be identified by the very short, sudden bursts in signal strength that take place when the ionized trail passes through the path of the signal. The signal increase, on the order of 20 to 40 decibels, is sharp and sudden, lasting for a few seconds then gradually decreasing. A burst may last from a few seconds to a half minute or so before fading into the background signal or noise level. A Doppler shift may also often be noticed on signals reflected from meteor trails. This is caused by the rapid motion of the reflecting point. In some cases the shift can amount to as much as 2 kc and last for several seconds.

Meteor reflected signal bursts are of little communication value unless they occur frequently enough, or are of sufficient duration to permit the transmission of some information. A 50 mc signal may appear as a few readable words, while on 144 mc the burst is usually shorter, often being nothing more than a ping. At this rate, even during major meteor showers, it requires a great deal of time and patience to transmit information between two stations. For this reason, high keying speeds are preferable to voice transmissions, although the exchange of voice information may at times be possible on 50 mc, especially when using voice-controlled s.s.b.

During a typical 24-hour period between 300 and 500 meteor reflected bursts lasting five seconds or longer can be counted on 50 mc. Approximately 25% of these will last from between10 and 30 seconds, and occasionally one may last considerably longer. A great number of bursts will be heard on 28 mc and the lower frequency bands and considerably fewer on 144 mc and higher frequencies.

Shower Name	Date of Peak Intensity	Shower Duration (Days)	Number of Meteors per Hour
Quadranids	January 3	1	35-40
Lyrids	April 21	2	12-15
Eta Aquarids	May 5	9	12-20
Delta Aquarids	July 29	10	20-30
Perseids	August 12	5	50
Orionids	October 21	4	20-25
Taurids	November 5 & 12	20	12-15
Leonids	November 17	4	20-25
Geminids	December 13	5	40-50
Ursids*	December 22	2	15

*Peaks during the early afternoon hours, all others peak during the hours of darkness.

Fig. 4—List of major meteor showers. The dates given are approximate, and the intensity of various showers may vary from year-to-year. About 20 other showers of less intensity also occur during the year; 7 between January and June, 13 between July and December.

While meteors may occur at any time, most of them enter the earth's atmosphere between midnight and dawn, peaking between 5 and 7A.M., local time. Since ionized meteor trails occur at an average height of 60 miles, the optimum communication range is approximately 800 miles, with maximum range about 1300 miles. Seasonally, considerably more meteors occur during June and July than at any other time, with a minimum number occurring during January and February.

From time-to-time, on a regular basis, the earth moves through areas in space in which there are very large swarms of meteors. During such periods, called meteor showers, meteors enter the earth's atmosphere with more than average frequency. During many showers meteors will appear at the rate of one to two each minute and during certain very large showers, many thousand may be observed during a single night. The possibility for 50 and 144 mc communication by means of ionized meteor trails increases considerably during meteor showers.

Figure 4 lists the major showers, the dates they occur and the average number of meteors that will probably enter the earth's atmosphere each hour during these periods. While meteor burst communication can be quite difficult, requiring a great deal of time and patience to move a small amount of information, it does provide a means for intermittent ionispheric communication on the v.h.f. bands over distances of between approximately 800 and 1300 miles.

Trans-Equatorial Scatter

Strong 50 mc band openings can occur, particularly during periods of moderate and high solar activity, over long north-south paths spanning the magnetic equator at times when the expected maximum usable frequency is considerably lower for the paths involved. These are called trans-equatorial or TE openings.

TE propagation was first observed by radio amateurs during the intense solar period of 1947. They also have pioneered into this propagation mode during subsequent periods of moderate and high solar activity.

In the western hemisphere the magnetic equator lies approximately 20 degrees south of the geographical equator and roughly follows an arc extending from Lima, Peru to Recife, Brazil and passing through La Paz, Bolivia. The optimum distances for TE openings range between 1500 to 2500 miles above and below the magnetic equator. Typical TE paths of high reliability are Puerto Rico to Argentina, Japan to Australasia, Southern Europe to Zambia, etc.

TE propagation is believed to be due to a highly ionized bell-shaped distortion known to exist in the ionosphere over the magnetic equator. Radio signals entering this area at a favorable angle are reflected considerable distances between the sides of the bulge in much the same manner that a ball rebounds off the sides of a billiard table. This may result in a long single hop opening, without intermediate ground reflection, of up to 5000 miles.

TE openings occur most often during periods of moderate and high solar activity, and hardly at all during the remainder of the cycle. Although they may occur during any season, TE openings peak during the spring and fall months. TE is a nighttime propagation phenomenon, with most openings occurring between 8 and 11P,M., local time at the path mid-point.

Signals must cross the magnetic equator in a north-south direction, or TE openings will not take place. A right angle crossing is optimum, but TE contacts have been reported between stations as much as 20 degrees off from a right angle crossing.

