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THE VARIABILITY OF SKY-WAVE FIELD INTENSITIES AT MEDIUM AND HIGH FREQUENCIES

BY NEWBERN SMITH AND M.B. HARRINGTON

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THE VARIABILITY OF SKY-WAVE FIELD INTENSITIES AT MEDIUM AND HIGH FREQUENCIES*

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Abstract. A summary of the time distribution of received radio field intensities at frequencies ranging from 770 to 15310 kc, recorded at the National Bureau of Standards and cooperating laboratories, is given. The study was made for the purpose of obtaining a factor that could be applied to the median required field intensity assuring transmission a given percentage of the time. Deviations from the median values showed no appreciable dependence upon frequency or distance, except in the case of auroral-zone paths, particularly in winter. It was found that multiplying the required field intensity by a factor of 2 would usually assure adequate intensities on 90% of the days.

Ionospheric absorption of radio waves is not constant but varies from day to day as well as from month to month and from year to year with the sunspot cycle. In order to make use of ionospheric absorption data in calculating distance ranges and lowest useful high frequency (luhf), it is necessary to know what percentage of the time a given field intensity will be exceeded, or what factor must be applied to the median required field intensity to obtain reasonable assurance that the field intensity obtained over a given path will be enough to be usable a certain percentage of the days.

For this purpose the time distribution of required field intensities as determined by atmospheric radio noise must be known, as well as the time distribution of received field intensities. As a first step in the evaluation of these factors, there is given in this report a summary of the distributions of actual received field intensities, as obtained by the Interservice Radio Propagation Laboratory and cooperating laboratories. Thus far the data have been evaluated from the continuous automatic field intensity recordings during 1944 of seventeen stations ranging in frequency from 770 to 15310 kc. The paths varied in length from 590 to 6580 km. WWV, 5000 and 10000 kc, emissions from Beltsville, Md., were recorded by five of the cooperating laboratories at distances from 600 km to 3900 km. All the paths lay within

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the W or I zones, as shown on the IRPL Base Map of the World. Two of the paths, GIH, 13525 kc, Dorchester, England to Riverhead, New York and GSP, 15310 kc, London, England to Washington crossed the north auroral zone. North to south as well as east to west paths were included in the study.

For the purpose of this analysis, values of field intensities equalled or exceeded by hourly values on 90% and 50% of the days, and exceeded on 10% of the days were tabulated for each hour of each month. The procedure was to order the values of field intensity for a given hour, and then to list the fourth value from the bottom, the middle value, and the fourth value from the top, respectively.

The results are shown graphically in Figures 1 to 6, for the paths indicated. Typical paths were chosen for the figures - W8XAL, 6080 kc, Mason, Ohio, 590 kilometers distant from Sterling, Virginia; WWV 5000 and 10000 kc, Beltsville, Maryland, 3900 kilometers distant from Stanford University, California; and GIH, 13525 kc, Dorchester, England, 5340 kilometers distant from Riverhead, New York. In so far as possible, values of field intensity obtained when the transmission was skipping (scattered reflection values) were disregarded. The values shown are thus typical of field intensity distributions to be expected under practical operating conditions of time, path, and frequency. Since the values of received field intensities were measured in logarithms to the base 10 of the microvolts input to the receiving set, the logarithm of ratios of field intensity were readily calculated. As an example the logarithm of the ratios of the 10% values to the median values were obtained by subtracting the logarithm of the median value of the microvolts input from the logarithm of the 10% value in microvolts.

Monthly averages of these ratios for the 90% and 10% values of field intensity to the median value are shown in Figure 1, expressed in logarithms. The ratios of the 90% and 10% values to the median were calculated for each hour of transmission for each month, from which the average ratio for the month was obtained. The plots show no appreciable dependence upon frequency or distance. Several of the paths studied show slightly increased deviations in January, June, July and December.

