An Effective Ground Conductivity Map for Continental United States*

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Summary—**The Federal Communications Commission has recently adopted a new effective ground conductivity map. The derivation of this map and its estimated accuracy are discussed in this paper.**

Introduction

A NEW EFFECTIVE ground conductivity map for continental United States is submitted in this report. This map represents estimates based on measurements over approximately 7,000 paths throughout the country which were submitted to the FCC. The previous ground conductivity map had been promulgated in 1938 and based upon relatively few measured paths plus the soil type map. Subsequent measurements had shown that the estimates of conductivity provided by this 1938 map were appreciably in error for various parts of the country. For this reason a more accurate map was considered desirable in the allocation of standard broadcast stations and the present map was adopted by the FCC for use as of April 5, 1954.

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At this time it is pertinent to point out that the conductivity over a given path may vary over wide limits with location, season, weather, etc. Consequently, the effective conductivity, as used here, must be defined as that value of conductivity which will result in the overall median field strength for the path or segment of path under consideration when used in conjunction with the Commission's ground-wave field strength versus distance curves.

The Central Radio Propagation Laboratory had previously undertaken a rather comprehensive effective conductivity study based on the field strength measurements, submitted to the FCC in various proof-of-performance and in connection with the processing of application for standard broadcast facilities. These paths, most of them less than 25 miles in length, were plotted on map overlays. From these overlays with the aid of the Department of Agriculture soil maps (Atlas of American Agriculture; 1935), those paths running over one subsoil type only were analyzed for correlation between measured path conductivity and subsoil type. From this study, typical conductivity values for 144 of the 243 subsoil types were evaluated. It was found that for any given subsoil type the logarithms of the measured conductivities were distributed about the average in a normal distribution. Considering log conductivity as the basic variable, the average standard error of estimate for the 144 subsoil types was 0.266. In more familiar language, this means that approximately two-thirds of the measured path conductivities for a typical subsoil type lay within the range of 1/1.85 and 1.85 times the subsoil median conductivity. Grouping these subsoil types into parent soil groups gave so large a standard error that this approach was abandoned. With so large a standard error even for the subsoil types, the correlation of conductivity with these subsoil types was not considered very promising. CRPL has prepared a report[1] of sectional maps, showing the paths over which measurements have been made as well as their conductivities. However, no effective conductivity map was planned by CRPL. In view of proposed revision by the Commission of the Standards of Good Engineering Practice Concerning Standard Broadcast Stations, it became necessary to promulgate the new conductivity map, which is given in Fig. 1 on the opposite page.

The following characteristics were considered desirable and incorporated into this conductivity map.

1. The indicated conductivity should not change at less than 10 mile intervals.
2. The base map should be on a scale of at least 1 to 2,500,000 and should employ Albers equal area projection to permit accurate scaling of distances.
3. The lines of demarcation between areas of different conductivities should be clearly defined in order that consistent estimates may be obtained by several different observers.

A brief study of the field strength versus distance curves revealed that the logarithm of field strength is approximately proportional to the logarithm of the conductivity for the shorter distances. Since the loudness of sound is approximately proportional to the logarithm of field strength it was decided to classify the map in steps proportional to the logarithm of conductivities. Also, it was noted that measured conductivities for paths over the same terrain often varied by more than 2 to 1, depending upon direction, frequency, interpretation, equipment, etc. Since the measured effective conductivity varies more than this amount in many cases and because of a standard error of 1.85 to 1 for subsoil types, it was decided that there was no point in having a conductivity map with classifications closer together than 2 to 1. Consequently, the following conductivity classes were established: 0.5, 1, 2, 4, 8, 15, 30, and 5,000 millimhos per meter. The 15 and 30 classes were chosen in preference to 16 and 32, respectively, because field intensity curves for 15 and 30 are already incorporated in the FCC Standards and, of course, the 5,000 class is for seawater. In line with the above system of classification the ranges of conductivity grouped into the specified classes are as given in Table I, the units being millimhos per meter.

TABLE I

Conductivity Class	Range of Conductivities
0.5	.707
1	.707– 1.414
1	1.414– 2.828
4	2.828– 5.657
8	5.657–10.95
15	10.95 –21.21
30	21.21 –45
5,000	seawater

The resulting conductivity map was drawn freehand almost entirely from data in the map overlays supplied by CRPL. These overlays, showing the locations and conductivities of all the measured radials, proved invaluable. Unfortunately, the distance scale of these overlays was not a standard size and an original map was not available, so that all the stations had to be relocated on standard maps. When there was more than one measured conductivity available for a given path or area, the geometric mean conductivity was used. Where there were no measurements available, the conductivity was estimated from those measurements in the same general area over the same subsoil type. If no measurements were available even for nearly similar subsoil types, then reference was made to the typical subsoil type conductivities computed by CRPL. Undoubtedly, had someone else drawn the lines of demarcation between the areas of different conductivity the map might have looked substantially different, especially in the region west of the Mississippi and east of the Pacific coast where comparatively few measurements were available. It is believed, however, that this map is a vast improvement over the old standard and does agree far better with the available data.