The TE maximum usable frequency is approximately 1.5 times greater than the daylight m.u.f. observed on the same path Thus 50 mc TE openings may be expected during the evening hours when an m.u.f. of 34 mc is observed during the daytime. TE openings may often occur on 50 mc when propagation is not possible on lower frequency bands on the same path, at the same time.

In the western hemisphere 50 mc TE openings occur almost every night during the spring and fall months over an area extending from Mexico City in the north to southern Chile and Argentina in the south. Within this area there is little variation in signals from night-to-night and reliability is high. Less frequent openings extend into the southern and central areas of the United States, with openings falling off rapidly at greater distances to the north.

Serious flutter fading is often noted on shorter path TE openings, but voice readability is seldom seriously impaired on longer path openings.

The 144 mc band is too high in frequency for TE propagation.

Ionospheric Scatter

When a frequency is at or below the muf, ionospheric propagation takes place by reflection from the ionized layers existing in the earth's atmosphere. Signals strike the ionosphere obliquely and are normally reflected in a forward direction. When the signal is above the muf, it will penetrate the ionosphere, with a very small amount of energy scattered back towards the earth in more or less random directions. The mechanism involved in ionospheric scattering is not yet fully understood, but it is believed to be due to roughness in the ionosphere and may involve the earth's magnetic field in a complex manner. Scattering may take place from any of the ionospheric layers.

Until the post-war introduction of super sensitive receivers, advances in modulation techniques and in antenna design, scattered signals were of little communication value. With high gain antennas, high transmitter power and a good receiver, scatter openings are often observed on 50 mc, when this frequency is considered above the regular muf. Because only a very small part of a signal's energy is returned to earth by scatter, such signals are extremely weak and fluttery and marginal communications is possible at best.

Scattering appears to occur most often from ionospheric regions in the vicinity of the magnetic equator. In northern and temperate regions ionospheric scattering increases considerably with increases in magnetic activity and during ionospheric storms. While 50 mc scatter openings can occur at any time, they seem to peak during the evening hours of the spring and fall months, during periods of high and moderate solar activity.

To communicate by means of forward scattered signals, it is usual for both stations to direct their antennas at each other along the great circle path. To communicate by means of back scattered signals it is often best to orient both antennas at the apparent point of scatter, which may be considerably off the great circle path. This point can best be determined by slowly rotating until signal strength is maximized.

Signals scattered in a forward direction from the D and E layers may permit 50 mc openings over distances between approximately 600 and 1200 miles, while openings over considerably greater distances may be possible with signals scattered by the F layers. Backscattered signals may often permit 50 mc ionospheric communication between stations separated by relatively small distances.

The various modes of v.h.f. ionospheric propagation and their signal characteristics are summarized in Fig. 5. While normally propagation may be due to a single particular mode, there are times when a combination of several modes may be involved and taking place at the same time. All-in-all, ionospheric propagation takes place often enough in the 50 and 144 mc amateur bands to add an extra dimension of interest in operating in these bands.

Propagation Mode	V.h.f. Bands Prop. Possible	Latitude Zone Peak	Time of Day Peak	Seasonal Peak	Optimum Sunspot Period	Communication Distance-Miles	Band Opening Period	Signal Characteristics
Regular F-layer reflection	50 mc	Temperate	Daytime	winter	High	E-W paths 1800-3600 N-S paths 1800-6000	Several minutes to an hour or more	Exceptionally strong
	50 mc	Low, Equatorial	Afternoon to late evening	spring & fall	High	E-W paths 1800-3600 N-S paths 1800-6000	Several minutes to an hour or more	Exceptionally strong
Sporadic-E	50 & 144 mc	High, Polar	Night	spring & fall	High & Moderate	300-1300	Several minutes to an hour or more	Weak to strong with some flutter fading
	50 & 144 mc	Temperate	Before noon & early evening	late spring & summer	All	800-2400 on 50 mc 1100-1300 on 144 mc	Several minutes to an hour or more	Exceptionally strong
	50 & 144 mc	Equatorial	All day	All seasons	All	800-2400 on 50 mc 1100-1300 on 144 mc	Several hours to a complete day	Strong with flutter fading
Auroral Ionization	50 & 144 mc	High & Temperate	Late afternoon & early evening	spring & fall	High & Moderate	300-1300 miles	Several minutes to an hour or more	Weak to moderately strong, with strong flutter fading. Voice badly distorted, c.w. recommended
Meteor Ionization	50 & 144 mc	All	Night & early morning	June & July & during specific shower periods	All	800-1300	Several seconds to a half minute or so per burst	Strong bursts High speed c.w. recommended
Trans-Equatorial	50 mc	Low & Temperate	Evening through midnight	Spring & Fall	High & Moderate	2400-5400	From one to several hours	Weak to moderately strong, with some flutter fading at times
Ionospheric Scatter	50 mc	Low & High	Evening through midnight	Spring & Fall	High & Moderate	600-2400	A few minutes to several hours	Weak, fluttery signals