Average hourly ratios of the 90% and 10% values of field intensity to the median value for the same paths are shown in Figure 2. The method was the same as that used to get Figure 1. The plots indicate that the hour-to-hour deviations are random, with the fluctuations during the hours of maximum absorption varying little from the fluctuations during the hours of minimum absorption.

In Figure 3 is shown the ratio of the average 10% values to the 90% values for each month of 1944. For each path the average 10% and 90% values were calculated for each month. The logarithms of the ratios were computed by finding the difference between the logarithms of the

90% and the 10% values. These plots indicate the average scatter of 80% of the values. Thus for any month and path 80% of the values of the hourly median received field intensity fell about the median in the interval given. The dotted line represents the average ratio of the 10% values to the 90% values for the year.

The plots of Figure 4 are cumulative frequency distributions of the ratios of the 90% and 10% values to the median value. The percentages of occurrence were used instead of the numbers of occurrence. The dotted vertical lines show the interval within which 80% of the values fell for 50% of the days. On all the paths, there is a greater scattering of values below the median than above, indicating that there are greater fluctuations when ionospheric absorption is greater than normal.

Cumulative frequency distribution plots of the ratios plotted in Figure 4, for all the stations, for the months indicated are shown in Figure 5. The solstitial months show greater fluctuations about the median than do the equinoctial months.

Variability of sky-wave field intensities according to frequency and distance is illustrated in Figure 6. In the upper plot the average ratios for 1944 of the 90% and 10% values of field intensity to the median value are plotted by frequencies. The ratios for stations transmitting on the same frequency were averaged and plotted as one point, irrespective of distance. Similarly, in the lower plot the average ratios for 1944 of the 90% and 10% values of field intensity to the median value are plotted by distance, irrespective of frequency. These plots indicate that the deviations from the median show little dependence upon operating frequency or path length. The greater spread on the higher frequencies which are also received at greater distances may be due to the fact that the paths cross the northern auroral zone.

This study of the actual received field intensities is also a study of the day-to-day variations in ionospheric absorption. Propagation over long paths, by several reflections, as well as the practical balance of operating frequency with path tends to iron out the extreme variations of absorption which might be encountered if the operating frequencies were not suited to ionospheric conditions.

The average logarithm of the ratios of 90% and 10% values of field intensity to the median value are about - 0.30 and + 0.25, respectively. This seems to be, to the first order, independent of path length and operating frequency, subject to the limitation that high frequencies are not used over short paths or at night, when the variation in absorption might be expected to be less, and low frequencies are not used over long paths where the absorption variation might be expected to be greater. Indications are that the fluctuations are greater over auroral-zone paths, particularly in the winter; further studies of such paths will need to be made before more definite and conclusive statements can be made as to this.

As a rough rule of thumb, therefore, in order to secure transmission on 90% of the days, the required field intensity should be multiplied by 2. In the use of the luhf nomograms, or for making luhf calculations, the "equivalent power" of the transmitting station should be divided by 4 in order to assure usable transmission on 90% of the days.

