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Sporadic E propagation

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ABSTRACT
Studies of sporadic E clouds indicate that the modal station separation at time of radio contact was 1,490 km, 2,800 km, and about 4,200 km for single, double- and triple-hop communication. Large E_s clouds having an effective diameter of about 925 km were found to be fairly prevalent.

A study of sporadic E propagation over North America was made during the three-year period 1949–1952. In this time-interval, radio amateurs operating in the 2- and 6-metre band assisted in forming a co-operative network which reported the occurrence of any unusual long-range communication. In most instances the long paths arose from the presence of sporadic E. The technique, which is relatively simple, has already been described. Most of the data were obtained during summer.

This note presents the results obtained when an analysis was made of the station separation at the time of radio contact. Fig. 1 displays the number of cases as ordinate versus the distance between stations (at the time abnormal communication was established) as abscissa. In preparing the graph, over 12,500 instances of propagation at 50 Mc/sec were utilized. All propagation attributable to auroral interaction and most instances of non-E_s reflection were eliminated from the tabulation. However, it is possible that in some cases (less than two per cent) F_2-layer or tropospheric propagation were included in the results. When data were plotted separately for each month (number of cases versus distance) a curve similar to that shown was obtained. Thus, it may be assumed that the curve portrayed in Fig. 1 is typical and that no appreciable departures are encountered during the course of the year.

From the diagram it is quite apparent that the most common station separation at the time of E_s propagation was about 1,500 km. In 80 per cent of the cases the station separation ranged between 1,060 and 1,920 km, and in 60 per cent of the radio contacts, the distance between sites was in the range 1,220–1,780 km. The greatest station separation reported in North America was 4,900 km; at 50 Mc/sec this radio contact probably required three ionospheric reflections (triple-hop communication). The shortest station separation attributed to E_s propagation was about 400 km. The equivalent vertical-incidence cut-off frequency for 50 Mc/sec propagation over a distance of 400 km is about 23 Mc/sec, corresponding to an equivalent electron density of $7 \times 10^6/\mathrm{cm}^3$. Such conditions were observed very infrequently.

Using the data provided by the tabulation, an attempt was made to differentiate those instances of abnormal propagation arising from single, double, and triple reflections from E_s areas. A tentative breakdown for the former types of E_s propagation is displayed in Fig. 1. Three categories are shown, which together synthesize the total number of cases: (a) single hop (single cloud); (b) double hop (single cloud); and (c) double hop (two clouds).

For E_s located at an altitude of 110 km, single-hop reflection at 50 Mc/sec may occur for paths of 600–2,200 km, while double-hop reflections would presumably double this range interval. It may be expected that the most common station separation at time of radio contact by E_s would be the average of the range involved; i.e., 1,400 km, 2,800 km, and 4,200 km, respectively, for one,

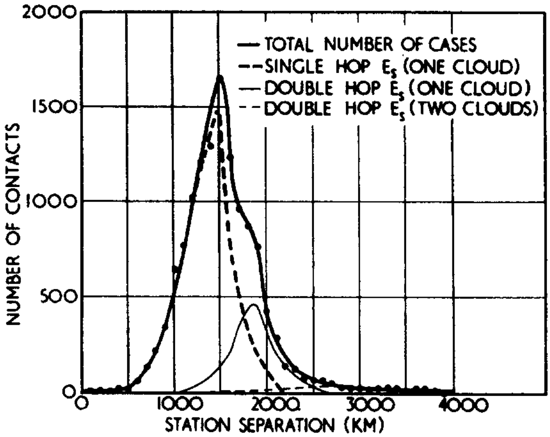

Fig. 1.

two, or three reflections. For the first two cases, the values deduced from Fig. 1 are 1,490 km and 2,800 km, respectively. An indication of the probability of occurrence of single-cloud E_s may be obtained from the ratio of the ordinates at these distances: $40/1{,}470 = 0{\cdot}027$. This ratio is a measure of P^2/P, where P is the occurrence probability of a single isolated E_s area. The value may be compared with the probability found during June 1950; the average probability for sporadic E to occur over the central portion of the U.S. was 0·032. The two values are in good agreement.