The estimation of a standard error for this effective conductivity map is not an attractive proposition in view of the variable density of the measurements throughout the country and in view of the freehand process of drawing the map. However, the writer believes that the utility of the map is greatly enhanced if its accuracy is known, even though this accuracy is only an educated guess. If there were no error of measurement or interpretation in the value of conductivity attached to each path or segment of path on the CRPL overlays, then, considering log conductivity as the basic variable, the estimated standard deviation or error in codifying the country on the conductivity map would be about 0.15—i.e. approximately two-thirds of the measured path conductivities were within 0.71 and 1.4 times the conductivities shown on the map. However, for the true over-all standard error the above standard deviation should be added in quadrature with the standard error of measurement and interpretation. The over-all standard error is then estimated to be in the order of 0.23. In other words, it is estimated, that approximately

[1] R. S. Kirby, J. C. Harmon, F. M. Capps, and R. H. Jones, "Effective Radio Ground Conductivity Measurements in the United States," Central Radio Propagation Lab., Boulder, Colo.; approved by the Bureau of Standards Editorial Committee and to be released in the near future.

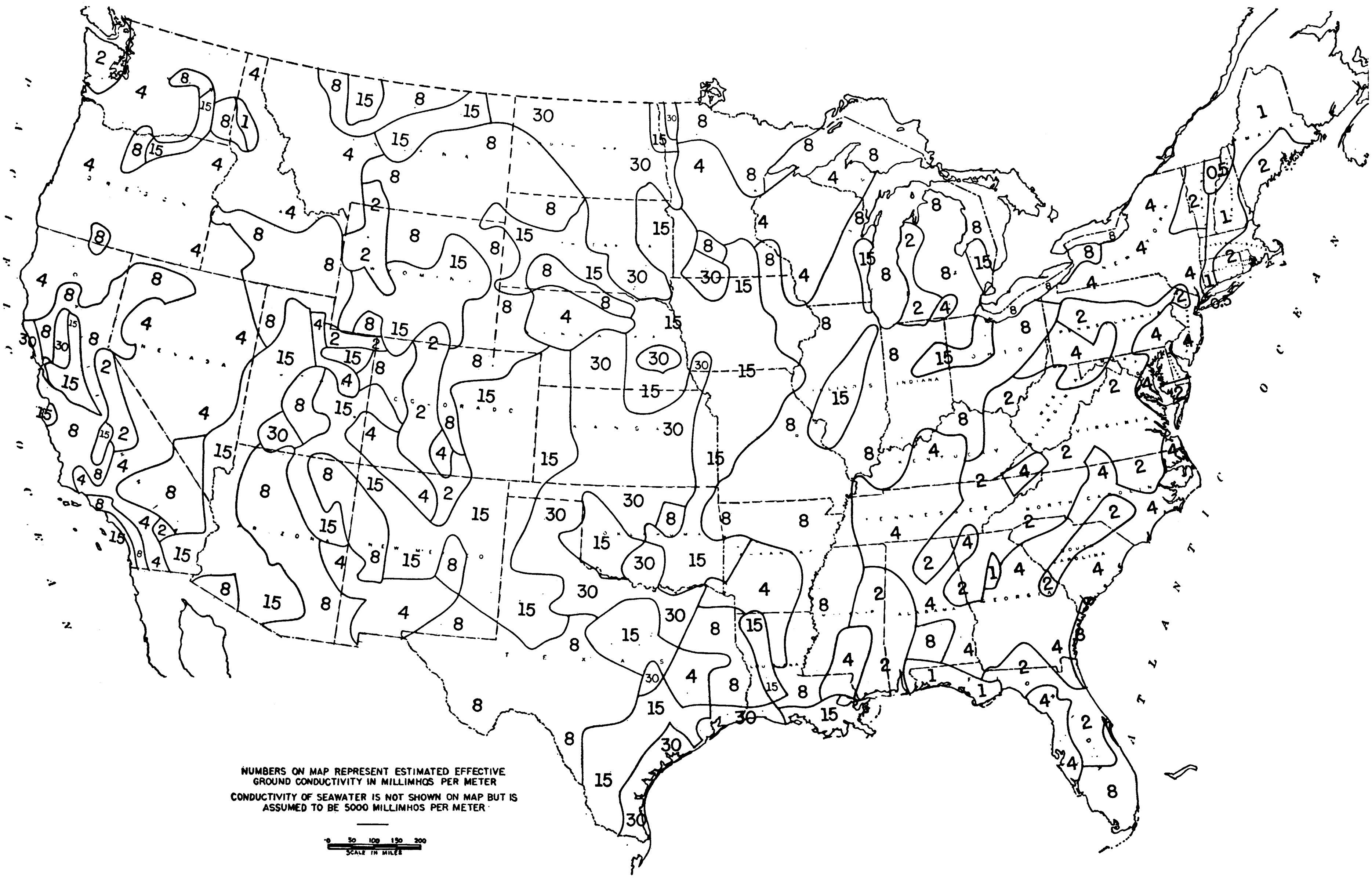

Fig. 1—Estimated effective ground conductivity in the United States.

two-thirds of the true effective median path conductivities for distances less than 25 miles from the transmitter were within 0.59 and 1.7 times the values which are shown on the map.

In summary, there is submitted a map of effective conductivities for the continental area of the United States. This map was based for the most part on measurements, submitted to the FCC by various standard broadcast stations. Enlarged copies of this conductivity map on a 1 to 2,500,000 scale are available for $3.50 from the Superintendent of Documents, Government Printing Office, Washington, D. C.

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