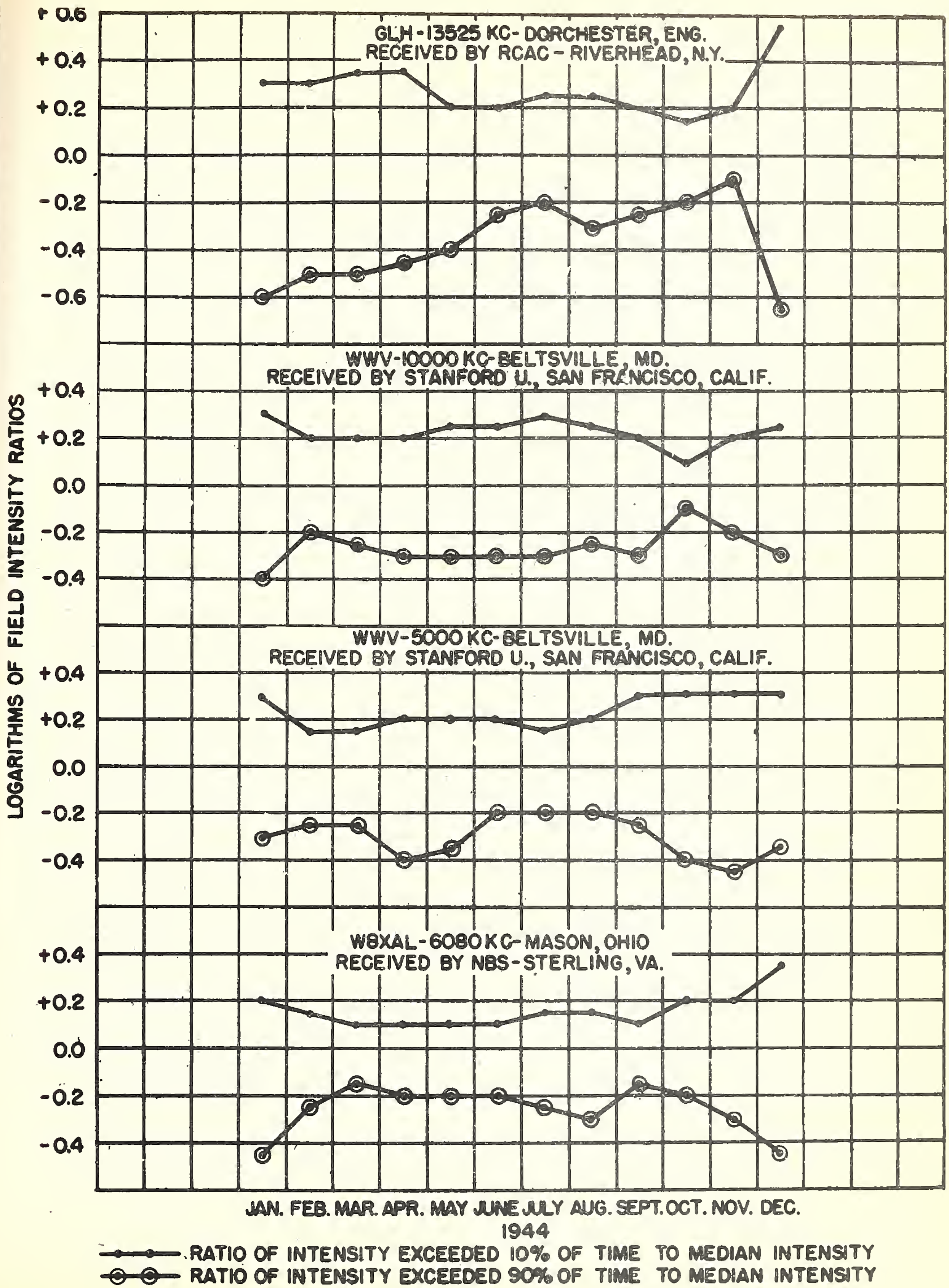

Fig 1. VARIABILITY OF MONTHLY SKY-WAVE FIELD INTENSITIES