Propagation at 50 Mc/sec attributed to (a) single hop and (b) double hop are depicted in Fig. 1 for one and two E_s clouds, respectively. However, this breakdown does not synthesize the total number versus distance graph obtained from the data. When the above cases are subtracted from the total, a residual is found which has its most common station separation at 1,850 km. Several considerations led to the conclusion that the residue probably involves double hop propagation (by means of sporadic E) but from a *single* E_s cloud rather than two. Thus, the residue has been identified on the diagram as "double-hop E_s, one cloud". The ratio of the maxima of the residual and single hop curves is 0·34, indicating that conditions favouring the latter are about three times as prevalent as those favouring the former.

Several possibilities for explaining the existence of the residue suggest themselves. Because of the station separation found, it seems fairly definite that double hop propagation is involved. If two distinct E_s clouds were required, the occurrence probability would be given by the ratio 0·34 determined above. Such a probability, however, is excessively high and is difficult to justify especially since by actual count, E_s capable of allowing communication at 50 Mc/sec occurs less than 3 per cent of the time over any given site. A second possibility considers the existence of large sporadic E clouds whose size allows double hop propagation. With the latter assumption both single and double hop reflections are possible from the same cloud. If both large and small clouds existed, the maximum of the residual curve would be materially less than that of the "single hop" curve, but would exceed that of the "double hop, two-cloud" curve. It is believed that the large-cloud hypothesis clarifies the residual curve found in Fig. 1.

Some estimates of the size of the large E_s clouds may be made. At the time radio contact was established, the distance between stations was mainly in the interval 1,200–2,500 km. For double hop propagation, the cloud size should be about half this value; i.e., 600–1,250 km with a mean of 925 km. This mean, incidentally, is identical with the modal value.

Preliminary studies have indicated that some large sporadic E areas over North America may be elliptical in shape, with their major axes oriented in the North–South direction. Full utilization of the maximum propagation distance possible in the N–S direction, however, has not been taken because most of the radio amateurs were located south of 50°N latitude. Under these circumstances it is felt that the E_s cloud size as used above refers to the length of a section having an East–West component through the cloud.

It might be mentioned that at a frequency of 50 Mc/sec the smallest station separation reported was 90 km. In less than fifty reports, radio contacts were made at distances from 200–550 km. When the distance between sender and receiver was less than 400 km, the contact was tentatively considered to arise from super-refractive or ducting conditions in the troposphere.

It would be extremely interesting to undertake an analysis of 50 Mc/sec propagation conditions in other continental regions. The greatest station separation possible in the present investigation was about 5,000 km. Contacts over this distance could be reported by only a limited number of stations. For these sender-receiver pairs to contact each other, the sporadic E areas must exist in specific locations over the continent—a condition difficult to realize. On North America the orientation of stations separated by distances exceeding 6,000 km would be mainly N–S, but the sparsity of northern observers prohibited the implementation of such a network. However, 50 Mc/sec communication over distances of 6,000–7,000 km should not be unrealistic.

In the present study there was greater possibility for an east–west orientation in the direction between station pairs; however, maximum station separations in other directions should be determined. For example, radio contacts at 50 Mc/sec between North and South America have shown that station separations of about 9,600 km are quite possible, although somewhat uncommon. Undoubtedly, this distance was spanned because of F_2-layer propagation. In any event, investigation of E_s propagation should be undertaken between Europe–Africa, New Zealand–Australia, over the oceans, etc., where station separations with east–west orientations to distances of 5,000–6,000 km can be readily obtained. Studies of this type will determine whether the average propagation distances using E_s may exceed significantly those found in a limited region of North America.

Another interesting aspect to be studied is transatlantic propagation at television frequencies during the summer, when intense sporadic E is most prevalent. At 50 Mc/sec, F_2-layer propagation between South American and South African stations on one hand and Europe and North America on the other hand requires much more intensive examination.