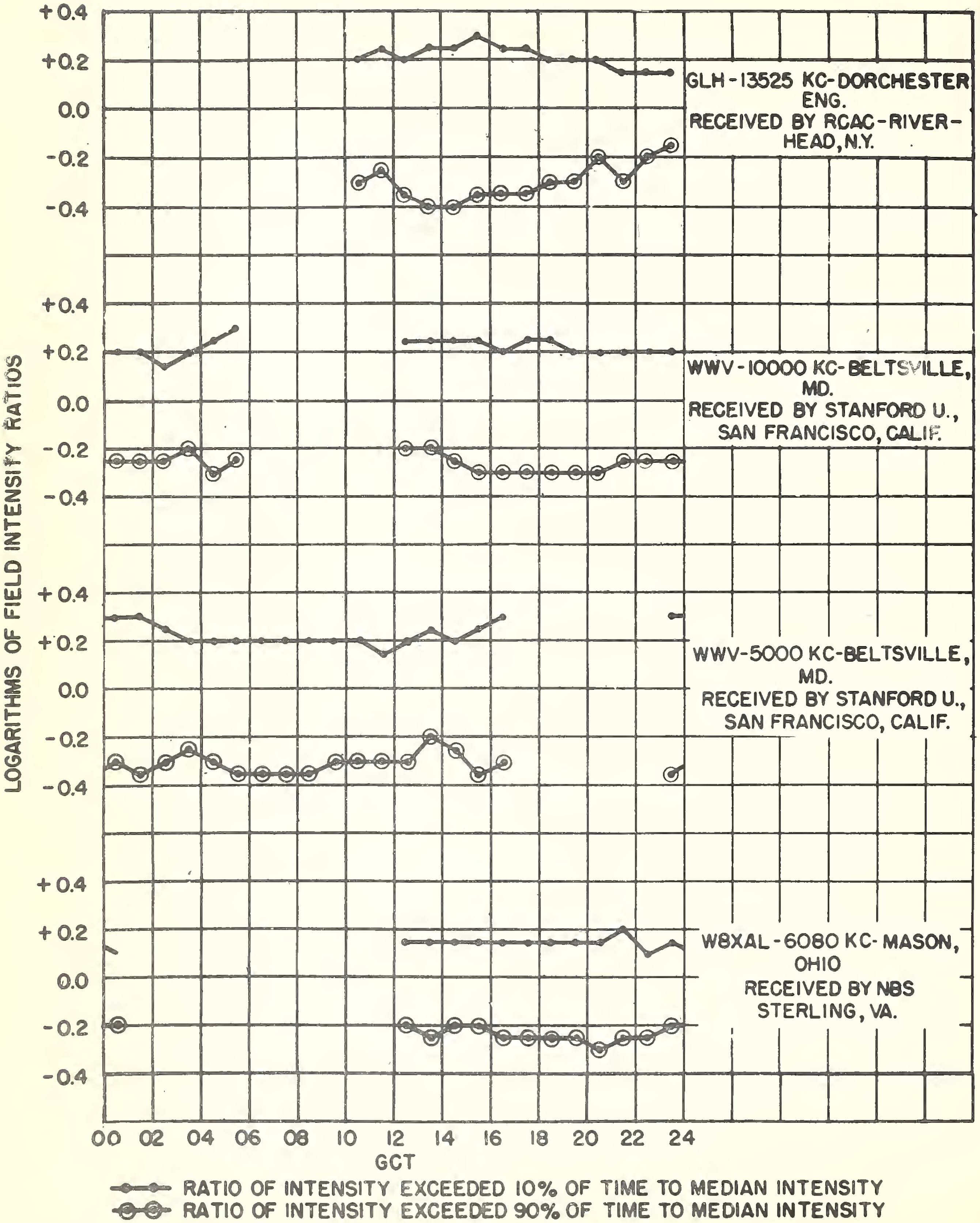

Fig. 2. AVERAGE HOURLY VARIATION OF SKY-WAVE FIELD INTENSITIES

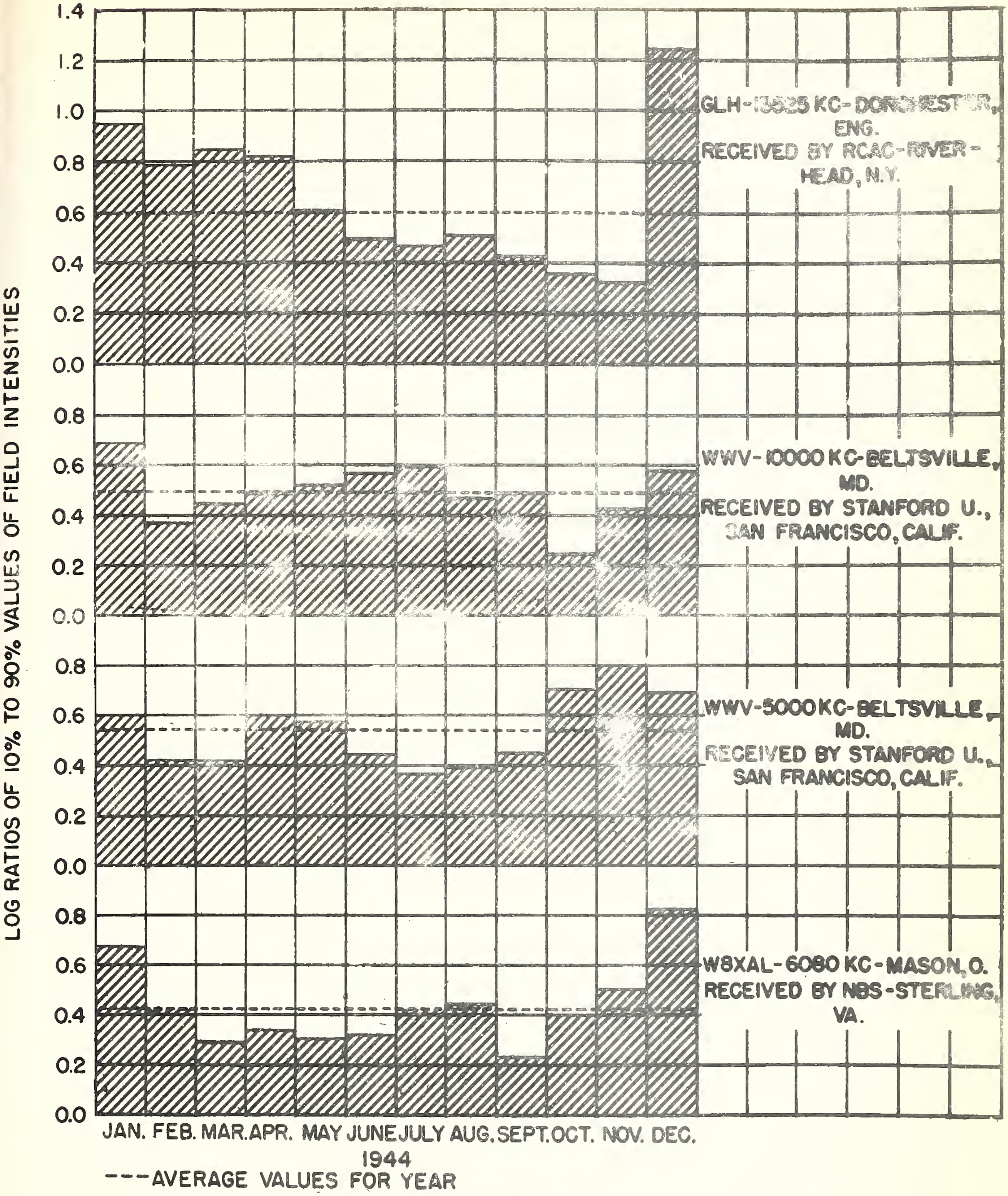

Fig. 3. SPREAD OF SKY-WAVE FIELD INTENSITIES

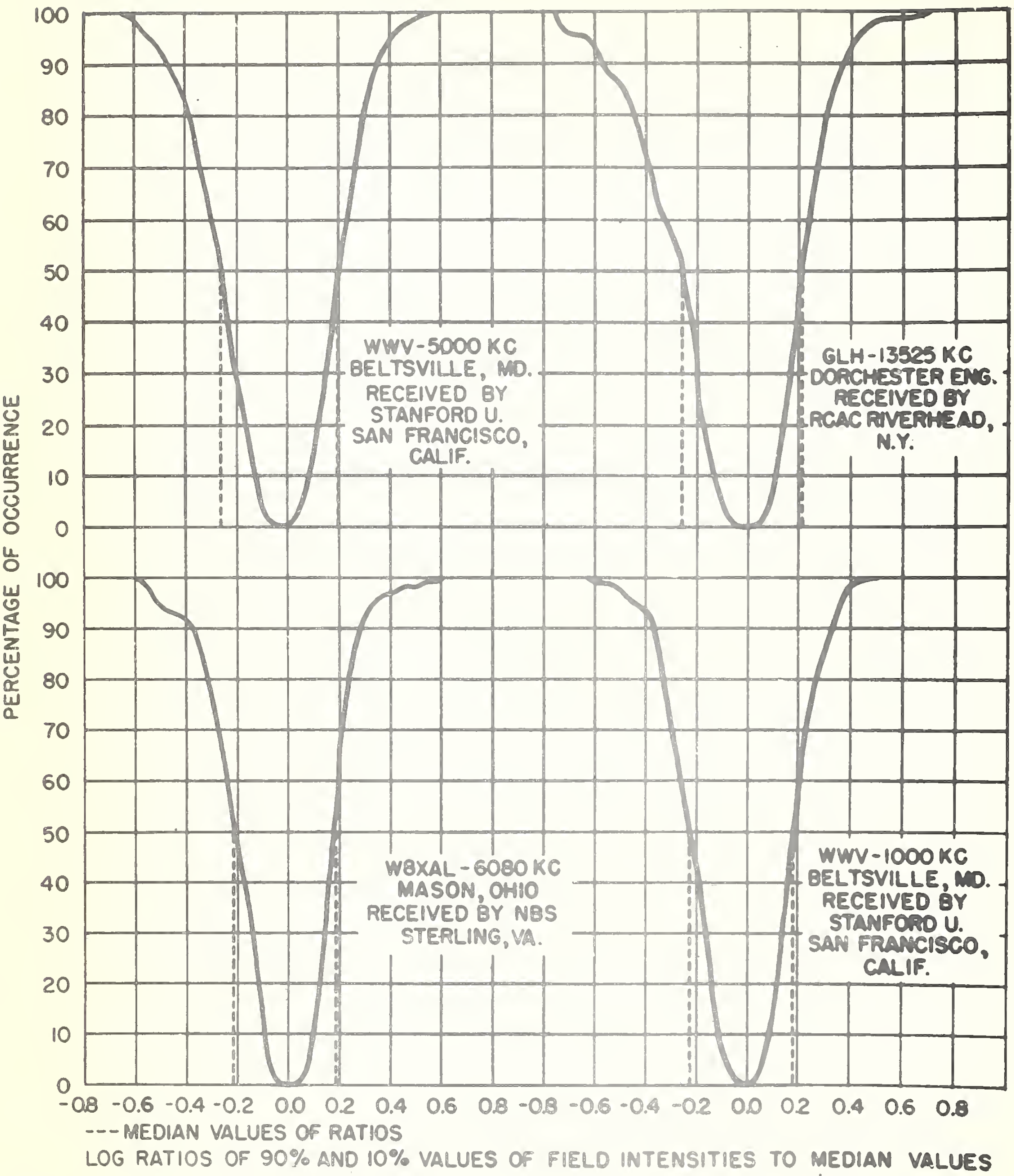

Fig. 4. PERCENTAGE DISTRIBUTION OF SKY-WAVE FIELD INTENSITIES

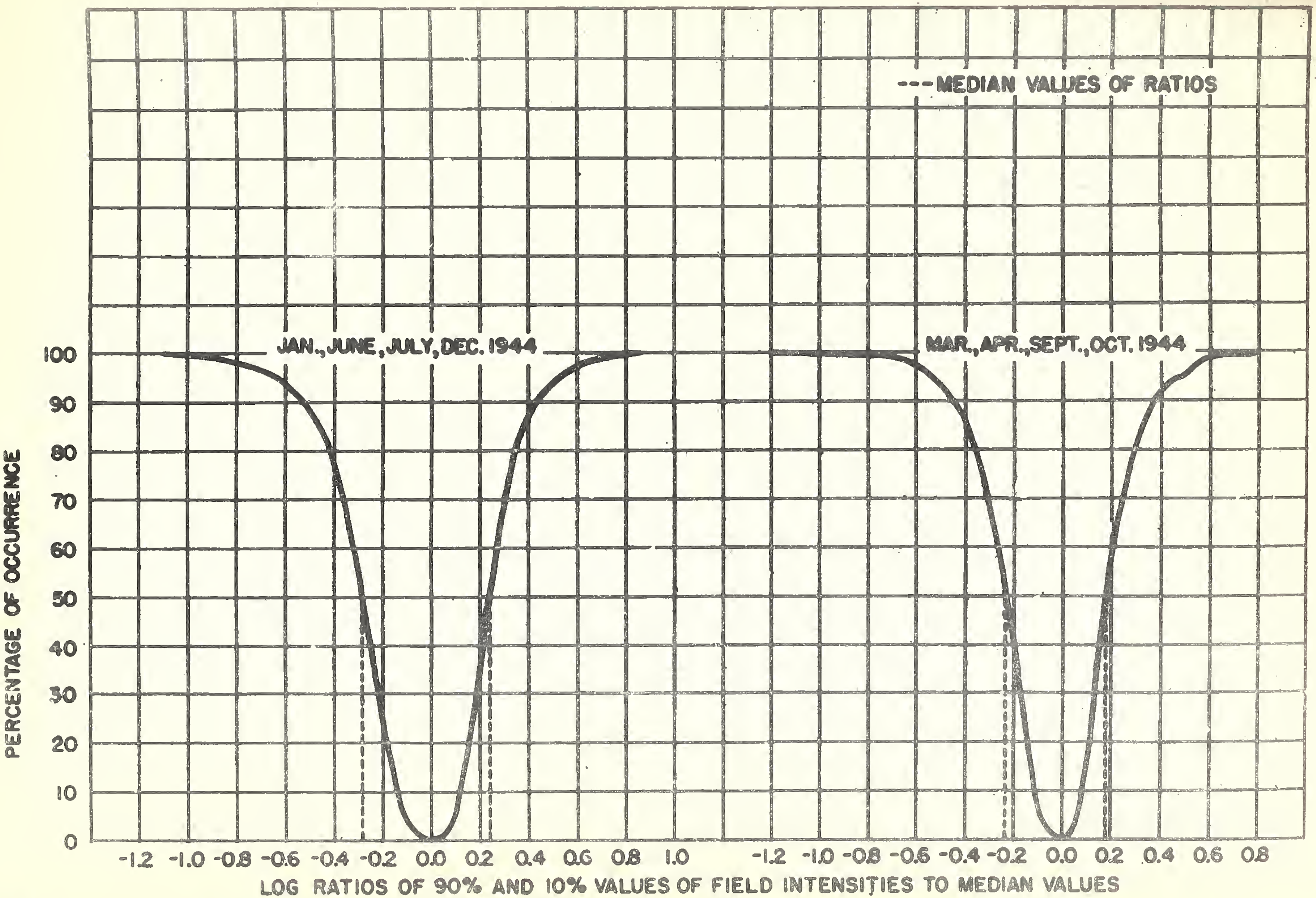

Fig. 5. PERCENTAGE DISTRIBUTION OF SKY-WAVE FIELD INTENSITIES FOR ALL STATIONS

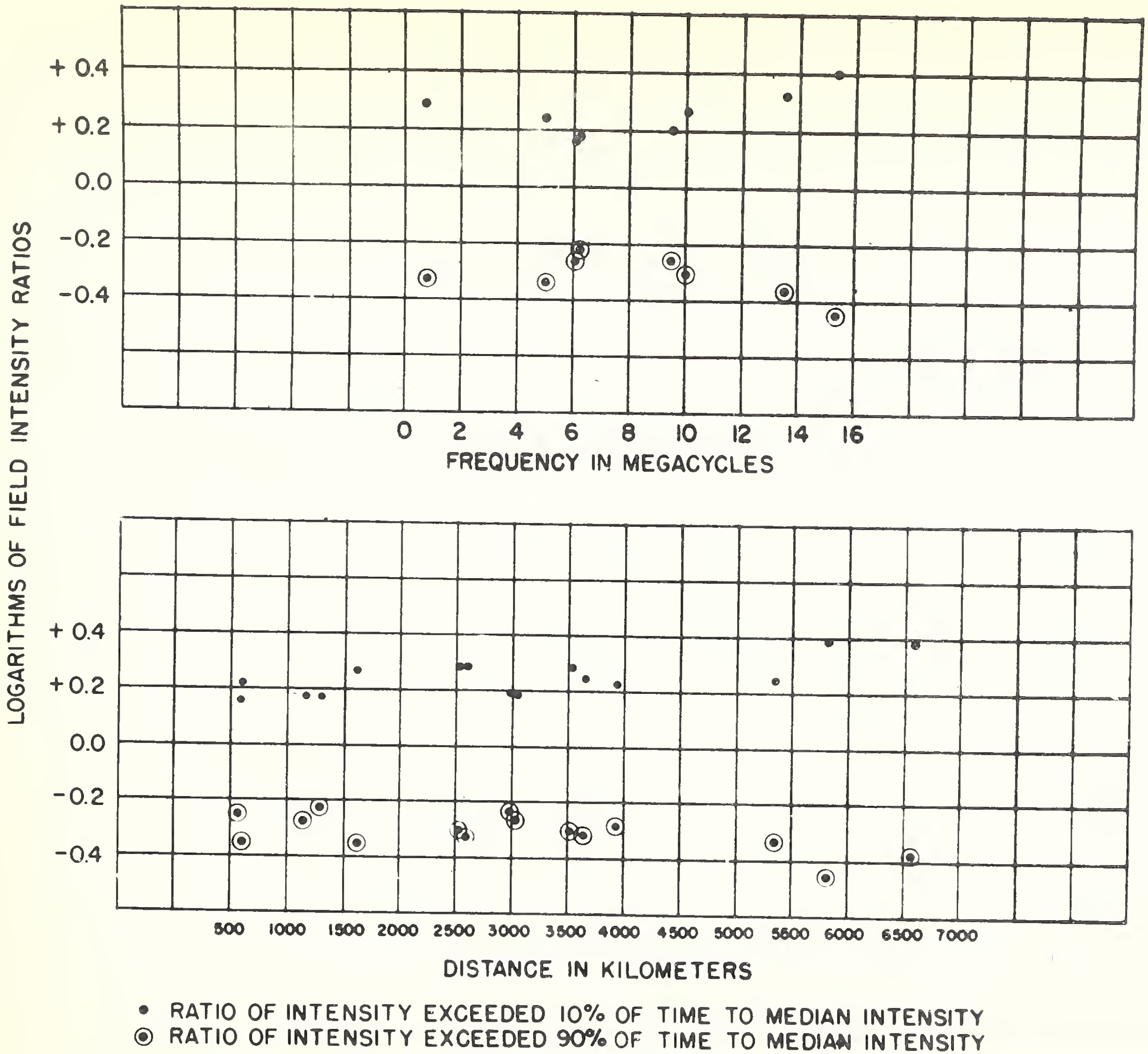

Fig. 6. VARIABILITY OF SKY-WAVE FIELD INTENSITIES ACCORDING TO FREQUENCY AND DISTANCE.